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February 1953

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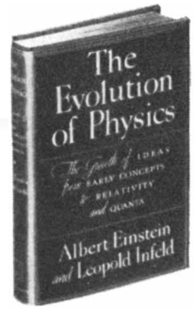

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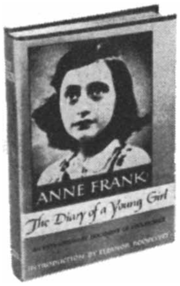

Written while the author hid from the Nazis in Holland, it is at once a remarkably sensitive record of adolescence and an eloquent testimony to the strength of the human spirit.
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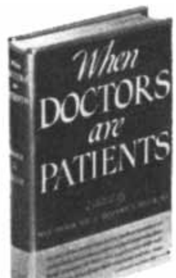

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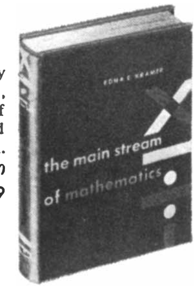

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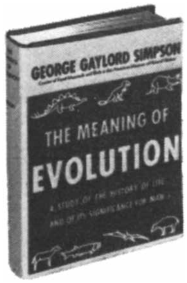

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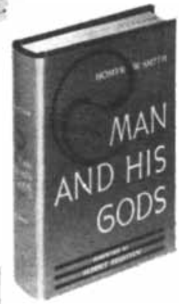

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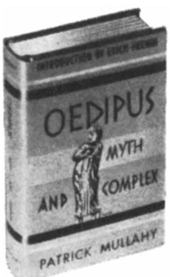

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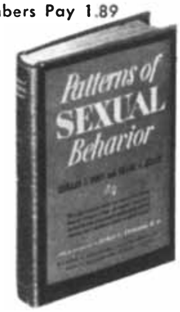

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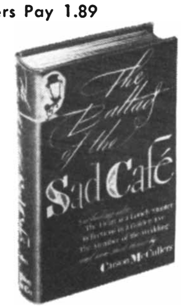

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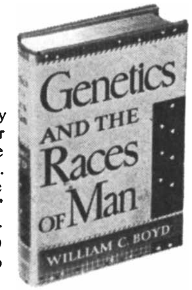

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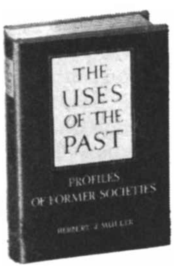

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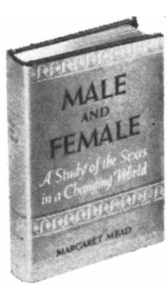

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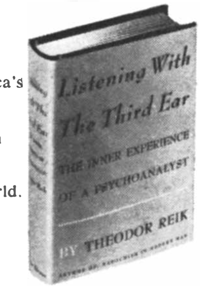

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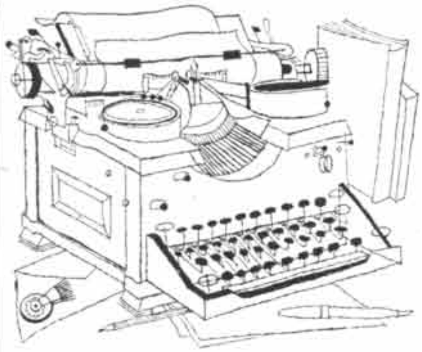

LETTERS

Sirs:

To accept Sheldon Judson's thesis that recent arroyo channeling in the southwestern U. S. is a result of a slight change in climatic pattern rather than of the activities of man and his grazing animals [SCIENTIFIC AMERICAN, December] would indeed be soothing to our collective conscience. Unfortunately not all of the evidence supports this thesis. If the assumption is true that heavy use of the ranges "was only a trigger force, setting off a process which had already been primed by natural causes," then, once the process of channeling is started, protection from grazing should have no effect on it. But there are protected or moderately grazed areas in northern, in central and in southern New Mexico in which vegetation is invading the arroyos, and there are indications that the flow of water and erosion of the channels have been materially reduced. The process is slow, but it happens. If to explain such recovery we assume that we are now "on the upswing of the climatic cycle," then we should be able to find some evidence of recovery of vegetation in the absence of a change in the grazing regime. So far I have found no hint of this. Again, if we are to assume that "the rainfall pattern has been improving during the past 50 years," and that heavy use was merely the force that pulled the trigger, is it not logical to surmise that vegetation on the upland and in the valleys of areas that had escaped channeling should have improved sufficiently, even under unrestricted grazing, to hold the valleys and swales? Yet under such conditions vegetation has continued to deteriorate and valleys to erode.

Such observations seem to lead to the conclusion that, in a region where the ecological balance is as delicate as it is in the Southwest, the action is on a hair trigger and the gun is always loaded.

J. L. GARDNER

State College, N. M.

Sirs:

The article by Francis Joseph Weiss entitled "The Useful Algae" in your December issue states that when *Euglena viridis* "is deprived of light for an extended period, it swallows solid food particles by way of a gullet, like any animal!" Present-day textbooks are in general agreement with this statement but I believe there is considerable doubt as to its accuracy.

Most of the statements that I have seen, concerning this holozoic method of feeding by Euglena, take as their authority an account in W. S. Kent's *Manual of Infusoria*. Kent claims to have repeatedly observed the entrance of very fine carmine grains into Euglena viridis and the accumulation of these fine grains into larger, irregular masses when the organism was deprived of light.

Working under the direction of Dr. D. H. Wenrich at the University of Pennsylvania, I subjected five cultures of *Euglena gracilis Klebs* to lack of light under carefully controlled experimental conditions and examined them daily over a period of 28 days. The 680 individuals examined showed no ingestion of solid matter.

A suspension of China ink was added to the cultures instead of the carmine particles used by Kent because it was found impossible to distinguish the carmine particles from the granules which formed inside the organism as the chloroplasts faded and began to disintegrate. Even in the control tubes, after 28 days, 1 per cent of the individuals examined showed a few of these granules. I suspect that Kent mistook the granules for particles of the carmine which he had placed in the water. Work reported by R. P. Hall in the *Transactions of the*

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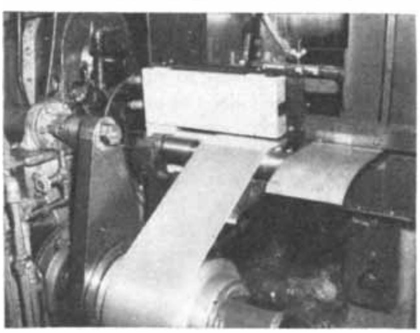
G-E 10-kv a-c winding insulation tester "finds" insulation defects that ordinary high-potential tests miss. Photo above shows actual waves on scope indicating several short-circuited turns in a coil. Correction of these hidden faults can improve and lengthen the life of your electric apparatus. Quick and easy testing makes equipment ideal for production use. Write for Bulletin GEC-321*.

SIMPLE INDUSTRIAL FIELD PLOTTING

Two dimensional problems in electrical field theory are easily plotted and solved with the G-E analog field plotter. Electric current flow patterns are set up in a sheet of thin conducting paper and analogy between the electrical field in the paper and related field problems as exist in electrostatics, electromagnetics, thermal and fluid flow allows rapid solution of the problem. See Bulletin GEC-851*.



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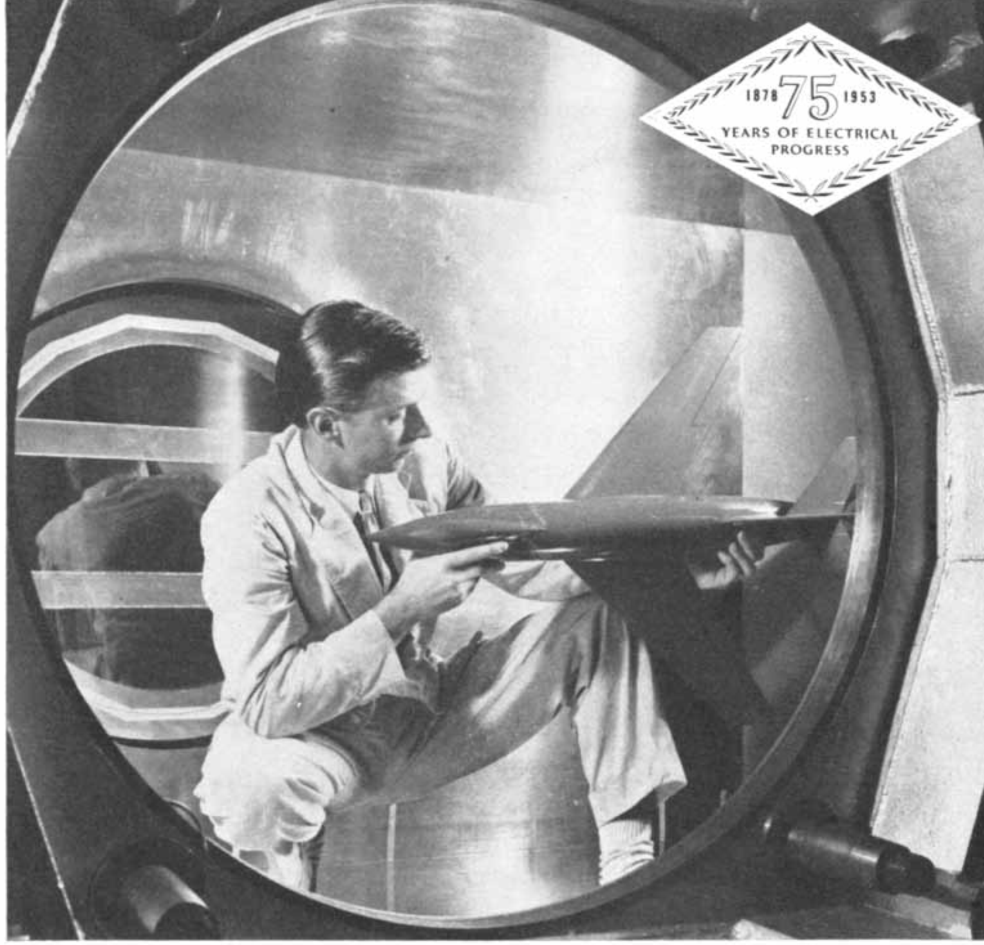

NACA RESEARCH SCIENTIST inspects airplane model after a test run at Langley Aeronautical Laboratory.

G-E recorder provides constant check of dewpoint temperature

Continuous, accurate indication of dewpoint temperature is provided by General Electric's dewpoint recorder.

As an aid in their aerodynamic research on supersonic aircraft and guided missiles, the National Advisory Committee for Aeronautics installed a dewpoint recorder at Langley Field, Virginia, to help avoid excessive condensation and flow disturbances in their supersonic wind tunnel.

Monitoring of moisture content is important in many other laboratories and industries. Dewpoint equipment is used to control chemical or mechanical air dryers; to study effects of condensible vapors; and to measure the moisture content of gases in various stages of manufacture. Further information about G-E dewpoint recorders is given in Bulletin GEC-588*.

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

FROST SPOT is checked for proper adjustment at NACA Laboratory.

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American Microscopic Society is in general agreement with these findings.

C. VINCENT RIPPLE

Philadelphia, Pa.

Sirs:

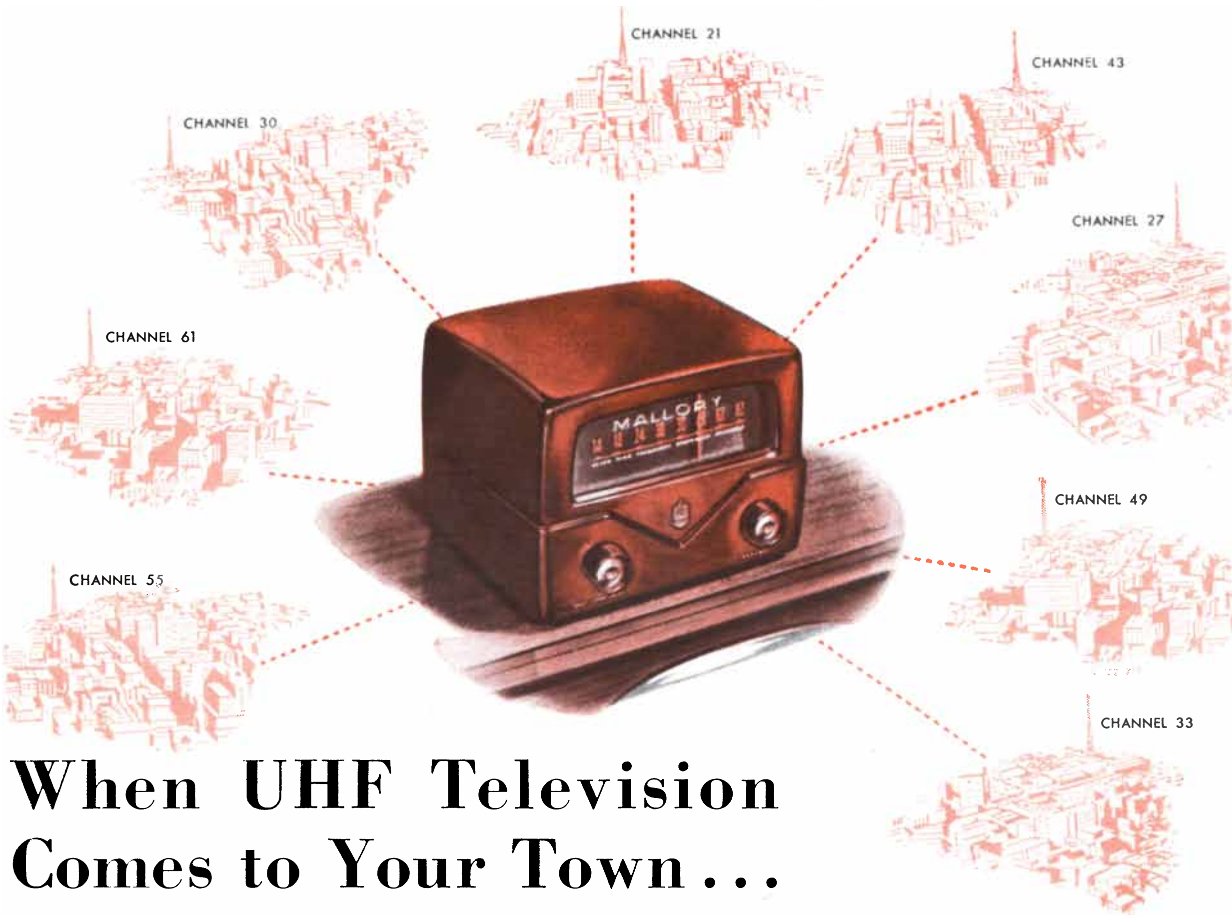
I read with interest Carl R. Rogers' article "'Client-Centered' Psychotherapy" in the November *Scientific American.* Dr. Rogers offers some challenging ideas, particularly in the light of the major practical problem facing psychotherapy today, namely, the inadequacy of the present methods of treatment and of training therapists to meet the increased demands of modern life. Rogers' type of psychotherapy could do a great deal to solve this problem, were it not for the fact that a few of his basic lines of thought are open to question.

First among these is the taking of the treatment of mental disorders out of the hands of medicine. Notice I do not say out of the hands of science. Rogers' approach is quite as scientific as that of most medical writers on psychotherapy, particularly his experimental work. But science is only a tool of medicine, and not the only one—perhaps not even the primary one. There were doctors long before there was science. People come to doctors not because they are sick—many sick people don't go to the doctor—but because they are *afraid* of something within their own bodies or personalities, and they want *help.* The doctor's response is to collect all the evidence and prescribe therapy based on experience. In any case medicine is based on the doctor's giving something *from himself* to the patient.

Rogers' approach, on the other hand, is quite unmedical. The counselor is specifically pledged not to direct the course of therapy, not to make a diagnosis and not to define the goal of therapy. The explicit assumption of the method is that the patient "has within him the capacity, at least latent, to understand the factors in his life that cause him unhappiness and pain, and to reorganize himself in such a way as to overcome these factors." If this is true of personality disorders, it puts them in a unique class; it is clearly not true of diabetes or poliomyelitis. One cannot avoid the conclusion that the method is only as good as this assumption: that when personality disorders are of such a severity and nature that the patient no longer has the capacity to solve his problems without *specific* elements being injected from outside, the client-centered approach must fail. . . .

JAMES FINKELSTEIN

College of Medicine
New York University
New York, N. Y.



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A Mallory Converter will equip your set to receive all channels

IF your town happens to be one that already has UHF television, then the Mallory Converter is probably no stranger to you. But, UHF is still new. Only a handful of stations are on the air . . . of the more than 1400 that have been authorized.

So, if you are like a lot of other people, you are probably wondering what to do when UHF comes to your town . . . on channels beyond the frequency range of your TV set. All you need is a Mallory Converter, and *all* the new UHF channels are yours to enjoy at the turn of a knob.

Regardless of the make or model of your present set, the Mallory Converter will equip it to tune in every channel in your area, both UHF and VHF. Should you move, there is nothing more to buy . . . no adjustments to make in order to receive all the channels in your new location. The Mallory Converter is no bigger than a portable radio and can be connected in a matter of minutes. It is your complete answer to UHF television.

The Mallory Converter is but one of the many products of Mallory research and engineering that make your everyday work easier . . . your leisure hours more pleasant. You'll find Mallory controls, tuners and capacitors in your radio and TV sets . . . timer switches on automatic washers . . . tiny mercury batteries in hearing aids . . . vibrators in your car radio.

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50 AND 100 YEARS AGO

FEBRUARY, 1903: "At the recent meeting of the American Association for the Advancement of Science, Professor Campbell spoke of 'the remarkable results obtained by Professor De Vries in his recent studies upon variation in plants.' He said: 'The conclusion reached by Professor De Vries is that, in addition to the variation within the limits of species, there may be sudden variations or "mutations," which, so to speak, overstep the limits of the species, and thus inaugurate new species. While the results obtained, especially in the case of *Enothera lamarckiana,* are certainly most striking, more data are necessary before we can accept without reserve the conclusions reached.' "

"The Autarith is the name of a most ingenious calculating machine recently patented by a young Viennese inventor. By means of buttons slid up and down slots the machine is 'told' what to do. If, for instance, 2,647 is to be multiplied by 6,892, the buttons of one row are placed in order opposite to 2, 6, 4, 7 respectively. The second number, 6,892, is similarly recorded in another row of buttons. Lastly, a large button is shifted to a notch marked 'multiplication.' The machine is immediately set into motion by the action of the motor, and presently stops, leaving the figures of the product required showing in certain spaces in proper order, and the large button returns to the 'off' notch. By a precisely similar process divisions, additions and subtractions are worked out."

"Speaking before the Astronomical and Astrophysical Society of America, Simon Newcomb discussed some of the more mysterious radiations from the sun. He said: 'We may regard it as a fact sufficiently established to merit further investigation that there does emanate from the sun, in an irregular way, some agency adequate to produce a measurable effect on the magnetic needle. We must regard it as a singular fact that no observations yet made give us the slightest indication as to what this emanation is. The possibility of defining it is suggested by the discovery within the past few years that matter sends forth entities known as Roentgen rays, Becquerel corpuscles and electrons.' "

"Some of the makers who exhibited at last month's automobile show announced that they had succeeded in abolishing the starting crank; but investigations proved these claims to be misleading and ambiguous, to say the least, the method consisting of leaving one or more cylinders, in a motor having verticle multiple cylinders, under compression, and then firing the charge with an electric spark from the battery. This, however, can only be done about once in every four trials, and then not at all if the charge is left standing over two hours. As proof that it is not absolutely reliable, the usual crank is also provided."

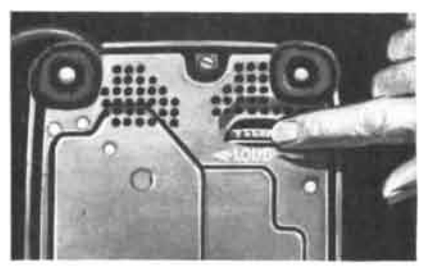
"Great interest attaches to the exhibit by Mr. George Westinghouse, during his recent stay in London, of the new lamp invented by Mr. Peter Cooper Hewitt. The lamp was shown in its commercial form to Lord Kelvin and a number of other prominent men. It consists of a glass tube with a bulb at one end which contains a small quantity of mercury. All air is exhausted from the tube, which thereupon fills with vapor from the mercury in the bulb. Electrodes are provided at each end of the lamp, the negative electrode in the bulb of mercury and the positive electrode at the opposite end. On passing a direct current through the lamp, the vapor which fills the tube is rendered incandescent and gives off a steady, blue-white light. Owing to the great resistance at the negative electrode to the initial flow of current, it is necessary to use a high voltage to start the lamp."

"Some time ago the British Board of Trade was able to announce that during a period of twelve months not a single passenger had been killed on the railroads of Great Britain. Since then another three months has passed without a fatality. Here, in the United States, our railroads have killed 77 passengers in fifteen days! We recently presented this comparison of railroad fatalities to the chief engineer of one of the leading railroads. In his prompt reply he put his hand at once on the weak spot: 'The different results are to be explained by a difference in national temperament—here, we take chances.' "

"Professor Langley's aerodrome took a rather unexpected flight on January 31. The machine was moored to a houseboat in the Potomac. During a heavy gale it rose from its usual recumbent position and tried to soar. It was fastened to the houseboat, but is said to have snapped

It adds miles to your voice

New "500" telephone. It has already been introduced on a limited scale and will be put in use as opportunity permits, in places where it can serve best. Note new dial and 25 per cent lighter handset.



Adjustable volume control on bottom of new telephone permits subscriber to set it to ring as loudly or softly as he pleases. Ring is pleasant and harmonious, yet stands out clearer.

For years the telephone you know and use has done its job well—and still does. But as America grows, more people are settling in suburban areas. Telephone lines must be longer; more voice energy is needed to span the extra miles.

Engineers at Bell Telephone Laboratories have developed a new telephone which can deliver a voice ten times more powerfully than before. Outlying points may now be served without the installation of extra-heavy wires or special batteries on subscribers' premises. For shorter distances, the job can be done with thinner wires than before. Thus thousands of tons of copper and other strategic materials are being conserved.

The new telephone shows once again how Bell Telephone Laboratories keeps making telephony better while the cost stays low.

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QUICK FACTS ON NEW TELEPHONE

Transmitter is much more powerful, due largely to increased sound pressure at the diaphragm and more efficient use of the carbon granules that turn sound waves into electrical impulses.

Light ring armature diaphragm receiver produces three times as much acoustic energy for the same input power. It transmits more of the high frequencies.

Improved dial mechanism can send pulses over greater distances to operate switches in dial exchange.

Built-in varistors equalize current, so voices don't get too loud close to telephone exchange.

Despite increased sensitivity of receiver, "clicks" are subdued by copper oxide varistor which chops off peaks of current surges.

the mooring lines of the boat and to have taken that along with it. According to the watermen along the river, the houseboat was dragged along for a while, while the machine maneuvered strangely in the air. After a number of peculiar twists and turns the aerodrome and the boat ran into a steamer."

"Professor Curie told a visitor to his laboratory that he would not care to trust himself in a room with a kilogram of pure radium, as it would doubtless destroy his eyesight and burn all the skin off his body, and probably kill him. He showed the scars on his arm, one of which looked as if he had had a very serious ulcer, due to a radium burn, which had taken fifty-two days to heal, and the other showed that the skin had been blistered and slightly scarred; the latter was caused by an exposure of but five minutes to some radium of very high activity; the more serious scar was due to an exposure of one hour and a half to some radium of much lower radioactivity."

FEBRUARY, 1853: "A memorial has been presented to Congress, asking for a grant of 1,500,000 acres of land, to be located along the line of a telegraph, which the memorialists propose to build between St. Louis and San Francisco, by way of Salt Lake City. The importance of the measure, they say, 'is too great to be measured by the value of a few acres of worthless land.' The scheme is a magnificent one; and so is the gift which they ask of the Government."

"M. Niepce has presented a third memoir on Heliochrome, or sun coloring, to the French Academy of Sciences. It is not *by contact*, but in the camera, that M. Niepce operates, and he obtains *every color*. M. Niepce has observed in his experiments that the morning light has a much greater photogenic action than the evening light. For example, if a prepared plate is exposed from nine o'clock till noon in the camera, the impression will be obtained in a much shorter time than if the same experiment were made from noon till three o'clock."

"Writing of Captain Ericsson's hot-air-driven ship, the New York *Tribune*, warmed with undue excitement, used these words: 'The age of steam is closed, the age of caloric opens, Fulton and Watt belong to the past. Ericsson is the great mechanical genius of the present and future.' One month since then has passed away and we have not heard of a single steamboat striking her colors to hot air. We have not seen a solitary scientific argument presented by the hot-air advocates in favor of it as a superior substitute for steam."

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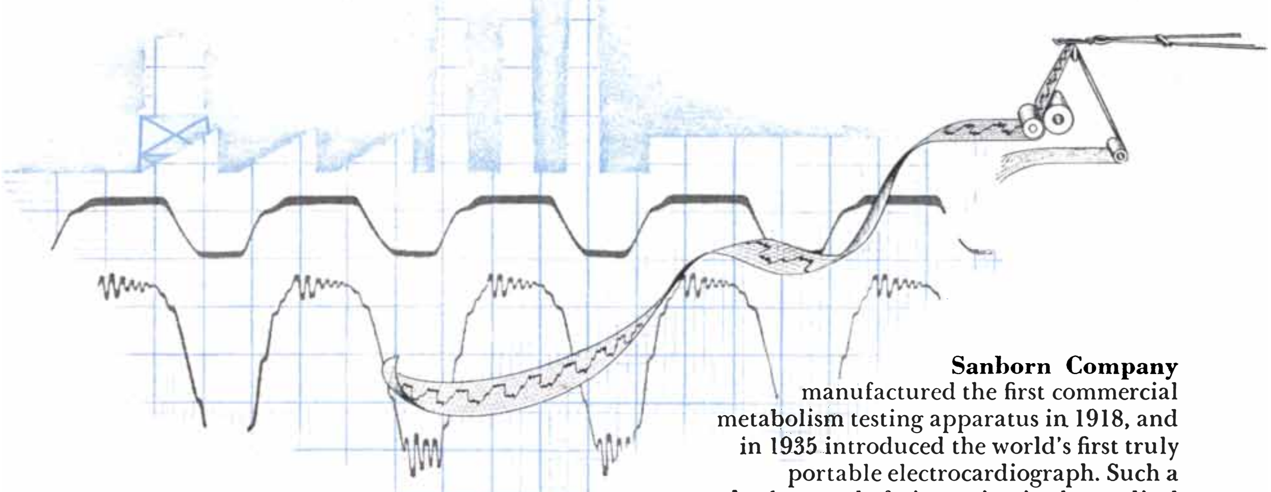

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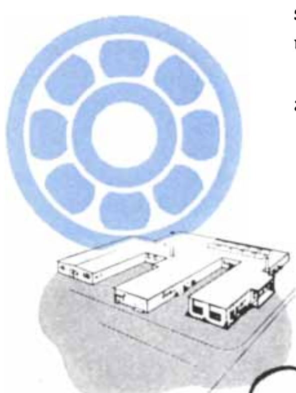

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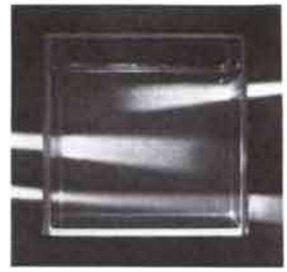

THE COVER

The photograph on the cover shows three beams of white light entering a colloidal suspension of sulfur from different angles. The particles of sulfur are extremely uniform in size, causing each colored component of the white light to be scattered at a different angle and each beam within the solution to have a different color (*see page 69*). The colors, called higher order Tyndall spectra, are used to measure the size of uniform particles by shining a single beam of white light through them. If the observer moves his head around the vessel containing the particles, he sees a series of colored bands, the number of which indicates the size of the particles. The picture was made in the laboratory of P. K. Lee at Columbia University.

THE ILLUSTRATIONS

Cover photograph by Paul Weller

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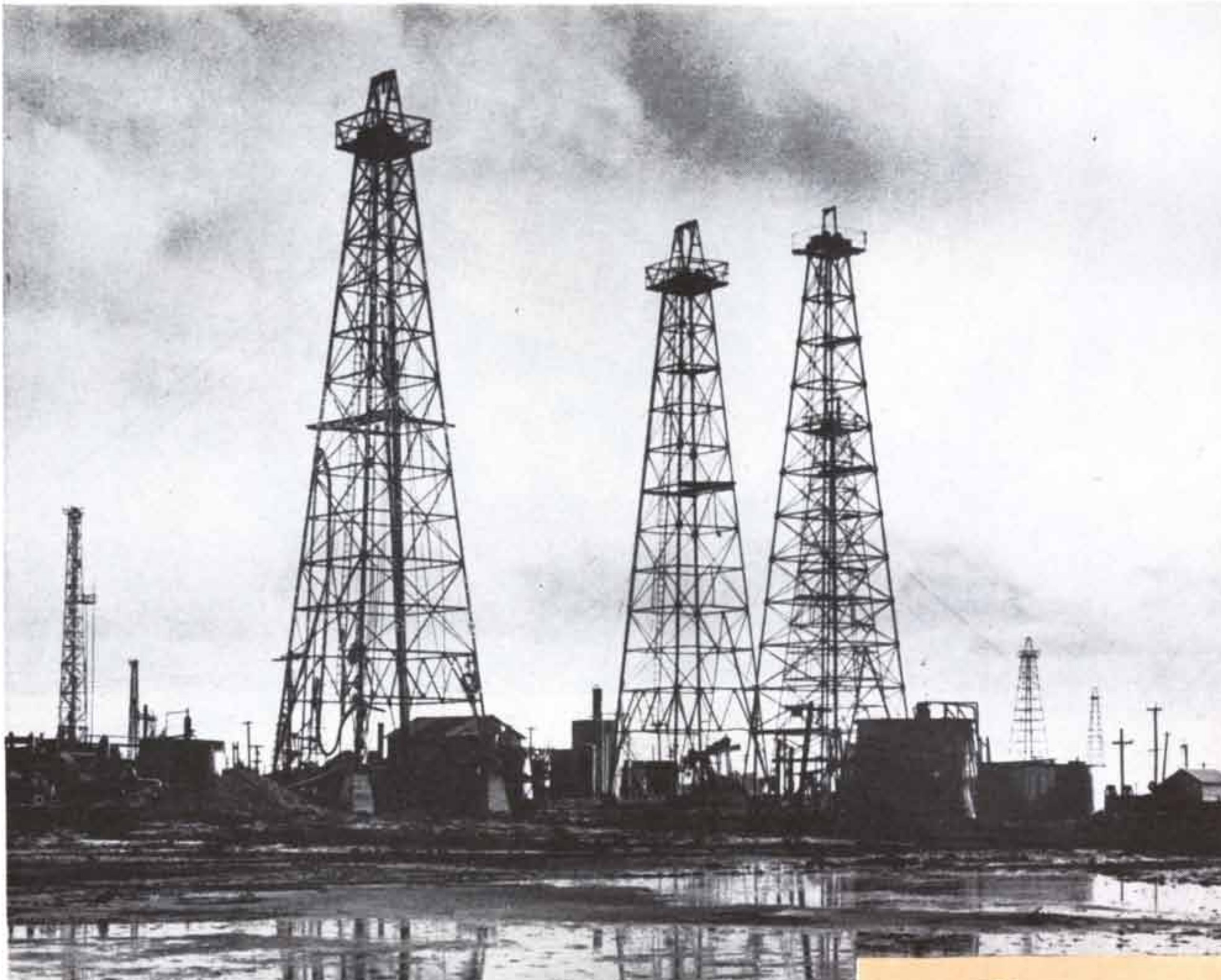

SCIENTIFIC AMERICAN

Established 1845

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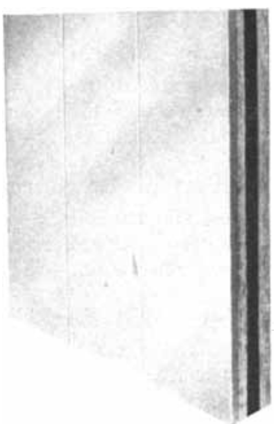
What's Happening at CRUCIBLE

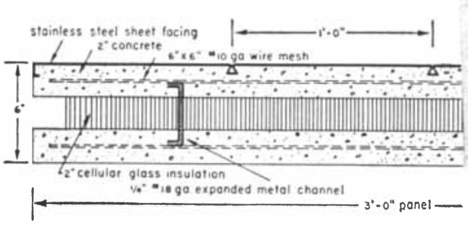
about stainless curtain walls

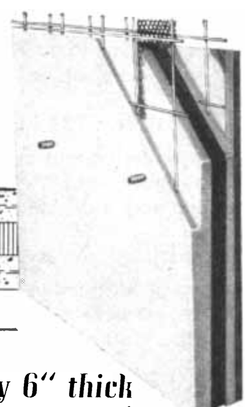
Modern construction methods have changed walls from the self-supporting type to a mere covering which does not support its own weight for more than one or two stories. Hence the definition of "curtain wall":—the facing or enclosure of the structural steel frame. This frame supports the entire weight of modern buildings.

The need has existed for a covering that would not only clothe the building, but be lightweight, economical and space saving. Because these requirements are more than adequately met with stainless steel curtain wall construction, this method is becoming increasingly popular with cost and space conscious owners, builders and architects.



the CRUCIBLE "sandwich"





the CRUCIBLE "sandwich"—only 6" thick
(can be less)

Crucible stainless steel curtain wall panels are in the form of 6-inch thick "sandwiches". The facing consists of flanged, light-gauge stainless steel sheets with a factory, or site-fabricated, sandwich consisting of cellular glass insulation between two layers of concrete with connecting reinforcing. Crucible 18-8 stainless as the outside face offers excellent resistance to weather and fire while providing eternal beauty with a minimum of maintenance; the inside face can be finished or painted to suit the requirements of modern building interiors. Since 18-8 is restricted in use, a good substitute material, type 430 stainless, now government decontrolled, offers the same benefits as 18-8 stainless.

moisture penetration

The unique characteristics of the cellular glass insulation stop moisture vapor migration from one face of the panel to the other. The cellular insulation properly designed and installed assures that condensation will not take place *anywhere* within the sandwich.

insulation

Although less than half as thick as the usual wall construction, this Crucible stainless steel panel construction has more than twice the insulating value. The "U" value (overall thermal conductivity) is approximately 0.15 BTU Hr./Sq.Ft./°F.

fire resistance

The Crucible sandwich met the requirements of a standard 4-hour fire test conducted in the testing laboratories of the National Bureau of Standards. This meets all old building codes and is double, or better, the requirements of modern enlightened building codes.

erection and fabrication

Since a building frame is not precision built, the attachment of the panel walls to the frame is done with fastening devices that provide necessary 3-dimensional adjustment. Panels can be made at the building site, and a 24-hour casting-to-fastening cycle is possible.

technical service available

Though the use of some stainless steel is now restricted, Crucible metallurgists and development personnel are continuing to investigate improved methods of curtain wall and other construction so that better buildings can be built when stainless is more freely available. For more information write: CRUCIBLE STEEL COMPANY OF AMERICA, General Sales and Operating Offices, Oliver Building, Pittsburgh, Penna.

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SCIENTIFIC AMERICAN

FEBRUARY, 1953 VOL. 188, NO. 2

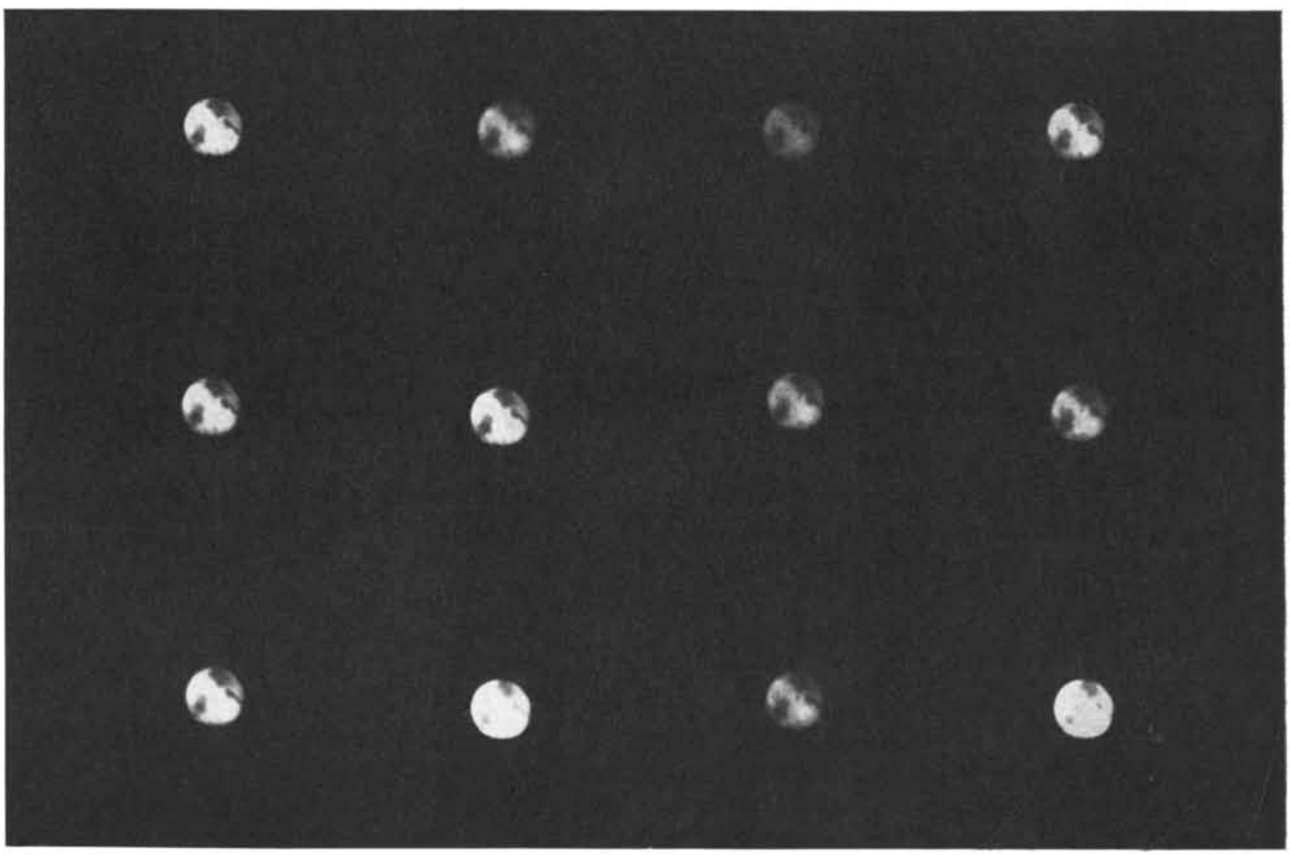
Planets from Palomar

The 200-inch telescope has now been employed to make photographs of objects within the solar system. What do the plates show, and how can better ones be made?

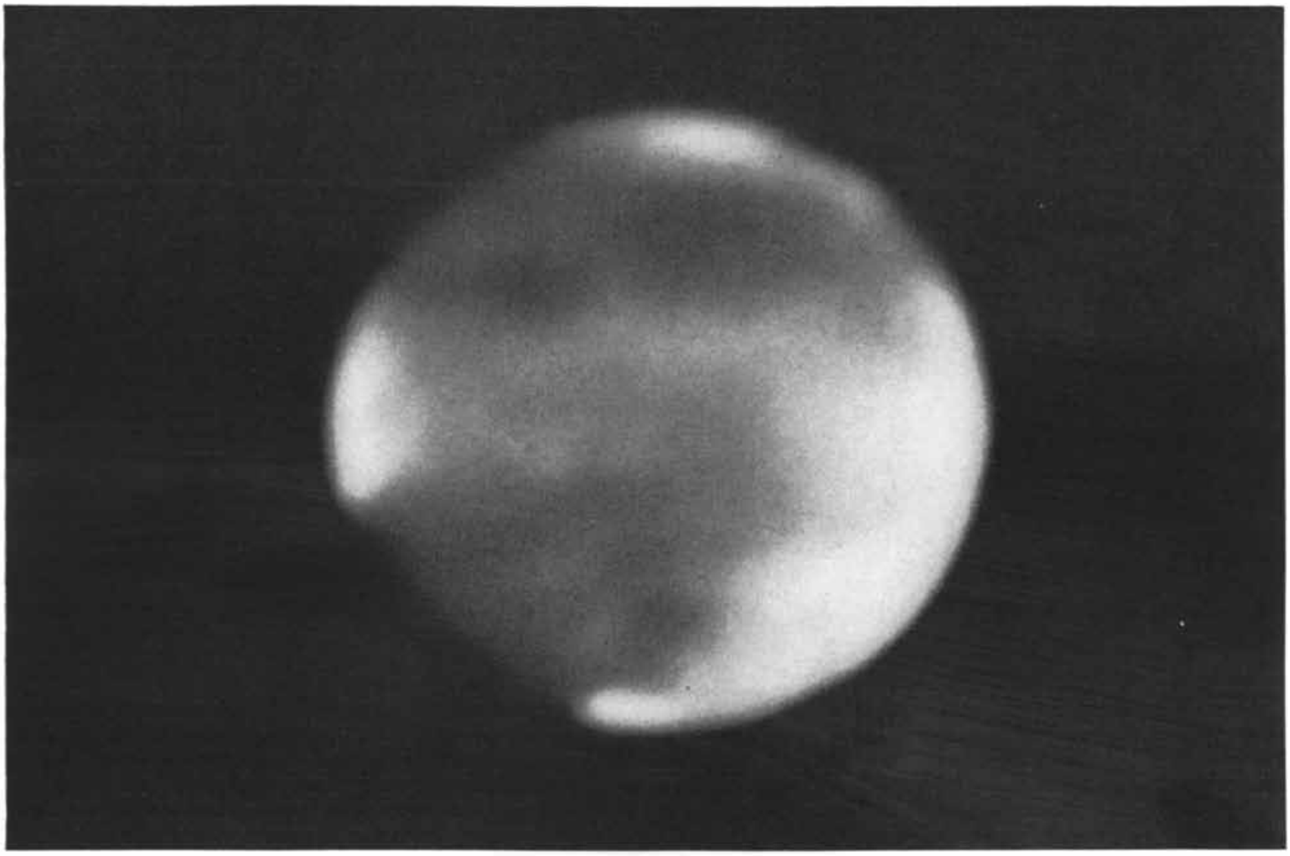
by Alice Beach

THE HALE Telescope on Palomar Mountain has been in operation for a little more than three years. Almost from the beginning people have been writing the observatory to ask what the 200-inch reflector reveals about the moon and the planets, and when the facts are to be released. Some of the correspondents are querulous and critical: they suspect that information they ought to have is being kept secret. If a planetary disaster is imminent, they say, the public should be informed. In any case, people should be given the latest news of our neighbors in space.

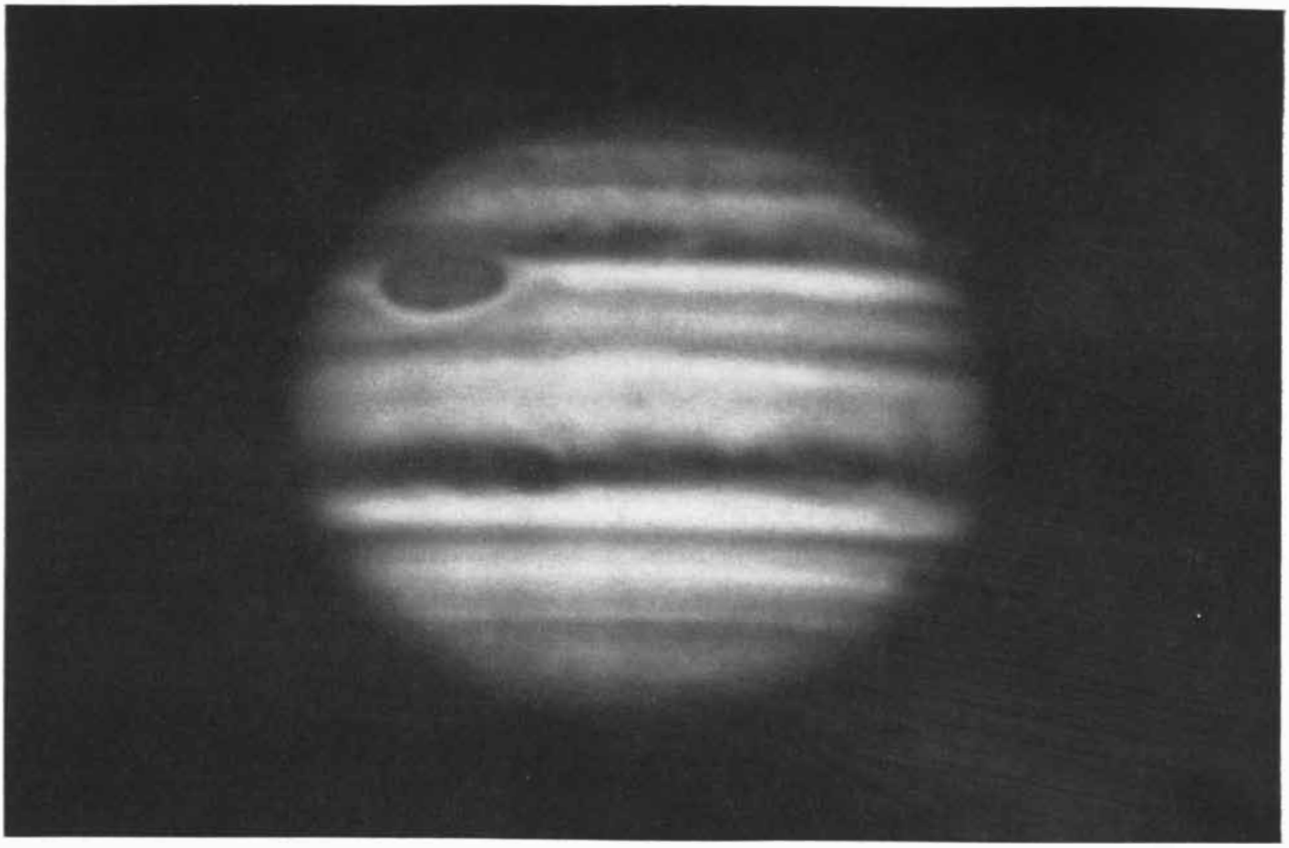
The facts, of course, are that none of the observatory's work is secret, and that the 200-inch telescope was primarily designed to photograph stars and galaxies, not the members of our own solar system. Nevertheless, a little of the busy telescope's time has recently been given to observations of our nearby neighbors, partly in response to the public interest

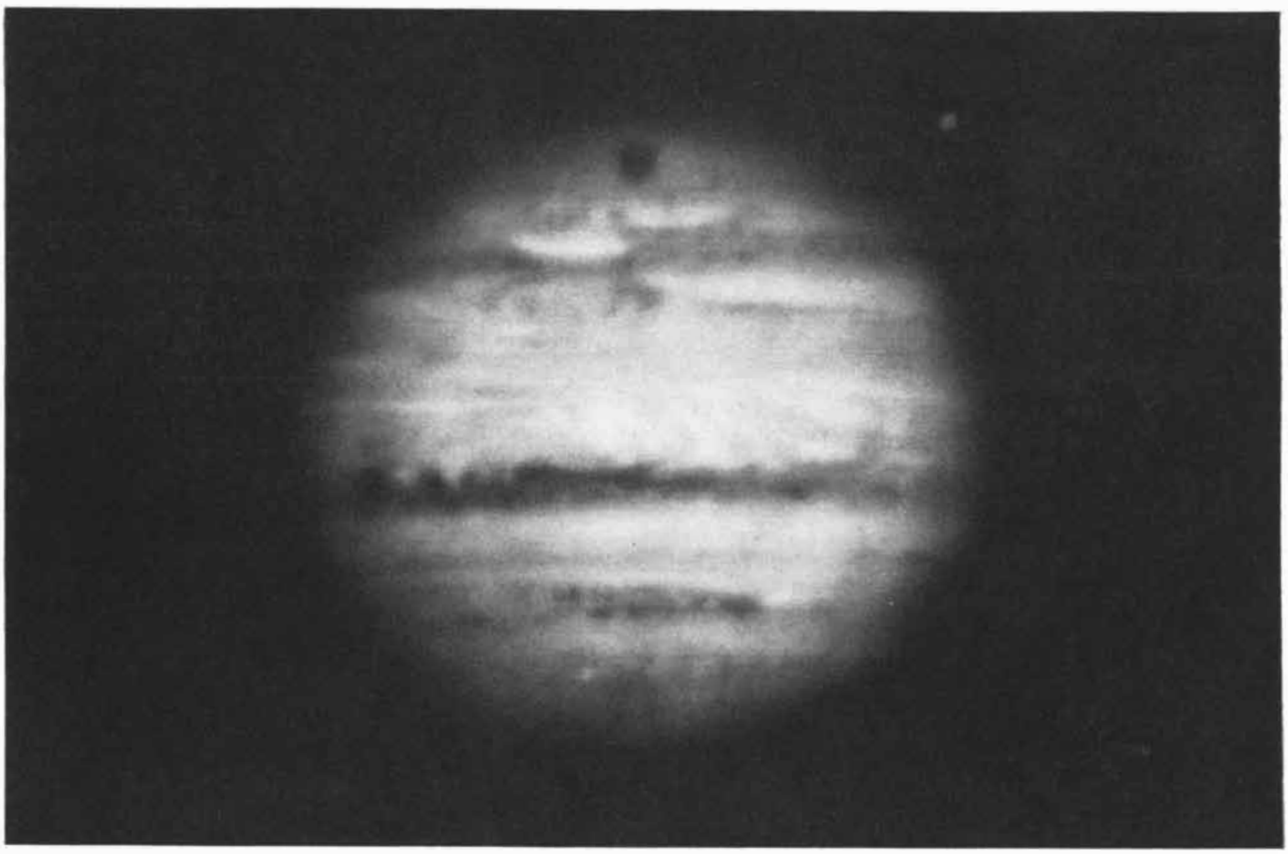


TWELVE IMAGES OF MARS appear on one plate made at the coudé focus of the 200-inch telescope. Between each exposure the plate was moved and the exposure time changed from somewhat less to somewhat more than a fifth of a second. The size of the images on the original plate was seven sixteenths of an inch.

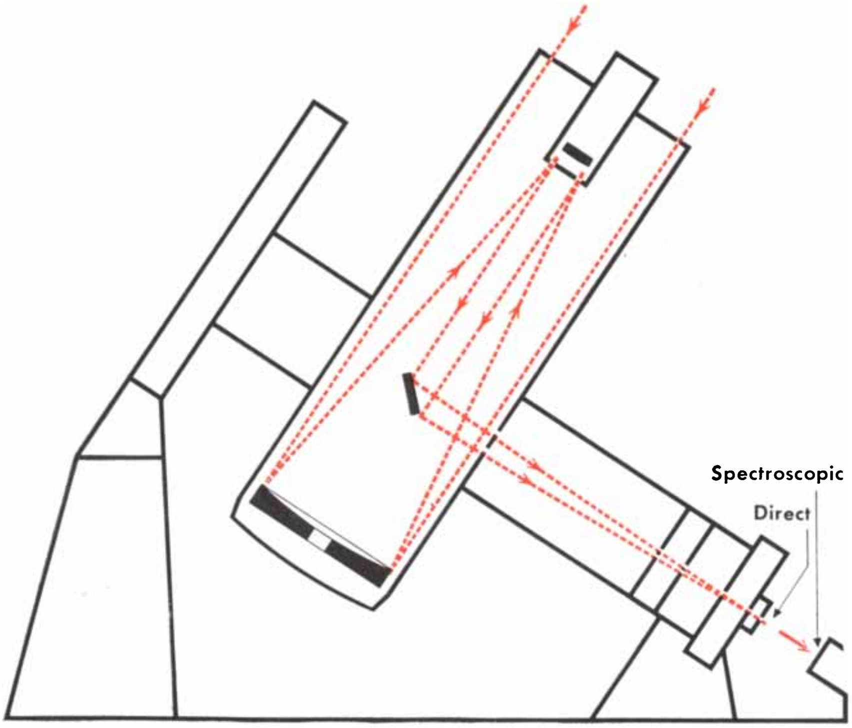


MARS is photographed in blue light (*top*) and red (*bottom*). Because red light penetrates the atmosphere of the planet more readily than blue, the bottom photograph shows the permanent markings of the surface. The top photograph shows the clouds of the atmosphere, notably those over the poles at the top and bottom.





JUPITER is similarly photographed in blue and red light. At the upper left in the blue photograph at the top is the Great Red Spot. The red photograph at the bottom shows details deeper in the Jovian atmosphere. At the upper right in the bottom photograph is one of Jupiter's moons; its shadow is at the top of the planet.



COUDE FOCUS of the 200-inch is at the south end of the polar axis (*right*). This focus is generally used for spectroscopic purposes; the direct photographs of the planets were made by mounting plates in the beam.

and partly to test the instrument's possibilities for this work. A number of photographs of the moon and the planets have been made. A few of the most interesting plates are published with this article. The selection includes views of Mars, Jupiter and Saturn. No lunar photographs are shown, because the pictures of the moon were not noticeably better than plates made earlier at Mount Wilson.

It must be said at once that while these strikingly beautiful photographs of the planets show details on a scale larger than has ever been possible before, they add nothing new to our information. They do not, for example, shed any light on the question as to whether there are "canals" on Mars. The reason is that large telescopes suffer from the same limitations as smaller ones when it comes to recording detail in objects that both can reach. The big telescopes have more light-gathering power and therefore can record fainter stars and see farther. But the observation of the planets is strictly limited by the atmospheric conditions known as "seeing."

This was pointed out many years ago by the late Percival Lowell, who founded the Lowell Observatory at Flagstaff, Ariz. He wrote in 1895: "A steady atmosphere is essential to study of planetary detail: size of instrument being a very secondary matter. A large instrument in poor air will not begin to show what a smaller one in good air will."

"Seeing" has little to do with clouds or local fog. A clear night when the stars sparkle brightly may seem an ideal time to study the skies, but the astronomer knows that the twinkling of the stars is a sure sign of poor seeing. The best seeing comes when the stars shine steadily. Unfortunately that condition is rare. The atmosphere surrounding the earth is never stationary. Pressure and temperature change constantly, and the mixing of cold and hot air causes turbulence. This, in turn, makes images dance in the telescope's field so that details are blurred. The larger and more sensitive the telescope, the more it is affected by this disturbance.

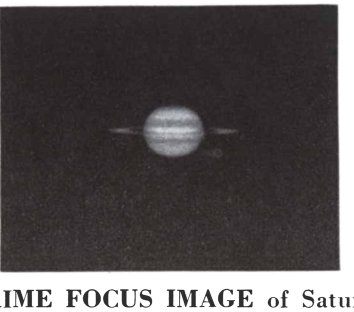
Some of the finest pictures and visual observations of the planets have been made with small refracting telescopes—as small as six inches in diameter. For many years the chief center for planetary research has been the Lowell Observatory at Flagstaff, with a 42-inch reflector and a 24-inch refractor. Much planet work has also been done at the Lick Observatory on California's Mount Hamilton, with a 36-inch reflector and a 36-inch refractor, and at the Yerkes and McDonald Observatories. The big telescopes have given only passing attention to the planets. In its 48 years of operation the 100-inch reflector on Mount Wilson, for example, has done relatively little extended research in this field. One of its few planetary projects has been a search for satellites of Jupiter, and since 1917 S. B. Nicholson has found three new ones with the Mount Wilson instrument. His most recent discovery was announced just two months ago. He found a tiny new moon of Jupiter only about 14 miles in diameter which raises the number of the known satellites of Jupiter to 12.

THE NEW pictures of planets from Palomar Mountain were made at times when the seeing was good and the giant telescope's main work of exploring the more distant regions of the universe could be interrupted. They were taken at the coudé focus of the 200-inch reflector. The coudé focus (named from the French word for elbow) is formed by reflection of the light by means of two auxiliary mirrors, one at the top of the tube and the other near the bottom (*see diagram at the left*). The coudé was primarily designed for spectroscopic work, but it can easily be adapted for planetary photography by inserting a base for the plateholder in the beam. The mirrors for the coudé focus can be brought into position quickly, and 36 photographs can be made without interrupting the regular program at the prime focus for more than an hour.

The coudé focal ratio is $f/30$, which makes the beam of light tremendously long—about 500 feet! The images of the moon and planets here are much larger than at the prime focus of the telescope. At their closest approach to us the unmagnified disk of Saturn at the coudé is about half an inch in diameter, that of Mars approximately seven tenths of an inch and that of Jupiter about an inch and a half. The picture of the moon would be almost five feet in diameter if it could all be put on one plate; only a small section of it can be photographed at a time. The scale is illustrated even more graphically by the Great Nebula in Andromeda; at the coudé focus of the Hale Telescope this star system is some 61 feet in diameter!

Photographs of the planets can also be taken at the prime focus of the 200-inch. In this case the focal ratio, with a correcting lens, is $f/3.6$, and the images are about one-eighth as large as at the coudé; the moon, for example, is about seven inches in diameter. At the prime focus photographs can be taken with extremely short exposures, and consequently the seeing need not be as good as is required at the coudé focus.

At the bottom of these two pages are



PRIME FOCUS IMAGE of Saturn is enlarged five times. This focus is at the top of the telescope tube.

two photographs of Saturn, one made at the prime focus and one at the coudé. They graphically illustrate the difference in size of the images (both photographs have been enlarged five times). The photograph at the prime focus was taken at a time when Saturn's rings were almost on edge to our line of sight.

PLANET pictures at the coudé focus are usually made on 8- by 10-inch plates. About a dozen images are made in quick succession and at varying exposure times on each plate. Seeing conditions often change rapidly, and by this method the observer can select the images that best meet his needs. The exposures shown in the illustration on page 17 were made with a red filter and with exposures of approximately one fifth of a second.

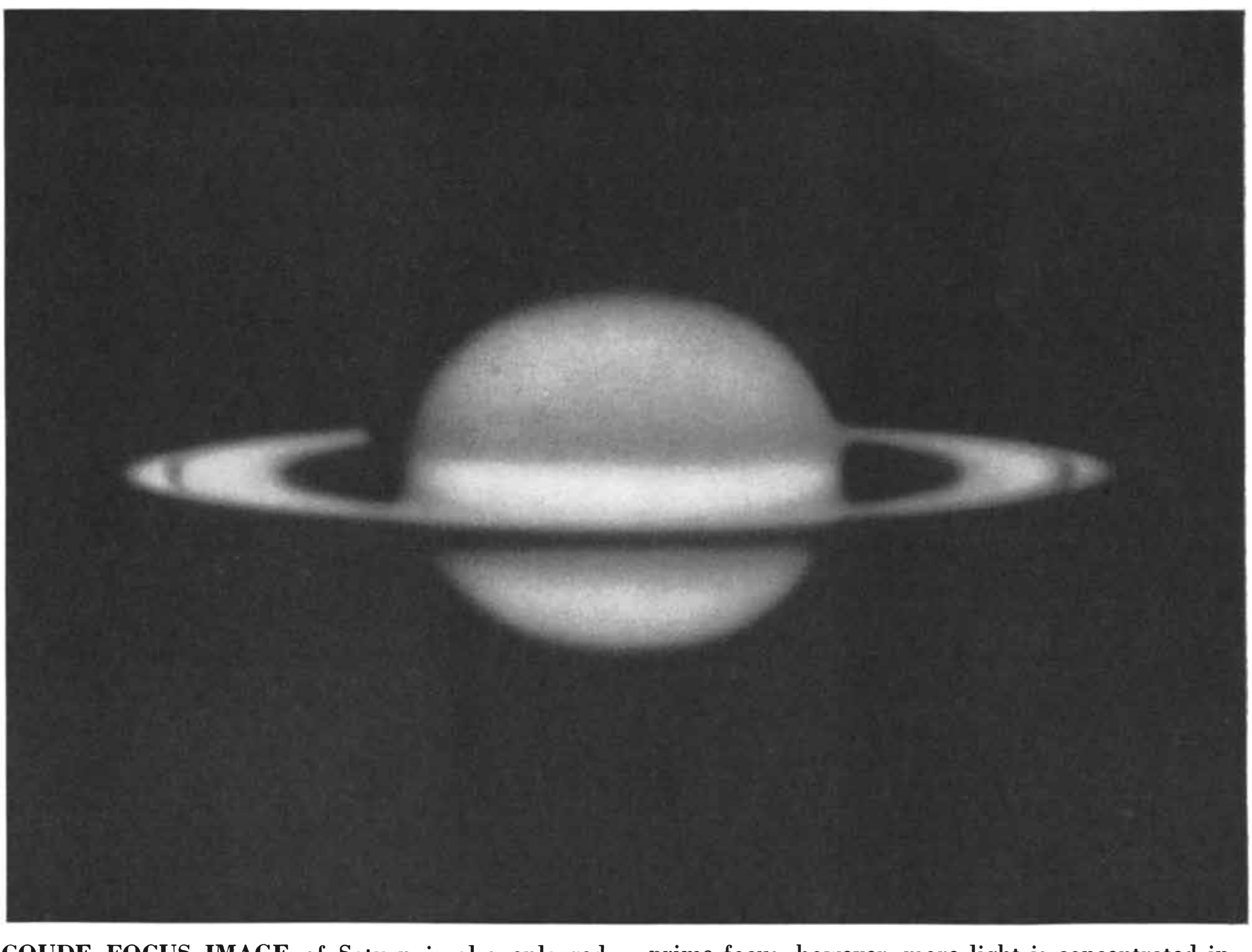
It is common practice to photograph the planets both in red and in blue light. Red light is more penetrating and can probe into the atmosphere of the planet. The two photographs of Jupiter on page 19 show the difference in the results obtained. The exposure in red light was about half a second; in blue light, about three times as long. The blue light records the upper atmosphere of the planet. The red light has penetrated farther but still cannot reveal the solid planet surface itself. We know that the broad bands and markings on Jupiter are clouds, because they change in shape, position and color.

The blue Jupiter photograph shows the Great Red Spot, a semi-permanent feature of the planet which was first noticed in 1878. This spot, looking something like a huge eye, seems to float slowly through the planet's atmosphere. Its color varies from red to grey; at present it has a yellowish tinge. Both Jupiter photographs show the flattening at the poles caused by the speed of rotation. The distortion is optically exaggerated in these pictures, because the center of the disk is much brighter than the polar regions.

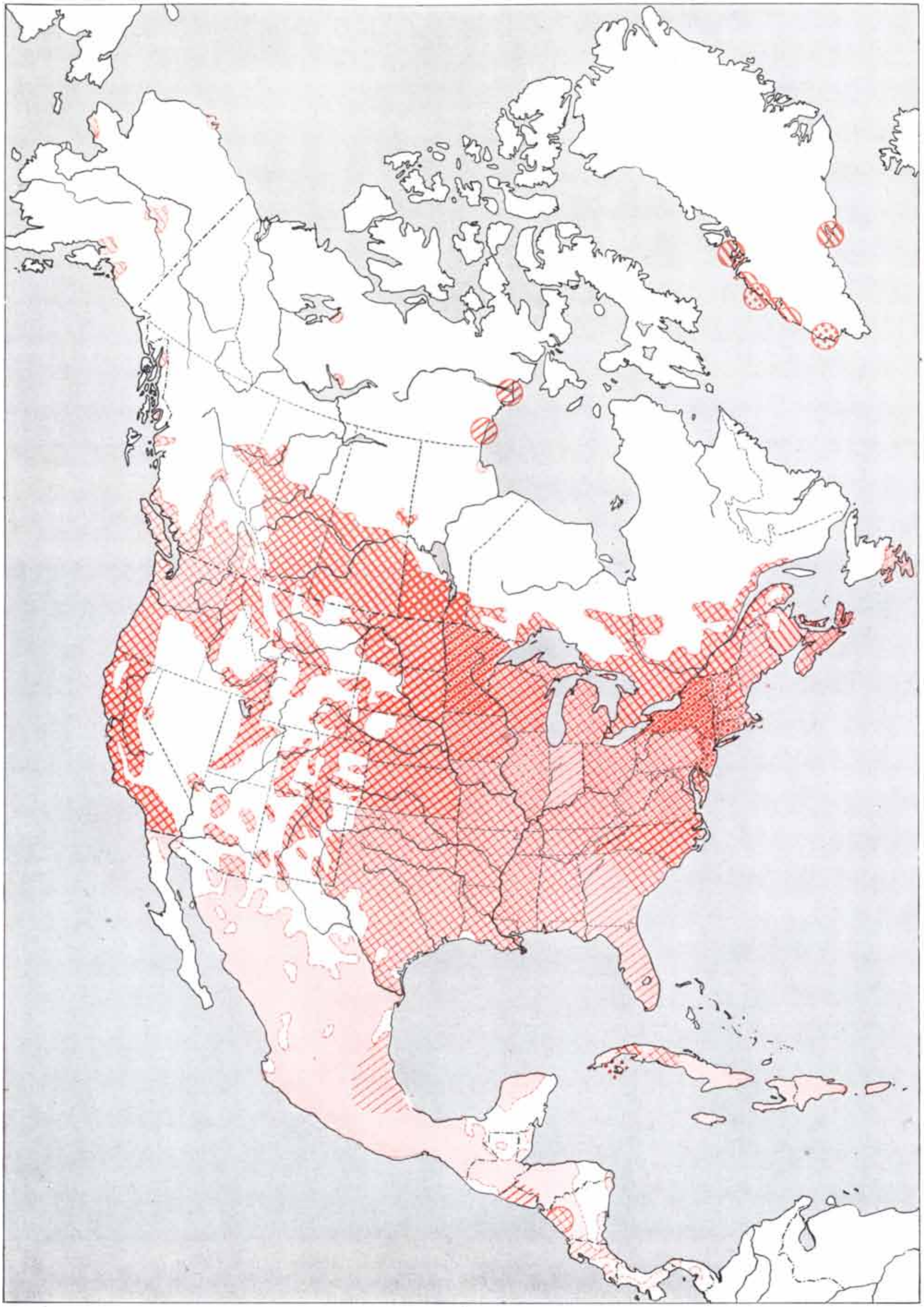
The two views of Mars on page 18 also were made in red and blue light. The red photograph was taken at a one-fifth-second exposure, the blue one at a full second. This time the red light has penetrated to the surface of the planet, but it does not show the network of lines that Lowell and many other observers saw and judged to be "canals." The lines are so fine that they will be extremely difficult to record on a plate, but it is hoped that eventually the 200-inch mirror may capture them.

The planet photographs so far obtained are undoubtedly not the best that may be made from Palomar Mountain. It takes many years to compile a collection of top-quality pictures, and seeing is not the only thing that holds up the work. Planets are not in a good position to photograph when they are far south or near the horizon, as atmospheric interference and refraction are aggravated by low altitude. Moreover, since the planets move around the sun in elliptical orbits, their closest approach to us may occur only at long intervals. For example, Mars's closest approach to us comes at intervals of a little more than 15 years. It will be in that position in 1956. To get better pictures than those shown here, therefore, we must wait until favorable positions of the planets coincide with nearly perfect seeing conditions.

Alice Beach is a member of the staff of the Mount Wilson and Palomar Observatories.



COUDE FOCUS IMAGE of Saturn is also enlarged five times, illustrating the fact that this image is some eight times larger than the one at the prime focus. At the prime focus, however, more light is concentrated in a smaller area; for this reason shorter exposures can be made and the effects of bad seeing can be lessened.



The Geography of Disease

Part of man's relationship with his environment is sickness; thus a greater knowledge of its pattern among peoples and places can assist in its control

by Jacques M. May

THE PATTERN of disease on our planet today dates back hundreds of millions of years to the time when the earth assumed its present shape and set the stage for our present pattern of climates. Disease is inseparable from its environment, and medical science is paying increasing attention to the vital factors of geography.

A striking example of the relationship between milieu and disease is offered by the Valley of the Nile. Here the fertile soil and dry, healthful climate attracted one of the earliest human communities. As the population multiplied, its prosperity brought overcrowding, and with it an economy and ways of living that favored the spread of certain diseases.

Among them is schistosomiasis. It requires for its development three elements—a snail, a worm and man. The snail thrives on the aquatic vegetation, on chemicals transported from the headwaters of the Nile in the mountains, and on the turbulent waters. The schistosome worm, helped by the cultural habits of the Egyptians and by the biological requirements of the snail, established itself firmly in the region. The resultant disease has done immeasurable damage to the health of the people in the Nile Valley. Its epidemiology is interwoven with the geographic factors of the environment in a complex way.

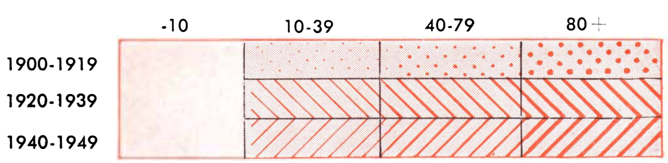
Man harbors the adult worms in the veins of the bladder or of the bowels. They mate and lay their eggs there. Voided in the urine or feces (depending on the species of worm), the eggs pass into the outside world, where in an aquatic environment which provides just the right temperature and *p*H, they hatch into free-swimming larvae. Within a few hours, under penalty of death, the larva must find a suitable snail to invade. The warmth of the Nile water gives it long enough life to locate its host. After entering its snail, the schistosome develops a second larval form. It then leaves the snail's body and swims in search of a human host. When it finds one, it bores through his skin, migrates through the tissues to the bladder or bowels, and there matures, gives birth to new eggs and so begins the new cycle.

Now a substantial change in any one of these environmental factors can stop the disease or alter its character. For instance, in recent years Egypt has established a system of continuous irrigation on some stretches of the Nile. This innovation has favored a species of snail which ordinarily would not survive in the dryness of southern Egypt during seasons when the river subsides. The snail in question harbors a variety of schistosome that produces the urinary form of schistosomiasis. Hence this form of the disease has increased in the parts of Egypt where the new irrigation ditches have been built.

To nourish the worms and maintain the disease, man himself, the final host, must cooperate. This he does in Egypt by virtue of habit and necessity, which daily take him barefoot into the snail-infested waters of the river. Were it not for this constant exposure, the disease would soon lose its hold.

AREAS of the world where the climatological factors are approximately alike can be expected to show similar disease prevalencies. When they do not, the problem is one for medical geography to investigate. Yellow fever is a case in point. It is rife in some parts of the tropics, absent from others. Why? In tropical America geographical conditions have favored the establishment of numerous mosquitoes. Each species prefers a different aspect of the tropical environment. Some thrive in the jungle, others in the plains. Some avoid human habitation, others seek it. Some like running water, others stagnant pools. The virus of yellow fever is harbored by monkeys and certain other jungle mammals. To spread among men it must travel a roundabout route. A jungle-dwelling mosquito, infected with the yellow-fever virus by a monkey, bites a hunter or woodcutter. The man goes home and is bitten by an urban mosquito, which in turn spreads the virus among the people in the town.

Many geographical factors converge in tropical America to foster yellow fever. The temperature, rainfall and chemical composition of the soil produce forests favorable to both monkeys and mosquitoes. Rivers, plains and the proximity of the sea encourage human settlements where urban mosquitoes multiply. Economic conditions force man into the jungle, and the two cycles interlock to sustain the disease. Similar conditions prevail along the western coast of Africa on the opposite side of the Atlantic, and there comparable epidemics of yellow fever arise. But eastward across the African Continent yellow fever moderates: mortality rates decline, and near the Continent's eastern coast the people show a natural immunity to the disease, probably acquired by mild early subclinical infection. Still farther east, across the Indian Ocean, an inexplicable phenomenon occurs. In India and Southeast Asia geographical conditions are similar to those in the American tropics. Yet in this region, with one of the world's most crowded populations, yellow fever is unknown. Here



DISTRIBUTION OF POLIOMYELITIS in North America for three periods from 1900 to 1950 is shown in the map on the opposite page. The tint or pattern of each area represents the number of cases per 100,000 inhabitants per year for one or more periods.

is an enigma which offers a fertile field for investigation.

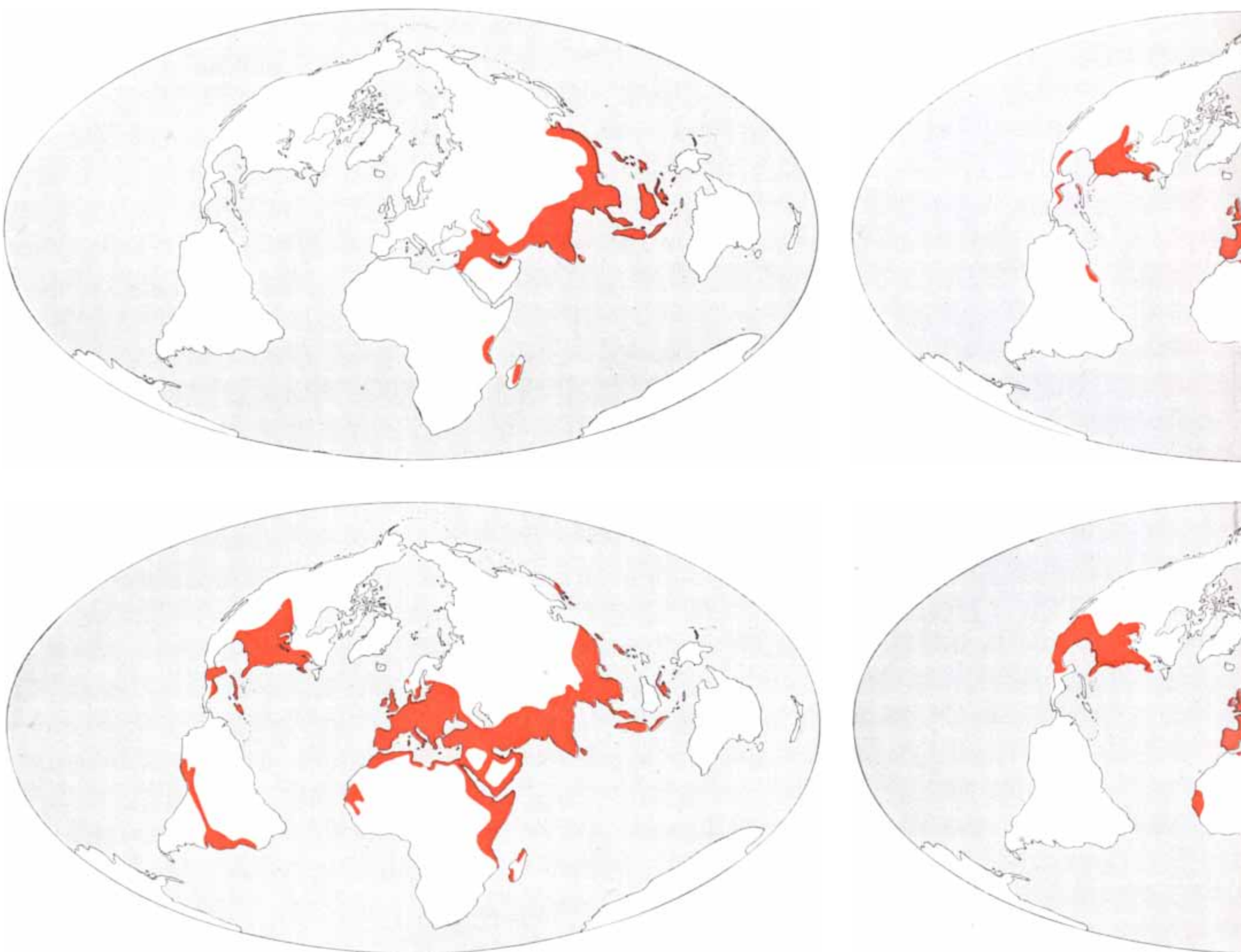
Schistosomiasis and yellow fever are but two examples of many diseases that have been related to geography. Goiter is believed to be connected with lack of iodine in the water supply. Yaws, typhus fever, poliomyelitis, cholera, malaria, sleeping sickness—all have their roots in the geographical pattern. And changes in environmental factors must account for the ebb and flow of some of the great plagues of mankind; this may be the explanation, for example, of the fact that leprosy, once widespread in Europe, gradually disappeared from the Continent during the Middle Ages.

THE EARLIEST physicians knew that certain diseases were associated with certain localities, but they lacked any way to establish a precise relationship between climate and sickness. In 1795 the German physician L. L. Finke urged studies of "the factors of location, soil, air, light, foodstuffs, mode of living, customs and habits of the people as they bear on health, disease and on local therapeutics." The great expansion of exploration and colonial development during the 19th century encouraged the study of local health conditions all over the world. In our century military necessity has added another motive. In recent decades a handsome crop of medico-geographical information has been collected by workers in entomology, parasitology and other fields. Yet no technique has yet been developed for correlating such information—for making a general, systematic investigation of the geography of pathology.

In 1948 the American Geographical Society initiated a program aimed at bridging this gap. It proposes to develop a method which will dig out possible causal relationships and to undertake a thorough investigation of environmental disease correlations.

Disease is a complex affair. It may take a combination of two, three, four or even more factors to produce it. Poliomyelitis and cholera require at least two—man and the germ. Schistosomiasis needs three—man, a snail and a worm. The same is true of yellow fever: the virus cannot possibly be transmitted from a sick person to a healthy one without the intervention of a vector, the mosquito. Each component of a pathological complex, as we have seen, must find a friendly environment if the chain of infection is to be maintained. Thus geographical pathology must study the environment of each factor.

Local environmental conditions form an infinite number of geographical patterns, each in turn creating a variation in the framework of disease. And when you have isolated the individual elements in a climate pattern, you are still faced with the problem of deciding which factor is primarily responsible for maintaining the disease. In the case of the tropical spirochete infection known



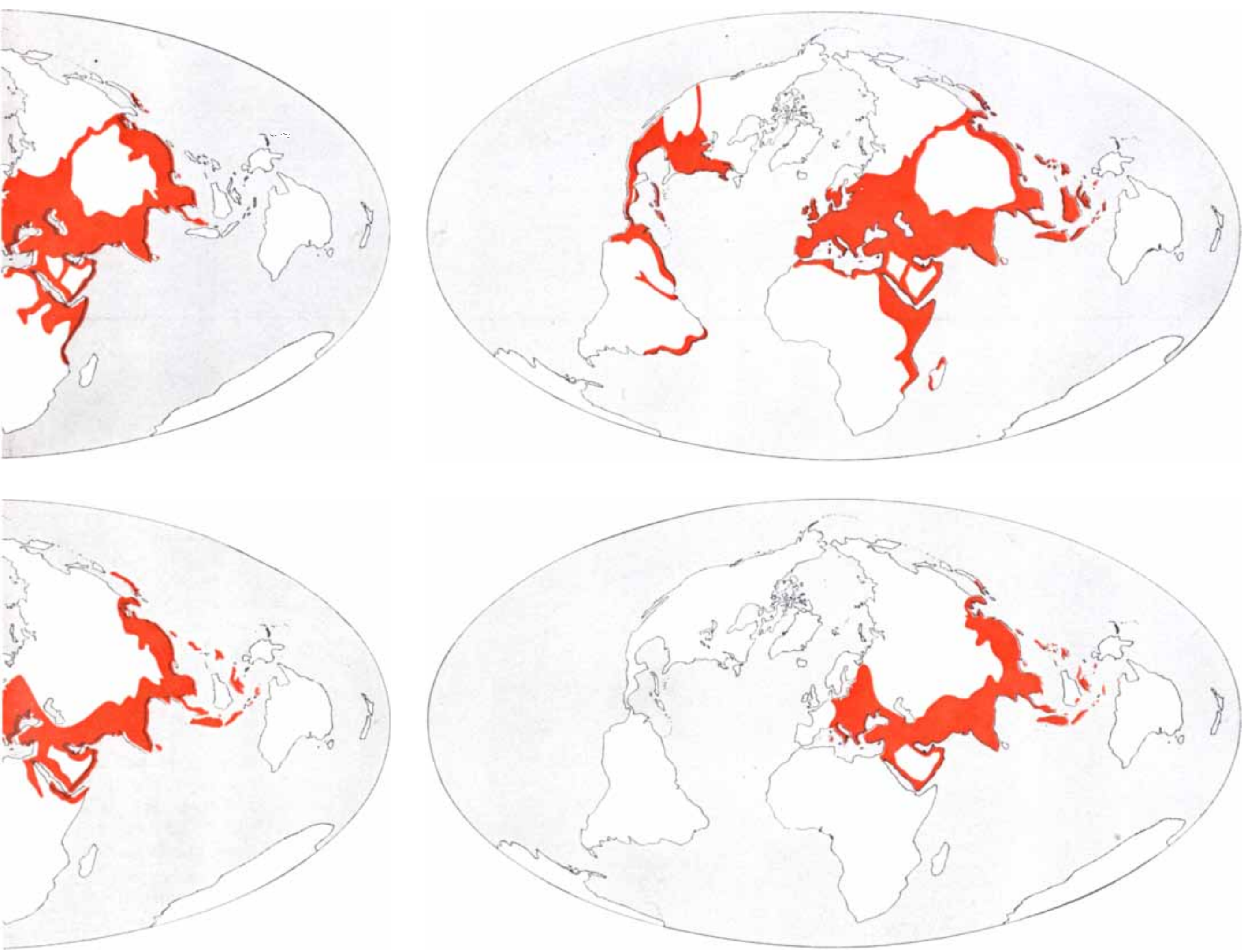
RISE AND FALL OF CHOLERA is outlined in the maps on these two pages. Reading from left to right, the maps show the distribution of the disease for the following six periods: 1816 to 1823, 1826 to 1837, 1842 as yaws, for example, the infection heals when a patient is transported from the hot, humid plains to the cooler and drier altitudes of the mountains. Is altitude, humidity, temperature or a combination of all three the critical factor? And on which element does it act—man or the spirochete?

To interpret nature's large-scale experiments in propagating disease, we need, first of all, censuses and maps of disease occurrence. Some of the necessary statistics can be obtained from the World Health Organization, national health agencies, hospital reports, limited public or private surveys, local newspapers. They are never as accurate or complete as a medical geographer might wish. In many countries only a small fraction of actual disease occurrence is recorded. Few Chinese farmers or African tribesmen, for example, seek medical aid for rheumatic fever or influenza. Nevertheless, even meager and partial knowledge represents a start. The American Geographical Society is now mapping several diseases for which reliable world-wide information is available. Six sheets of this "Atlas of Diseases" have already been published.

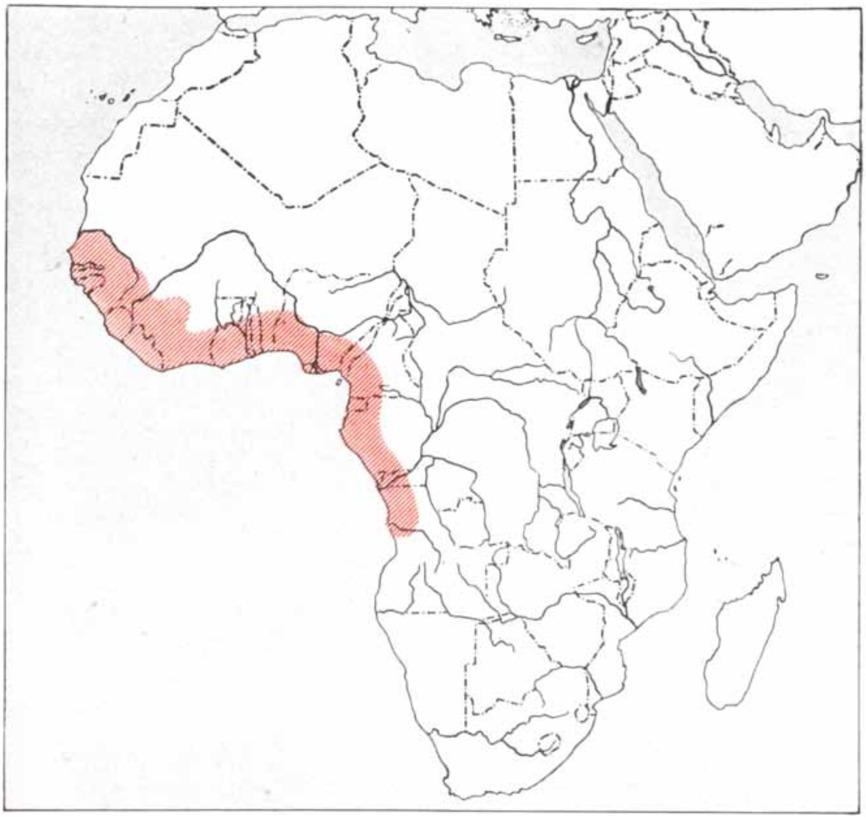
ONE is a map of poliomyelitis. It indicates that the disease exists in every populated region of the world but breaks out in epidemic form only in certain areas. In a country such as Brazil polio strikes mainly children; in Scandinavia and the northern U. S. it hits the older age groups. Since Brazil rarely has epidemics and tests show that from 80 to 100 per cent of its people have antibodies against the virus, we can assume that its people are more commonly exposed to the virus during childhood and become immunized. In Scandinavia and the U. S. exposure is less frequent; therefore adolescents and adults are more susceptible to the disease.

The epidemiological peculiarities of cholera also have been plotted on a world map. It shows how the disease spreads along trade routes at the speed of the prevailing means of transportation (months by caravan; days by steamship); how it retreats under the attack of modern sanitation; how today it concentrates in certain districts of India. Yellow fever and dengue, plotted on a single map, show a strange reciprocal pattern. Where dengue is extremely prevalent, there is no yellow fever; where yellow fever is common, dengue epidemics are infrequent. No one has yet explained this phenomenon. Plague, another disease that has been mapped, is making steady progress among the wild rodents of the western U. S., yet has attacked few human beings. In China plague has long been endemic, and "bacteriological warfare" has nothing to do with it; lack of sanitation and the harmonious partnership between rodents and the flea vectors of the bacteria account for it.

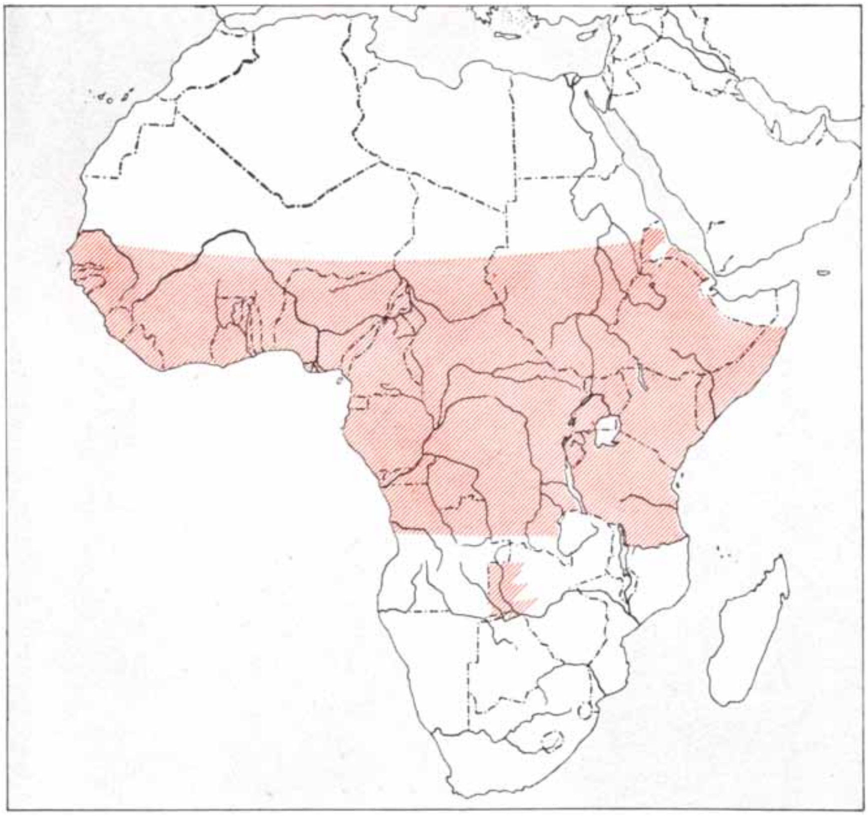
The degenerative diseases also have their geography. Goiter, nutritional dis-



to 1862, 1865 to 1875, 1879 to 1911 and 1912 to 1923. Over this span cholera spread from Asia to other parts of the world. Quarantine eliminated it from the Western Hemisphere after 1911 and from Europe after 1923.



BEFORE 1933 the distribution of yellow fever was reported on the basis of clinical symptoms of the disease. In 1930 its occurrence in Africa was thought to be limited to a strip along the West Coast of the continent.



AFTER 1933 the distribution of yellow fever was reported on the basis of tests that revealed the presence of antibodies in the blood. This subclinical evidence greatly extended the known range of the disease in Africa.

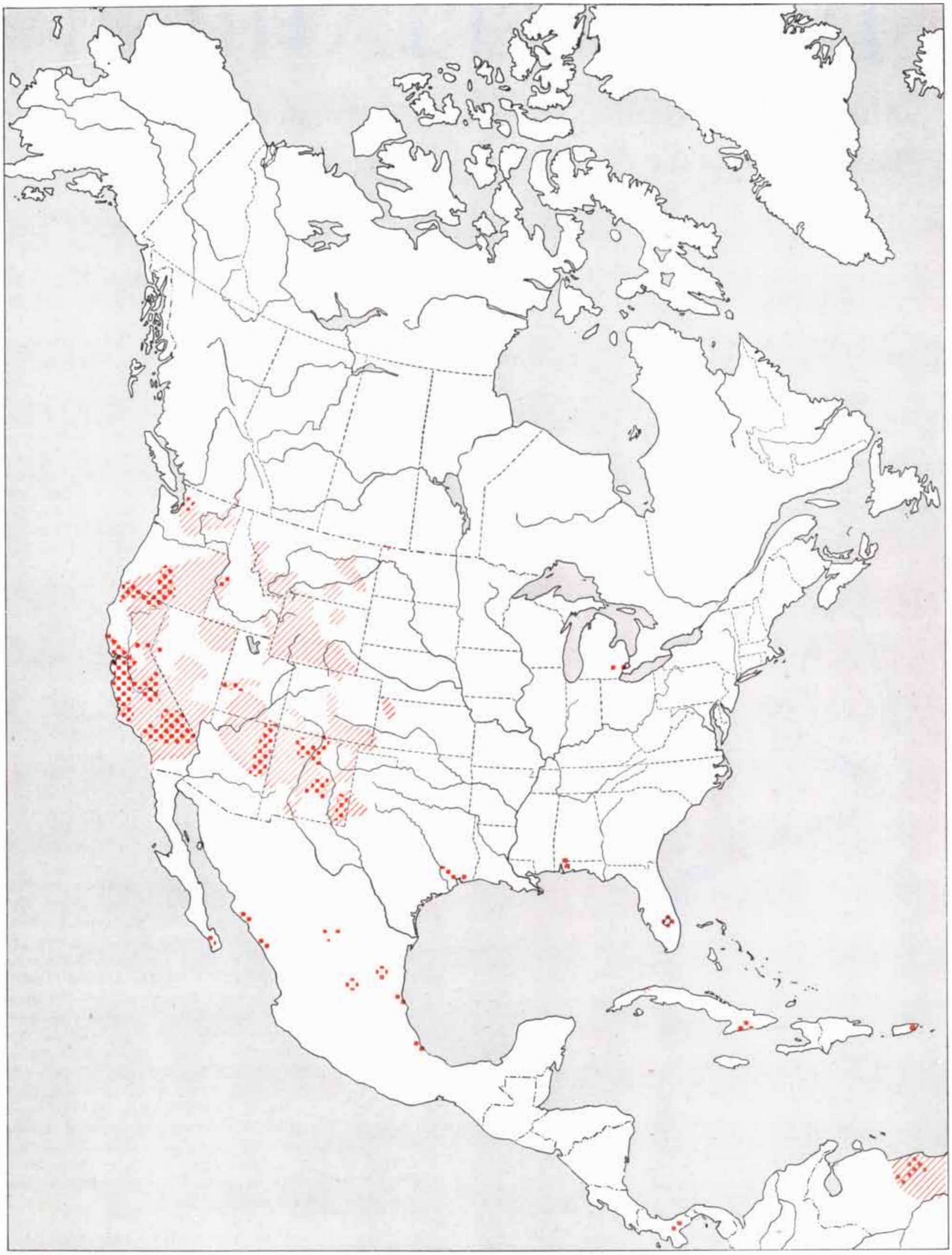
eases and allergies can readily be traced to their environmental sources. We shall understand the degenerative diseases much better when we learn how climatic stress affects the liver, the basal metabolic rate, the kidney, the blood chemistry and other physiological functions.

Comparative studies of the disease distribution by sex and age groups often bring to light correlations not otherwise apparent. Cancer is a striking example. Since it occurs mostly in men and women of middle age, its prevalence is closely linked to the age statistics of the population. We should therefore expect the cancer incidence to be higher in North America than in India or Africa, where fewer people live to middle age. To say without qualification that people in India and Africa are more resistant to cancer is to misrepresent the facts. In those regions the average person does not live long enough to reach the vulnerable cancer years. As a matter of fact, some types of cancer are more common there than elsewhere, taking into account the age levels. Age for age the rates of cancer of the breast in males in Africa are the highest in the world. Cancer of the liver is strangely common among Bantu Negroes and Southeast Asians, even at ages where one observes low rates of cancer in general and no primary cancer of the liver whatsoever in western Europe and North America.

THE SKETCHY nature of disease reporting, particularly in the more backward areas of the world, makes imperative a better system of coverage. Among the plans which the American Geographical Society has developed for this purpose is a project for cooperative work by geographers and physicians. The geographers would map the region, subdividing it according to essential geographical characteristics, as was recently done by the government of Puerto Rico. Following the geographical survey, a medical team would move in, examine a sample group of the population and study as many as possible of the geographical factors. The people would be examined not only for present disease but also—and chiefly—for traces of past infection. With maps showing both the geographical and the pathological pattern of a given region, the medical geographer could then draw correlations which would otherwise escape him.

Medical geography represents not a new science but a new combination of two very old sciences. In these days of specialization, when the over-all picture is often lost even to the best minds, such a cross-fertilization of knowledge is of practical and philosophical importance.

Jacques M. May is director of the department of medical geography at the American Geographical Society.



PLAGUE, contrary to the general belief, occurs in North America. On this map the distribution of cases of human plague from 1900 to 1952 is indicated by small squares; the distribution of sylvatic, or wild-rodent, plague in the same period, by diagonal lines. Both forms of the disease appear to be moving to the East.

INSECT BREATHING

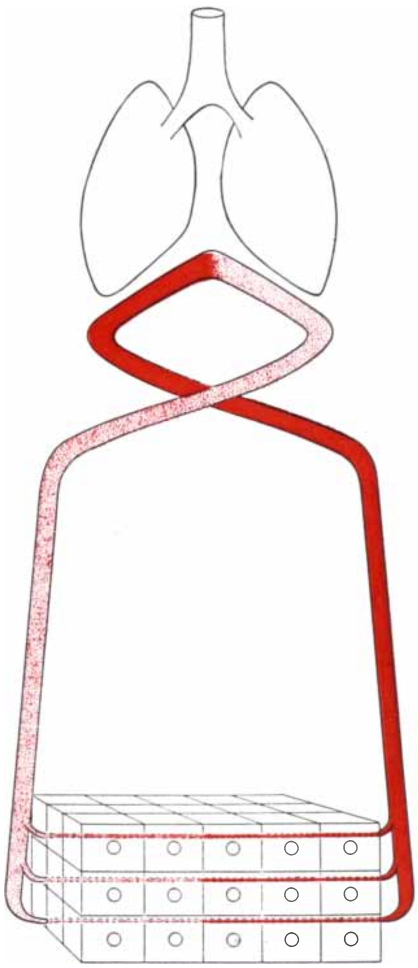
Although these small creatures use oxygen, they have no lungs. Each cell gets the gas from a private conduit, a fact that is not only interesting but also important to the welfare of man

by Carroll M. Williams

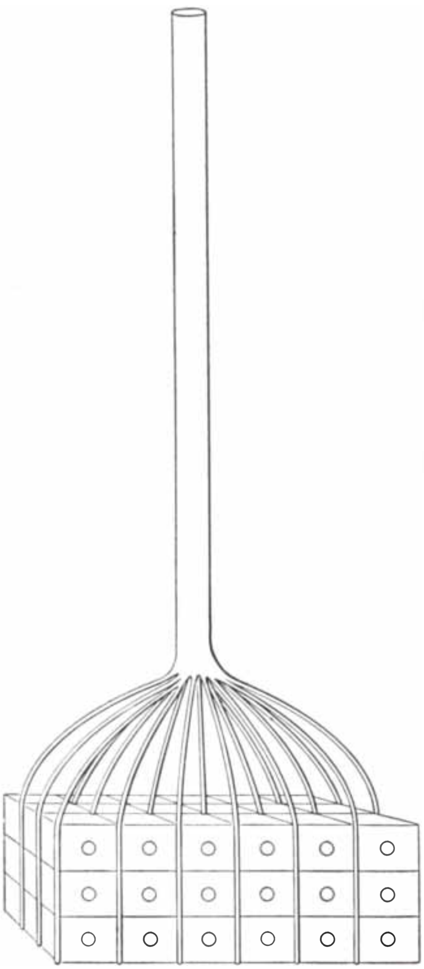
INSECTS, like men, must breathe. Indeed, to maintain their unparalleled rate of metabolism flying insects require more oxygen, ounce for ounce, than larger animals do. Insect evolution has met this demand by designing a respiratory system totally different from that of higher animals. Our "rhythmic sipping of the air" supplies oxygen to our body cells by the roundabout route of lungs and bloodstream. The insect respiratory system by-passes the blood and delivers oxygen directly to each and every one of the millions of cells buried deep in the various tissues and organs of the body. Each insect cell, in short, has its own private lung to keep the fire of its metabolism burning.

The insects and other tracheates (centipedes, millipedes, certain spiders, and so on) accomplish this by an amazingly efficient "tracheal system" of tubes and tubules. For practical as well as purely scientific reasons there is a growing interest in the tracheal system of respiration. Since the really serious enemies of the human race are all smaller than a horsefly, and since the life of such a creature as the mosquito depends upon the proper functioning of its tracheal system, entomologists have a favorite vision: a tracheal system filled, not with air, but with insecticide. Physiologists find equally good reasons for interesting themselves in the tracheal system. It embodies a refinement of biological engineering almost past belief. It also makes insects ideal animals for investigation of certain basic questions in biochemistry. By way of the tracheal system an investigator can introduce gaseous promoters and inhibitors of enzyme action into insect tissues and see them take effect promptly and directly.

In its ground plan the tracheal system is simplicity itself. During early embryonic development the skin of an insect pushes inward at certain points to form hollow tubes opening to the atmosphere. As these primary tracheae grow inward toward the tissues, they branch repeatedly. The branches spreading from the main trunks become progressively finer and their walls more delicate. The terminal twigs, called tracheoles, are so minute that the smallest capillaries in the human circulatory system would appear as large as pipelines in comparison. One or more tracheoles comes into intimate juncture with each cell in the insect and sometimes actually penetrates the cell. The insect is thus an intricate network of minute, air-filled tubes and tubules which convey the oxygen from the environment into immediate contact with the individual cells.

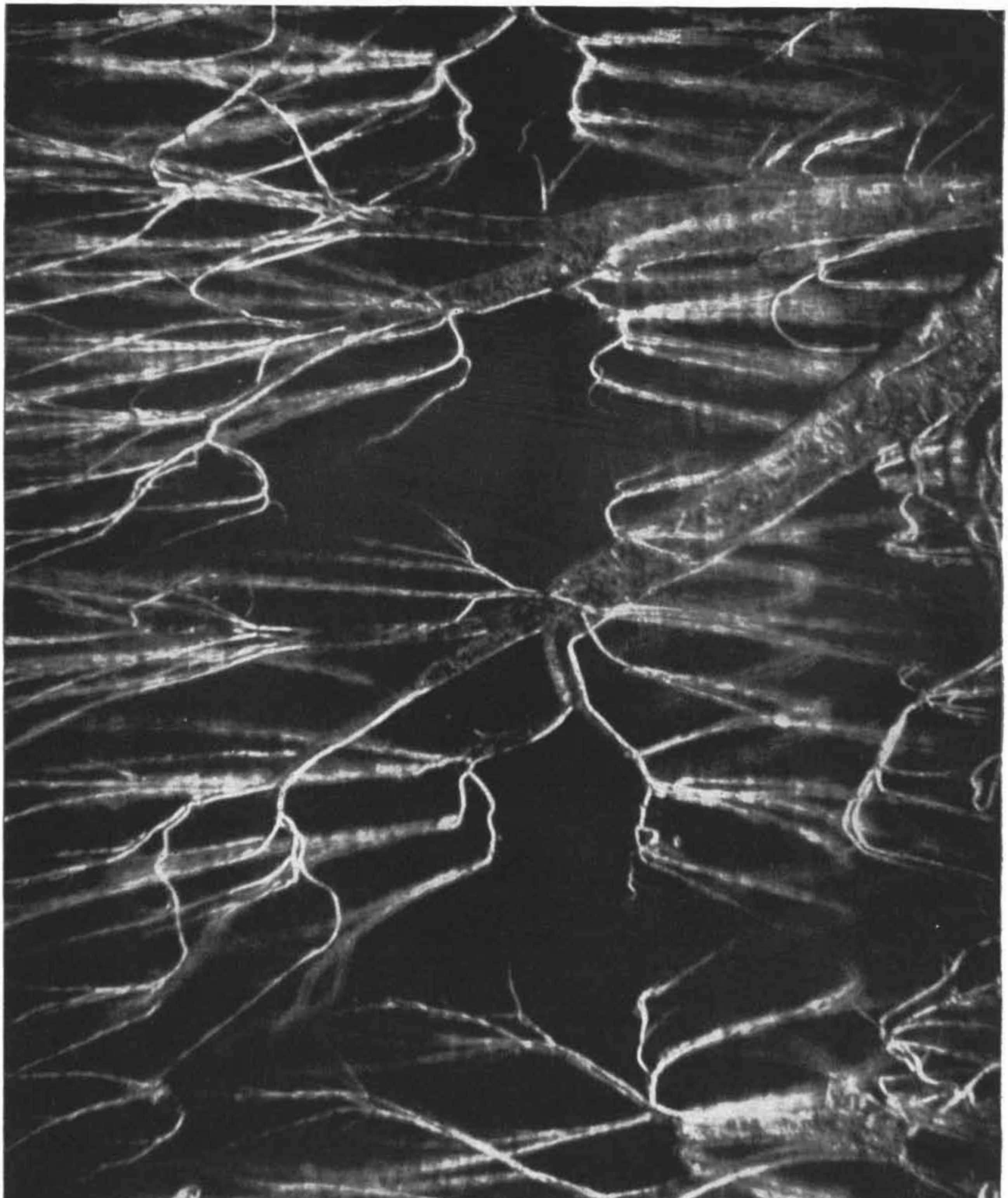


LUNG SYSTEM uses blood to move oxygen (*dark red*) to cells and carbon dioxide (*light red*) from them.

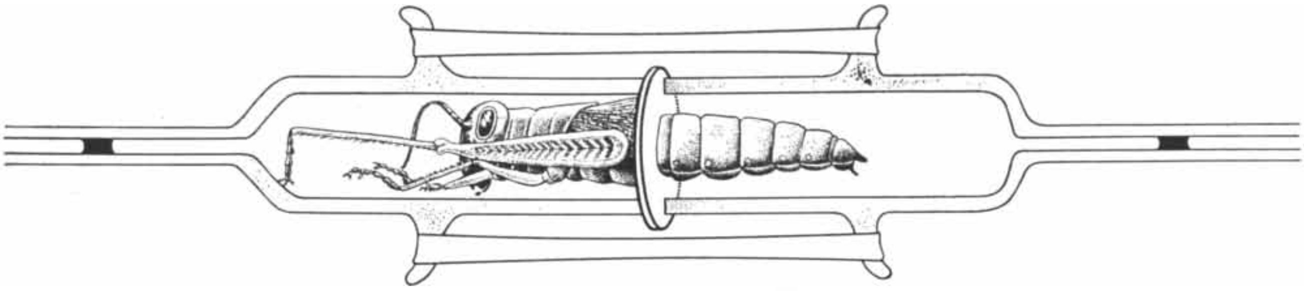


TRACHEAL SYSTEM consists of air-filled tubes which branch into others. Oxygen diffuses through air.

THE FACT that insects possess such an elaborate system of air-filled tubules was discovered in the 17th century by the versatile Italian biologist Marcello Malpighi. It was apparent that



TRACHEAE AND TRACHEOLES are magnified 1,000 diameters in this dark-field photomicrograph of a living muscle fiber in the wing of a blowfly. The relatively large tracheae, the most conspicuous of which enter the picture from the upper right, branch into the fine tracheoles, each of which supplies a single cell.



GRASSHOPPER was mounted in a glass chamber by Gottfried Fraenkel to determine the movement of air in the tracheal system of the insect. Around the middle of the grasshopper was a rubber diaphragm that divided the chamber into two parts. The oil drops at the far left and far right soon moved to the right, indicating that the grasshopper inhales through spiracles located in its thorax and exhales through those in its abdomen.

the tracheal system had something to do with respiration. But how could such tenuous tubules deliver enough oxygen to the cells?

The matter was settled early in this century by the Danish Nobel prize winner August Krogh. He was the first to appreciate the biological advantage inherent in the extreme agility with which a gas such as oxygen can diffuse through another gas. He showed that molecules of oxygen diffuse through air 300,000 times faster than through water and a million times faster than through living tissue. This, in a manner of speaking, was a measure of nature's good sense in equipping the tracheates with air-filled tubules instead of depending upon diffusion through tissues.

To prove that the tracheal system is in fact a respiratory system, Krogh had to carry the investigation a few steps further. Diffusion, like so many physical processes, is always downhill: a gas in diffusion always moves from a region of higher pressure to a region of lower pressure. The oxygen pressure in the atmosphere at sea level is three pounds per square inch. Given this limit on the pressure available to drive oxygen through the insect tracheal system into its tissues, Krogh had to show that the tracheal tubes are sufficiently short and their combined cross sections sufficiently great to deliver oxygen at the required rate. He did so in a series of simple and ingenious experiments of the type for which he was famous.

Krogh first measured the oxygen consumption of the caterpillar *Cossus*. Then, by a method which he developed himself, he made a wax cast of the insect's tracheal system. This involved injecting liquid wax into the tubes and dissolving the tissues away after the wax had hardened. Now Krogh was able to measure the dimensions of the tubes. The results were astonishing. He found that simple diffusion could supply the caterpillar with 15 times the amount of oxygen it needed.

Thus in small insects the act of respiration is reduced to a simple matter of pressure and automatic diffusion. As the tissues consume oxygen and reduce the local pressure, oxygen flows in through the tracheae from outside. The tissues can obtain more oxygen merely by using it. Since the tissues always have some positive pressure of oxygen which may be reduced to let in more oxygen, there is a clear margin of reserve which can be tapped as the occasion demands.

Besides admitting oxygen, a respiratory system has a second responsibility: getting rid of carbon dioxide. Krogh found that carbon dioxide, unlike oxygen, diffuses through water or living tissues with great ease. In insects a significant fraction diffuses out through the skin itself without ever entering the tracheae. Thus a diffusional system which is adequate to supply oxygen will always be more than adequate to excrete carbon dioxide.

THE PASSIVE system of respiration demonstrated by August Krogh suffices, however, only for small insects. As an animal becomes larger, the volume of its oxygen-demanding tissue increases as the cube, but the supply of oxygen by diffusion can increase only in direct proportion to the linear increase in size, partly because the gas must travel farther through the tracheal tubes and partly because the cross-sectional area of the tubes cannot increase as fast as the insect's mass. Nature provides a partial solution by slowing down the pace of cellular metabolism as its creatures grow larger ("The Metabolism of Hummingbirds," SCIENTIFIC AMERICAN, January). Thus the rate of oxygen consumption increases approximately as the square rather than as the cube of linear size. Nonetheless, there remains a disproportion between the squared increase in the demand and the linear increase in possible supply. Beyond a certain size an insect would soon arrive at respiratory bankruptcy if it were to continue its passive dependence on diffusion. This is probably the main reason why insects are small animals.

The largest insects have had to evolve mechanisms for supplementing passive diffusion. They exert active respiratory movements which have the net effect of ventilating the larger tracheal trunks. The insect rhythmically compresses or flattens its abdominal segments by contraction and relaxation of the intersegmental muscles. The blood that fills the body cavity transmits the pressure of these contractions to the larger tracheal trunks. This, incidentally, is the sole contribution of blood to the respiration of most insects; not more than half a dozen genera of insects are furnished with hemoglobin or any other oxygen-carrying pigment.

In many insects the pressure is transmitted by way of thin-walled sacs placed at intervals along the larger tracheal trunks. In insects that lack such sacs, the trunks themselves, commonly oval in cross section, collapse in response to the pressure. Sometimes the trunk walls, of helical structure, are too strong to be compressed; in that case the trunks behave like spiral springs, shortening and expiring air when the blood pressure rises, and elongating and inspiring air when the pressure falls. Thus the larger tracheal trunks behave as hydraulic bellows, sucking and blowing air in and out with each respiratory movement.

The respiratory movements of insects, which expire air by contracting the abdominal muscles and inspire simply through the elastic recoil of the abdomen and tracheae, are just the reverse of those of mammals, where inspiration is active and expiration passive. The same result, however, is achieved in both cases. A current of air is moved to and fro in the larger air passages, and by this mechanical means the atmosphere is brought closer to the tissues. In insects the distance through which oxygen and carbon dioxide must diffuse is thereby reduced to the lengths of the smaller tracheal vessels which cannot be mechanically ventilated.

None of these adaptations was overlooked by Krogh. He even succeeded in measuring the magnitude of an insect's breath, and found that in one breath it could inspire a volume of air equal to half the total volume of the tracheal system.

Some insects have progressed a step beyond this to-and-fro ventilation. An example is the grasshopper. Gottfried

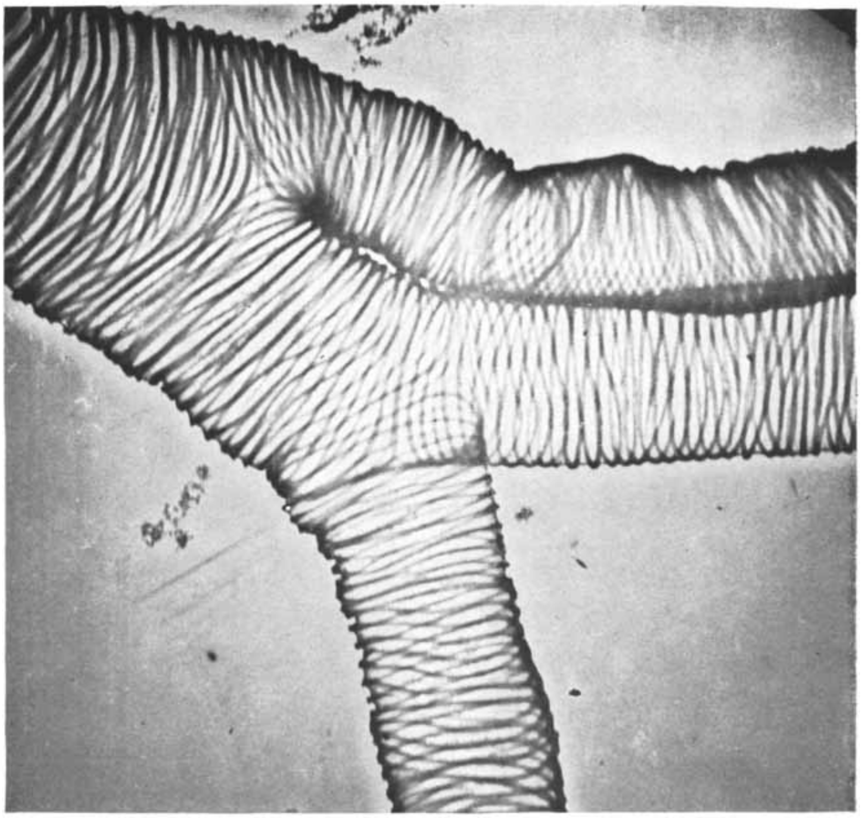
Fraenkel of the University of Illinois has studied its breathing. He placed a rubber diaphragm around the insect so that the abdomen could be enclosed in one chamber and the head and thorax in another chamber [*see drawing on the opposite page*]. The air pressure steadily decreased in the chamber enclosing the head and thorax and increased in the other. Obviously the air must have been sucked through the insect's longitudinal tracheae from thorax to abdomen. Closer inspection showed that the valves on the spiracles (openings to the air) open and close in such a sequence that inspiration must occur through the thoracic spiracles and expiration through the abdominal. By this maneuver the larger tracheal trunks are ventilated more efficiently than is possible by the to-and-fro method.

Both the respiratory movements and the opening and closing of the spiracle valves are under the control of respiratory centers within the central nervous system. There is a center in each body segment and apparently one in the thorax which coordinates the actions of the individual segments. The segmental centers are primarily sensitive to carbon dioxide; any increase in the carbon dioxide pressure augments the respiratory movements in a spectacular fashion. In contrast, the thoracic center seems to be especially sensitive to any decrease in oxygen pressure and, in this sense, is analogous to the aortic and carotid bodies which help govern the respiration of mammals. Even in the insect, nature has found it prudent to safeguard the organism against lack of oxygen and excess of carbon dioxide.

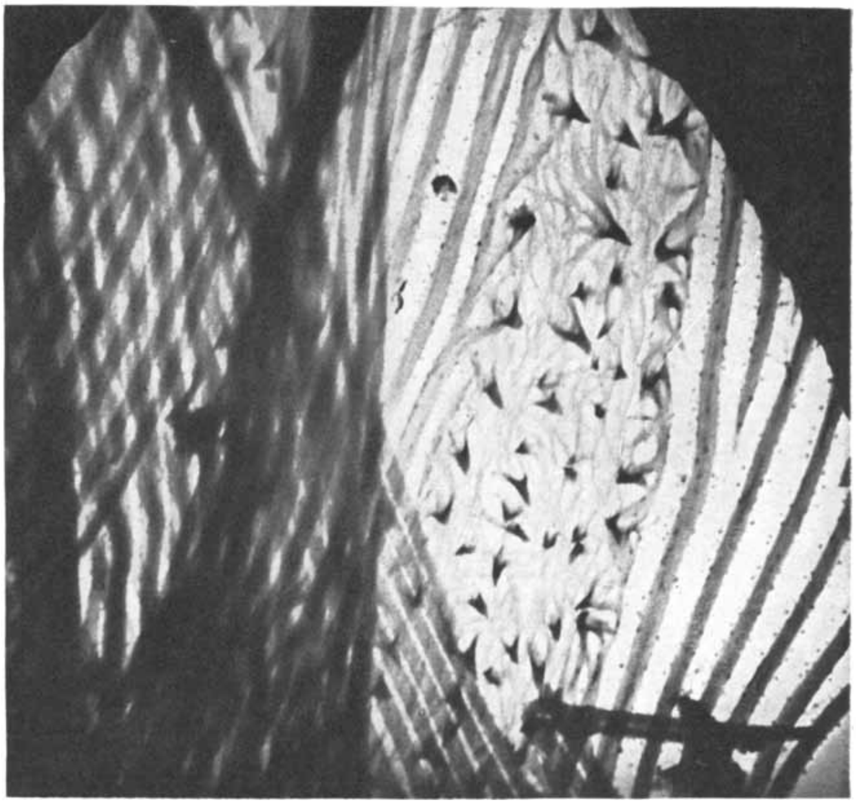
THE TRACHEAL system as described so far is clearly a mechanism adapted for life on land. It is an excellent piece of evidence that insects and their ancestors have always been primarily land-living animals. But an enormous number of insects desert the land to spend their immature phases in the water. After metamorphosis they usually give up their aquatic way of life and return to their ancestral home on land.

Although insects have been eminently successful in this secondary invasion of fresh water, the sea seems to present an insurmountable barrier to them. The truly marine species can be numbered on the fingers of one hand. Apparently it is not the sea's salt that bars insects, for some species are able to thrive even in salt lakes and the waters of brine pits. More probably their inability to adapt to the sea has something to do with the tracheal system; in the few marine insects the tubes are generally filled with fluid and have no function. An explanation of these facts awaits discovery.

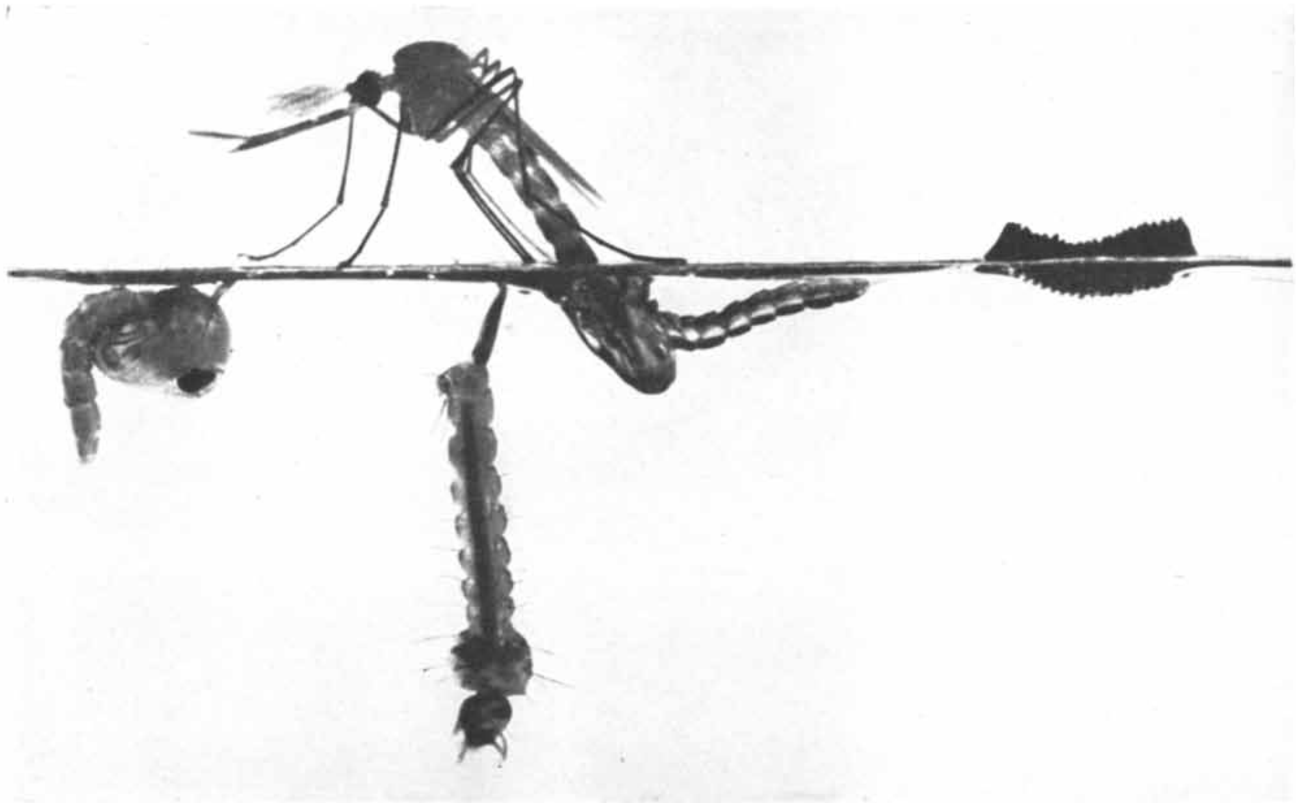
The insects that have invaded fresh water have evolved an array of ingenious devices adapting the tracheal system to



MOSQUITO TRACHEAE have a spiral construction which permits them to become longer or shorter. The mosquito is thus able to assist the flow of gases through its tracheae by alternately expanding and compressing them.



MOSQUITO TRACHEA is enlarged 6,000 diameters. This electron micrograph and the one above it were made by A. G. Richards of the University of Minnesota and T. F. Anderson of the University of Pennsylvania.



UNDERWATER BREATHING of the mosquito in the early stages of its life is illustrated in this photograph by the Australian entomologist A. J. Nicholson. The larva (*center*) and the pupa (*far left*) breathe through tubes that open at the surface. The adult mosquito at the top has just emerged from its pupal skin.

aquatic life. The devices include breathing tubes, diving bells and gills.

Enormous numbers of insects have applied to their underwater activities the principle of the "snorkel," such as is used in the latest submarines. Still dependent on the atmosphere for their supply of oxygen, they stick the snorkel above the surface from time to time for air. Some of them (*e.g.*, the rat-tailed maggot) even have a retractable breathing tube which they pull in when swimming under water.

The tip of the snorkel is generally equipped with two or more valvelike flaps. The mosquito larva's valves open automatically when it reaches the surface, for the simple reason that the outer surface of the flaps is wettable by water, whereas the inner surface is nonwettable. This superb little mechanism can be jammed, however, when the surface of the water is coated with oil or some other liquid able to wet the inner surface. The surfacing mosquito larva then inhales kerosene instead of air, as was first discovered by Aristotle. For the mosquito larva this is what the British biologist V. B. Wigglesworth has termed the "weak spot in the ecological armor" —a weak spot not without significance for the human race.

The diving-bell insects take oxygen along with them when they submerge. The "bell" consists of a bubble of air collected at the water's surface and held on one or more points of the body. During the dive the insect sucks oxygen from the bubble. Students of the phenomenon were long puzzled by the fact that the insect can stay under water long after it should have exhausted the bubble's oxygen content. The puzzle finally was unraveled by the Danish physiologist Richard Ege. He found that the bubble can serve as a veritable underwater lung. As the oxygen pressure in the air-filled bubble falls below that of the oxygen dissolved in the surrounding water, oxygen from the water diffuses into it. The insect can remain submerged until the nitrogen that keeps the bubble inflated diffuses into the surrounding water. So, strange as it may seem, the most important ingredient in the bubble of air which the insect picks up at the surface is nitrogen, not oxygen. The nitrogen, which makes it possible to use the bubble as a lung, allows the insect to be submerged 13 times as long as an equivalent bubble of oxygen would permit.

The third group of aquatic insects, equipped with gills, has managed to escape dependence on the atmosphere. Their gills are generally outfoldings of the body wall, richly supplied with tracheal tubes. By vibration or undulation of the gills, the insects equilibrate the gaseous content of their tracheae with the dissolved gases in the water. To reach the enclosed chambers of the tracheal system, oxygen must diffuse through the cuticle of the gill, through a thin layer of blood and finally through the walls of the tracheal tubes. But once a molecule of oxygen gets inside the tracheae, it can diffuse through the gases in the tubes and tubules about 300,000 times faster than through blood.

In a sense the gilled insects are not so different from the diving-bell types. In the bubble-breathers the bubble is external. In the gill-breathers the bubble is internal, contained within the tracheae of the gill. By this device the insect increases the surface area of the bubble, stringing it out through its tracheal system, and it also insures that its bubble will not collapse.

THE TRACHEAL system of respiration, different as it is from that of higher animals, proves to be one of evolution's most successful and versatile adaptations. It seems to have had the initial function of aiding and abetting the passive diffusion of oxygen and carbon dioxide between the atmosphere and the tissues. To the basic plan evolution gradually added ingenious new devices which permitted insects to increase in size, to fly and to live under water. In the tracheal system nature seems to have devised a method of breathing which, for small animals, is nearly perfect.

Carroll M. Williams is associate professor of zoology at Harvard University.

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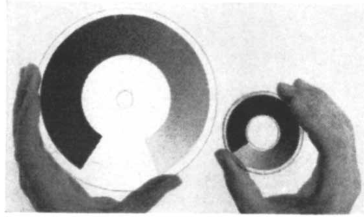

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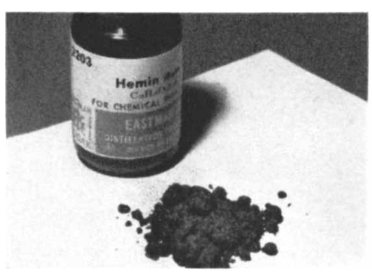

acid, slow crystallizations from various solvents without stirring, etc., etc. From all this emerges the product, the chloride salt of an iron porphyrin in which four substituted pyrroles are joined by methylene linkages around a central iron atom. Despite the conservative "97+%" stated in our catalog and on our label, our control lab reports semi-confidentially that the actual purity usually runs above 99%.

This is but one of over 3500 organic chemicals appearing in Eastman Organic Chemicals List No. 38. If you haven't a copy, write to Eastman Organic Chemicals Department, Distillation Products Industries, Rochester 3, N. Y.

High speed

As a tool for the engineering analysis of mechanical motions too fast for the eye or even for the sports newsreel type of "slow motion," we make the Kodak High Speed Camera. It can take from 1000 to 3200 full 16mm frames per second and can superimpose the corresponding oscillograph record on the pictures if required. It is simple to operate, and gives pictures of excellent photographic quality. We have sold a very respectable number of them to people who have found its speed range just right for the great majority of mechanical design problems. Nevertheless, there *are* problems, mostly in fundamental research, where simplicity, economy of operation, and even image clarity must be sacrificed for higher repetition rates. Several high speed cameras of such specialized design have appeared in recent years, and we are frank in our admiration of them. The history of this branch of instrumentation dates back at least to 1880 and has its own terminology, literature, regular symposia, and a collection of impressive successes. A scholarly and exhaustive summary of these lately appeared in one of the engineering journals. We have had it reprinted and shall be happy to send you a free copy.

For the reprint ("Special Report on High Speed Photography in Design"), for inquiries about the Kodak High Speed Camera, or for help in selecting film or plates for any form of high speed photography, address Industrial Photographic Sales Division, Eastman Kodak Company, Rochester 4, N. Y.

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

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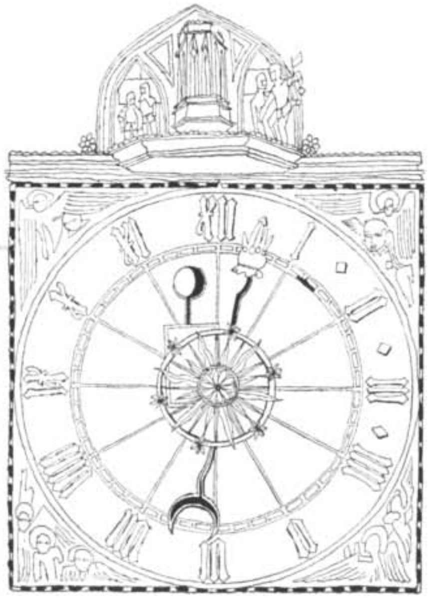


A.A.A.S.

At its 119th meeting last month in St. Louis the American Association for the Advancement of Science took steps to change its character and functions. It selected as president-elect (to serve in 1954) Warren Weaver of the Rockefeller Foundation, who has been urging the Association to concentrate on public education and on integrating the sciences, leaving to the separate professional societies the presentation of detailed scientific papers ("Science and the Citizen," SCIENTIFIC AMERICAN, February, 1952). A resolution endorsing such a program was adopted at the Association's 1951 meeting. In the coming year the A.A.A.S. will appoint two committees, one to study how the specialized branches of science can be brought together for common discussions, and the other to look for new ways to make effective one of the stated purposes of the Association: "To increase public understanding and appreciation of the importance and promise of the methods of science in human progress."

Scientists' concern with public appreciation of their problems was highlighted in the address of the retiring president, Kirtley F. Mather of Harvard University, who spoke on "The Common Ground of Science and Politics." Mather asked that scientists' ideas on security regulations be given "more respectful consideration than they have thus far received," and that "joint task forces" of scientists and government officials be set up to solve "the technical problems involved in providing adequate subsistence" for the world's population.

Edward U. Condon, research director of the Corning Glass Works, was installed as this year's president of the A.A.A.S. As the convention began the House Committee on Un-American Activities released a report which, conceding that it had no information "that Dr. Condon was a Communist or committed any act of espionage," nevertheless pronounced him "not qualified for acceptability to any security position" because of his "propensity for associating with persons disloyal or of questionable loyalty and his contempt for necessary security regulations." Condon retorted: "My record of scientific service to the government and scrupulous regard for all security regulations is absolutely spotless. . . . Not one of the persons with whom I have associated has ever been formally accused, let alone convicted, of any espionage activity. . . . The Committee's statements about contempt and disdain for security regulations are outrageous and contemptible lies."

In an address "On the Proper Role of Scientists in a Schizophrenic World" Maurice B. Visscher, professor of physiology at the University of Minnesota Medical School, urged the A.A.A.S. to assess its membership to raise funds for "an educational campaign to protect the free enterprise system in ideas" and to oppose "the rising tide of anti-intellectualism in America," fostered by "organizations and individuals displaying overtly paranoid behavior toward scientists." Visscher said later that he will present his proposal formally to the A.A.A.S. Board of Directors. He has in mind a large-scale, professionally directed campaign of publicity and advertising in newspapers, magazines, radio and television.

The A.A.A.S. program included some 1,500 scientific papers and several symposia.

The $1,000 Newcomb Cleveland prize for an outstanding individual paper was awarded to Andrew M. Gleason, 31-year-old Harvard University mathematician. His paper on "Natural Coordinate Systems" was described by Saunders MacLane, president of the Mathematical Association of America, as "the most important mathematical advance, either here or abroad, of the year 1952." It presented his solution of "the fifth problem of Hilbert"—one of 23 important problems in mathematics propounded in 1900 by the great mathematician David Hilbert. The problem is whether, in a certain type of geometrical space (a "locally Euclidean group"), a system of coordinates can be found that makes it possible to describe the space in workable mathematical equations. Gleason proved that such a system can be found.

Frank J. Dixon of the University of Pittsburgh Medical School won the $1,000 Theobald Smith award for medical research for his work on antigens and antibodies. He has shown that exposure of the body to radiation before an invasion of antigen inhibits its ability to make antibodies and may prevent the development of immunity. Dixon has also investigated the life span of various antibodies and found that it depends on the body's rate of metabolism, which in turn depends on the animal's size. He determined that gamma globulin antibodies have a half-life of two weeks in a human being and somewhat less than two days in a mouse. Dixon's findings were used to compute dosages in last summer's field trials of gamma globulin for polio prevention.

A new $1,000 prize was given for work in social science which the anonymous donor specified should be based on "the best formulated evolutionary naturalism and experimental or operational logic of the last half-century or more." The winner was Arnold M. Rose of the University of Minnesota for his paper on "The Theory of Social Organization and Disorganization."

Shields Warren, director of the Division of Biology and Medicine of the Atomic Energy Commission, received the $1,000 William Proctor Prize of the Scientific Research Society of America. The award was given in recognition of his "brilliant record of service in military medicine and of research into the biological effects of atomic nuclear reactions."

The $1,000 A.A.A.S.-George Westinghouse Science Writing Awards went to Alton L. Blakeslee, science editor of the Associated Press, and Morton M. Hunt, freelance writer. Blakeslee's prize was for a series of articles on the Jackson Memorial Laboratory at Bar Harbor; Hunt's was for an article in *Esquire* entitled "Neurosis Factory," describing research by Cornell University psychologist Howard S. Liddell on experimentally induced neuroses. Honorable mention went to Milton and Margaret Silverman, freelance writers, and to Charles A. Federer of the Harvard College Observatory, editor of *Sky and Telescope*.

Some other reports at the meeting:

Barry Commoner, biochemist at Washington University in St. Louis, presented new information on how viruses reproduce. He split tobacco leaves in half, inoculated one half with the tobacco mosaic virus and cultured both halves in a nutrient containing labeled nitrogen. Analysis of the nitrogen uptake showed that the virus does not reproduce itself but forces the host cell to use its own chemical supplies to make new virus molecules instead of normal cell protein. Thus the virus molecule serves as a model for the synthesizing activity of the cell. Commoner believes that a cell builds normal proteins in the same way.

N. W. Flodin of E. I. du Pont de Nemours & Co. announced that several amino acids have been synthesized artificially. One of them, methionine, is already being produced on a commercial scale for use in poultry feeds. Flodin predicted that synthetic amino acids would help overcome protein deficiencies and become important additions to the world's food supply.

Loh Seng Tsai, psychologist at Tulane University, reported that rats can be taught to recognize coins, to exchange money for cheese, to save the money for when they are hungry, to hoist a ladder on a chain pulley to get at food on a high shelf. It is the first time that animals other than man and apes have been observed to be able to use tools and coins. Like chimpanzees, the rats learn these tricks by trial and error. They now provide an opportunity to study complex behavior with inexpensive laboratory animals whose genetic history and experience can be carefully controlled.

Old Fish

In the Indian Ocean off Madagascar fishermen last month netted a five-foot, 100-pound fish which evolutionists promptly hailed as the "most important zoological discovery of this century." J. L. B. Smith, South African ichthyologist, flew 3,000 miles in a government-supplied military plane to reach the fish in time to preserve it. When he arrived, and found it smelling somewhat strong but largely intact, he broke down and wept. The object of his emotion was a coelacanth, the earliest type of bony fish. Until a few years ago it was believed that such fish had been extinct for 75 million years.

Among the very early forms of animal life on earth was a group of fish known as crossopterygians. About 350 million years ago these fish evolved into three different forms: the lungfish, which still exist today; the amphibians, which later developed into land-living vertebrates, and the coelacanths. The latter were thought to have died out with the early amphibians about 75 million years ago, but in 1938 one was pulled out of the water by a South African trawler. By the time Smith got hold of it, only its skeleton and skin were left. Since that time he has been on a constant lookout for another specimen, and has distributed thousands of leaflets to native fishermen asking their help. The campaign paid off when a fisherman recognized the coelacanth in a Madagascan village market last month.

During the almost 300 million years of their fossil history the coelacanths changed very little. Consequently Smith believes that the surviving specimen is still much like the very earliest forms. As for what he hopes to learn from the fish, Smith said: "Here are some of my jostling thoughts: What is the composition of the flesh of the coelacanths? What are its component amino acids? . . . The coelacanth just drips oil; what is its nature, and will it help us to decide whether fish oil was really the origin of our mineral oil deposits? What was the nature of the cells in the earliest creatures? Did they have a liver? Did they have spiral valves in the intestines? What sort of digestive juices did they have? . . . There is hardly a limit to what we may learn through the coelacanth."

Smith will not get all the answers from his present fish because it lost some of its soft parts when the fisherman who caught it clubbed it on the head. He hopes, however, to get more specimens.

Sunlight and Life

A POSSIBLE major break in the problem of photosynthesis has recently been announced by Melvin Calvin, University of California chemist. Like many other scientists all over the world, Calvin has been patiently digging into the mechanism by which plants use light energy to convert water and carbon dioxide into the complex, energy-yielding organic molecules of living tissue. The first step has long been known. Electrons in chlorophyll molecules pick up quanta of energy from light and are raised to a higher energy level. They remain in this excited state only for a few thousandths of a second, however, and the big question is: Where does the energy go from there? Now Calvin thinks he is on the track of the answer.

He picked up the clue rather by accident. He had two samples of a recently discovered growth substance called protogen from the Lederle Laboratories: one, the natural chemical as found in plants; the other, a synthetic preparation. Calvin noticed that natural protogen was yellow, whereas the synthetic material was colorless. This led him to suspect that in its natural form protogen contains pairs of sulfur atoms as links in the molecule. It is known that these links can be broken by absorbing no more energy than is available from the excited chlorophyll electrons. Calvin suggests that protogen molecules in contact with the chlorophyll molecules absorb enough energy to part the disulfide links and break down into highly reactive free radicals. These react with other substances in a plant, taking hydrogen from them and starting the chain of reactions which eventually produces the organic molecules and free oxygen.

The California chemist has synthesized the disulfide part of the protogen molecule and has demonstrated that it can be broken apart by the action of light. Further, protogen is known to be plentiful in green plants.

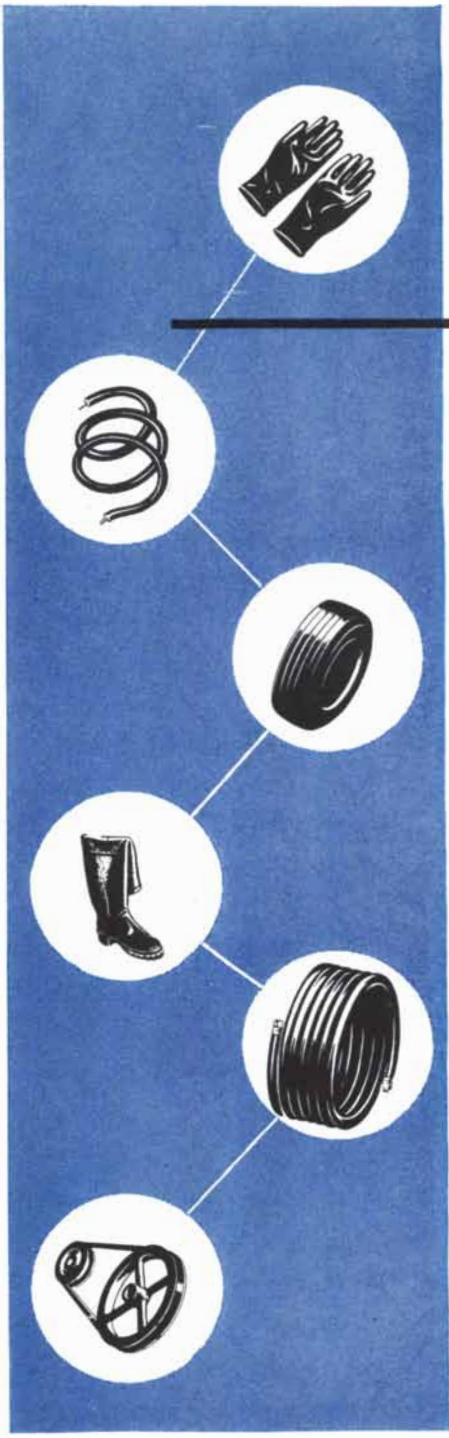
Green Goods

THE magic phrase "contains chlorophyll," came in for some rough handling last month. Before the American Chemical Society Alsoph H. Corwin, head of the department of chemistry at the Johns Hopkins University, examined the claims for chlorophyll as (1) a blood tonic, (2) a disinfectant, (3) a wound-healing agent and (4) a deodorant. He concluded that none of these claims is backed by acceptable experimental evidence. Antibiotic substances in plants can account for its "weak" action against bacteria, and no one has demonstrated that chlorophyll-soaked wound dressings especially promote healing. Corwin quoted a National Bureau of Standards report that "we have no reason whatever to believe that chlorophyll ever has anything to do with deodorization." Even if it did, Corwin pointed out, this would still be no reason for believing that chewing or swallowing chlorophyll could deodorize the sweat glands. There is no evidence that it is transported through the bloodstream; indeed, it is fortunate that chlorophyll does not get into the blood, because it would have toxic effects. Corwin added that chlorophyll derivatives usually contain an excess of copper which may be poisonous. The whole question, he said, "is certainly one which needs investigation."

Einstein Vindicated

AFTER the telescopes, cameras and other equipment set up in Khartoum last winter to observe the solar eclipse had been dismantled and sent home, one instrument remained in the desert. It was a special telescope with which George van Biesbroeck of the Yerkes Observatory had photographed the edge of the blacked-out sun. He locked the telescope in the same position, covered it with tarpaulins and went home. In August he returned, unwrapped his instrument and took more pictures of the same part of the sky. Since then he has been studying his plates at Yale University with a supersensitive measuring device. Last month van Biesbroeck announced a new verification of Einstein's general theory of relativity, which predicts that light passing near a massive body will be bent from its straight path.

Einstein had calculated that the sun should displace starlight rays grazing it by 1.75 seconds of arc—about a thousandth of the diameter of the full moon as seen from the earth. The first measurements, made during the total eclipse of 1919, showed an apparent displace-



RUBBER GROWS ON IDEAS. In fact, one idea—vulcanizing—virtually created an industry. Since then, new ideas and ingredients have fitted rubber for more and more uses. Today more than a thousand different chemicals and other raw materials are used by over twelve hundred companies to make *5 billion dollars* worth of rubber products annually.

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...suggests many ideas for product improvement

Ozone resistance is important in the rubber industry. If a product has *good* ozone resistance, it stands up longer under normal usage . . . resists failure from surface cracking and loss of strength. That's one of the reasons why rubber-goods manufacturers are so interested in "Hypalon"* S-2 (chlorosulfonated polyethylene)—the new Du Pont polymer that combines *complete* ozone resistance with excellent abrasion and weather resistance, good chemical and heat resistance, long flex-life and unlimited color possibilities.

The rubber industry has many ideas for putting "Hypalon" S-2 to work—both as a basic vulcanizate and as a blend with other elastomers. Because of its remarkable combination of properties, it is being evaluated for such applications as floor coverings, footwear, white sidewall tires and weather stripping. Its ozone and chemical resistance properties are suggesting its use for spark plug boots and wire jacketing . . . for belting and other mechanical goods. In addition, its outstanding resistance to strong oxidizing acids and alkalies and many other chemicals promises much for its use in acid hose and tank linings.

But "Hypalon" S-2 is only one of the products from the Du Pont Polychemicals Department helping the rubber industry do a better job. The list includes Crystal Urea, "Lorol" fatty alcohols and Adipic Acid—to name a few.

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ment very close to that predicted by Einstein. Attempts to check the results at subsequent eclipses were disappointing, however. In every case there was a shift, but far from the expected amount. Van Biesbroeck's new attempt was the most carefully designed and controlled observation yet made. His observed displacement: 1.70 seconds of arc.

Big Bertha

LAST month Stanford University unveiled a new 200-foot linear accelerator which boosts electrons to an energy of one billion electron-volts and a hundred-thousandth of 1 per cent of the speed of light. At this speed electrons weigh 2,000 times as much as when they are at rest. The fast-moving particles will be used to study the atomic nucleus. When electrons strike a nucleus, they usually pass through, instead of smashing it as protons do, and their paths upon emerging give a diffraction picture of the nuclear structure.

In the Stanford machine an 80,000-volt electric pulse tears bunches of electrons off a hot tungsten filament at the rate of 60 times a second. They come off at about half the speed of light, are bunched in a two-foot coil and then at 10-foot intervals down the long tube are kicked along by a series of giant klystrons.

The linear design is much simpler than that of circular cyclotrons and synchrotrons. The electron beam can be tapped "like water out of a spigot."

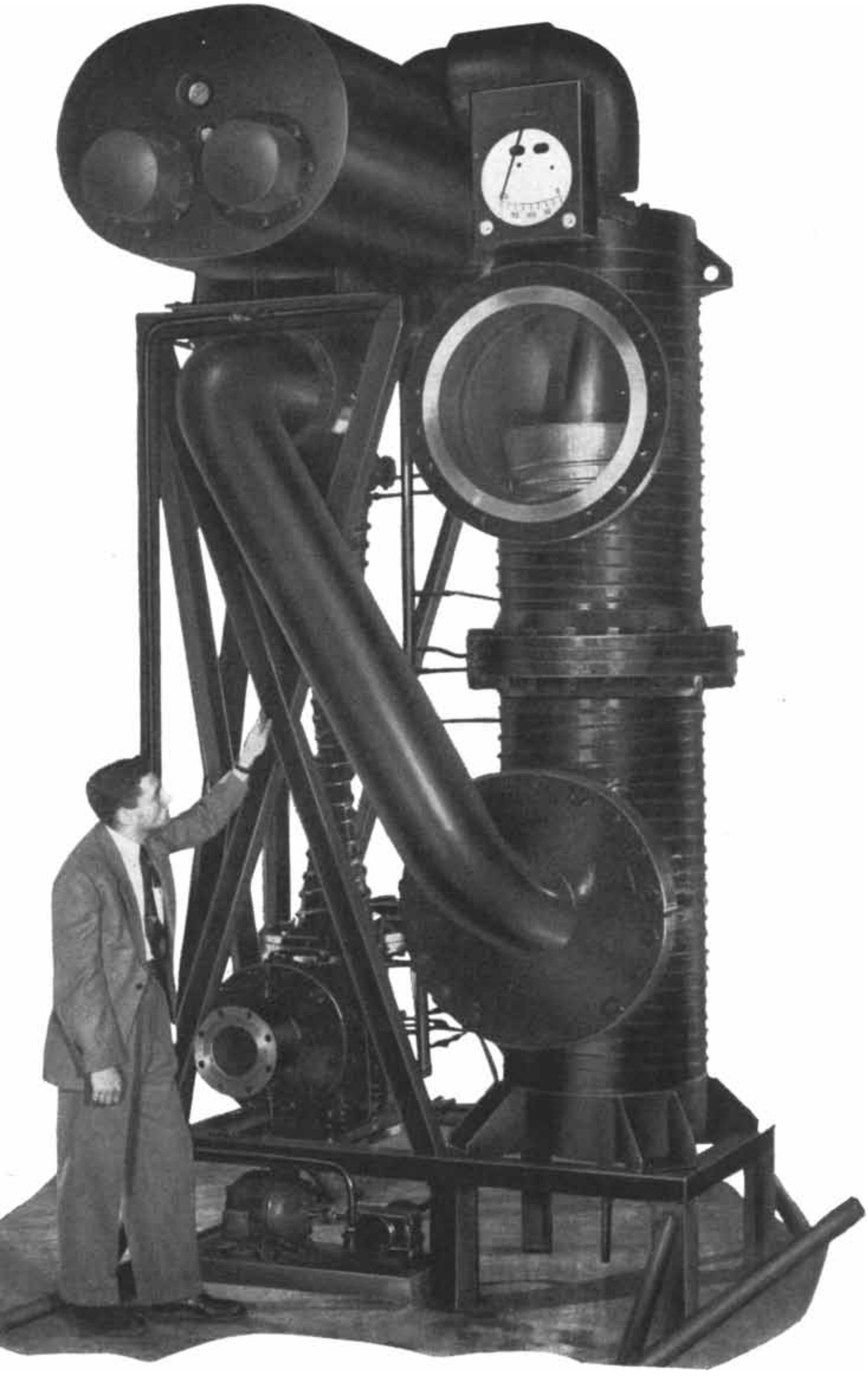
New Hearing Aids

THE first consumer product incorporating transistors has just been placed on the market. Transistor hearing aids manufactured by the Sonotone Corporation and by the Maico Company are now on sale. Sonotone's machine contains one germanium crystal and two conventional miniature vacuum tubes. The company explained that present transistors are too noisy to use in amplifying stages; hence they are employed only in the power section of the circuit. Its new hearing aid is somewhat smaller and lighter than conventional ones and has twice the power and much longer battery life. The Maico device uses three transistors and no tubes. The battery is a single "energy capsule" about the size of a dime.

Some transistor engineers are doubtful that the device is ready for general use. They say that present transistors not only produce noise but are unstable; a circuit matched to one transistor may perform poorly after a month or two because of "drift" in its characteristics.

The Nation's Health

A METHOD of financing to make adequate medical care accessible to everyone in the U. S. was proposed last



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month by the President's Commission on the Health Needs of the Nation, headed by Paul B. Magnuson.

The Commission, after a year's study, suggested a health insurance system, administered largely by physicians practicing in groups. For families unable to afford the premiums, the Federal and state governments would pay all or part of the cost, the U. S. Government contributing from general tax revenues and social security funds. Existing prepayment health plans would be expanded to cover as wide a group as possible, and new units would be formed on the initiative of the states to reach those whom present plans cannot. The services would offer dental as well as medical care, would be set up and administered locally but under a single state authority, would include consumer representatives with medical men on their administrative boards.

In recommending group practice for specialists the Commission pointed out that this is the most efficient way to use the talents of highly trained people, to remedy the isolation of rural medicine from "fast-moving medical developments" and to make maximum use of expensive equipment.

The report drew sharp immediate criticism from the American Medical Association on one feature—the proposal to use Old Age Insurance funds to buy prepaid medical care. Louis H. Bauer, president of the A.M.A., called it "in effect, national compulsory health insurance." He added that an A.M.A. committee would soon release a detailed study of the entire report.

The Commission found the country's supply of doctors and other health workers far below what is needed. It estimated that to give "reasonably comprehensive medical care" to the whole population by 1960 will require 30,000 more physicians than are expected to be available at that time. It recommended federal aid to schools of medicine, dentistry, nursing and public health, to expand facilities, make up operating deficits and establish scholarships.

The Commission suggested that Congress set up a Department of Health and Security with Cabinet status, and that the President create a permanent Federal health commission which would keep continuous watch on the changing health status and needs of the nation and report annually to him.

The Government now spends about one billion dollars per year on civilian health activities. The Commission estimates that its program would cost a billion more. Major annual expenditures called for in its proposals are: aid to schools, $100 million; support of local health services, $60 million; medical research, $20 million; grants-in-aid to states to help pay for personal health services, $750 million.

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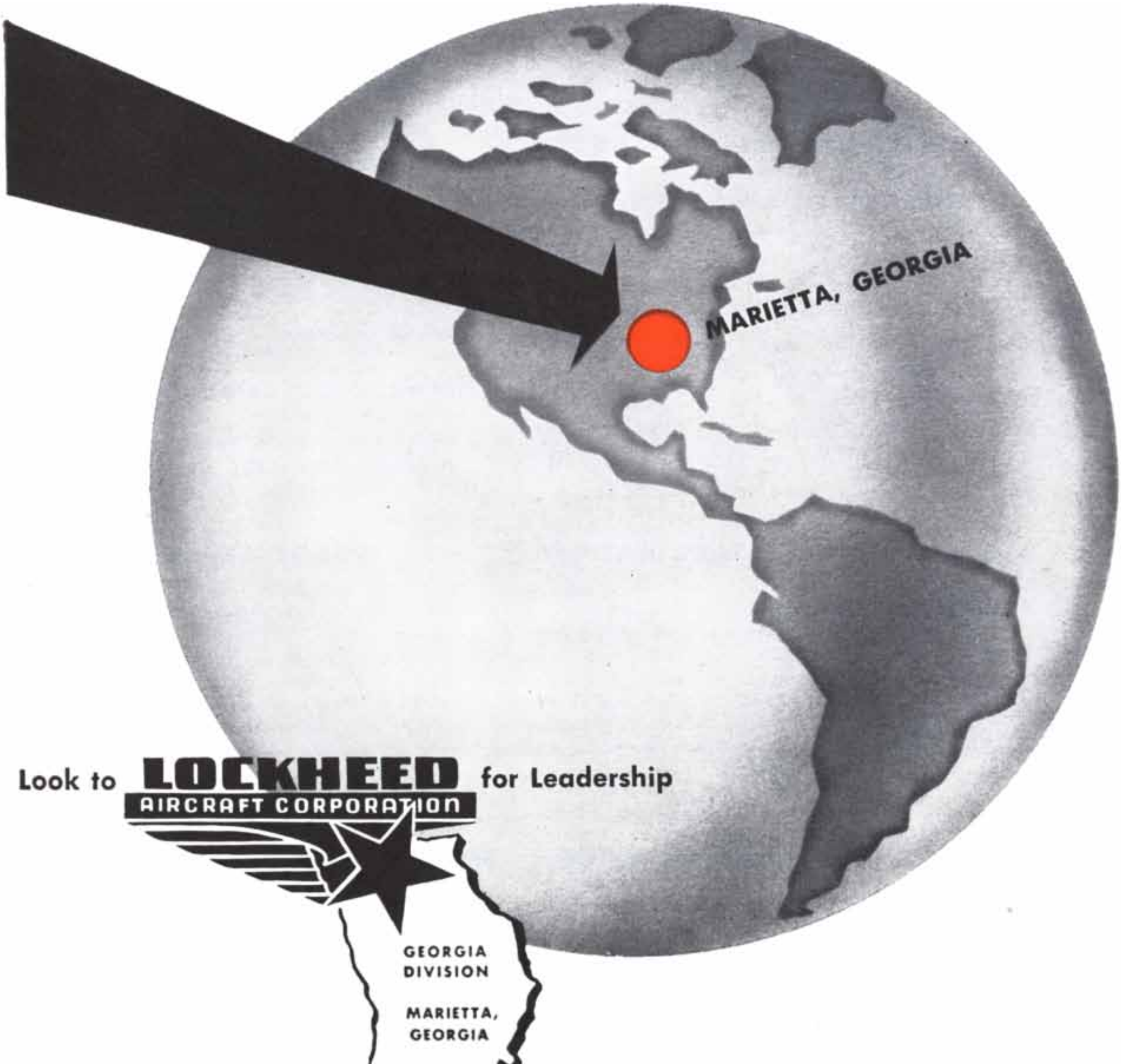

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The Chemistry of Heredity

We know that factors in the nucleus deeply influence the life of the cell, but exactly how do they do so? The search for an answer proceeds by the chemical investigation of chromosomes

by A. E. Mirsky

OUR ANCESTORS are present in our chromosomes, and they reach down to influence the chemistry of every cell in our bodies. That chemistry is the fundamental instrument of heredity there can be no doubt. The genes—the factors of heredity—must depend on the chemical composition of the chromosomes; the growth and division of the chromosomes are chemical processes, and it is by chemical processes that the chromosomes are able to influence the rest of the cell and so make manifest the hereditary factors. When, for example, a chromosome influences the color of a person's eyes, it must do so by taking part in some way in the chemical synthesis of a pigment.

The study of the chemistry of chromosomes is, therefore, a study of life at an elementary level. This article is an account of that fascinating investigation and what has been learned from it.

A living cell, animal or vegetable, has a nucleus within which is a certain number of chromosomes, the number depending on the species of animal or plant. The nucleus may occupy anywhere from less than one hundredth to more than two thirds of the volume of the cell; the rest of the material is the cytoplasm. The chromosomes have individuality: each one differs from all the others in the same set. Within the chromosomes are the genes, arranged in a linear order.

The formation of a new individual begins when the nuclei of an egg cell and a sperm cell fuse to form one cell. The fertilized egg now has two sets of chromosomes, one from each of the parent cells. The two sets are equivalent (except for those chromosomes concerned with sex), and thus there is a pair of each kind of chromosome. The cell then divides to start the building of the body cells of the new organism, and one can see through a microscope that the division proceeds in as orderly and complex a ritual as a courtly 18th-century ballet. Each chromosome grows in size and then splits lengthwise into two identical copies of the original. The couples are promptly separated by two sets of threads that pull them to opposite ends of the cell. The membrane surrounding the nucleus has meanwhile broken down, so that there is no barrier to impede their movement. The two sets of chromosomes become bunched at the opposite points. Once the sets are separated, the threads disappear and a membrane forms around each set. Now there are two nuclei, each containing a complete set of pairs of chromosomes, inherited from the two original parent cells. The two new nuclei are surrounded by cytoplasm, the non-nuclear material of cells. But since cytoplasm divides in a different way from the nucleus, the two daughter cells may have unlike quantities of it.

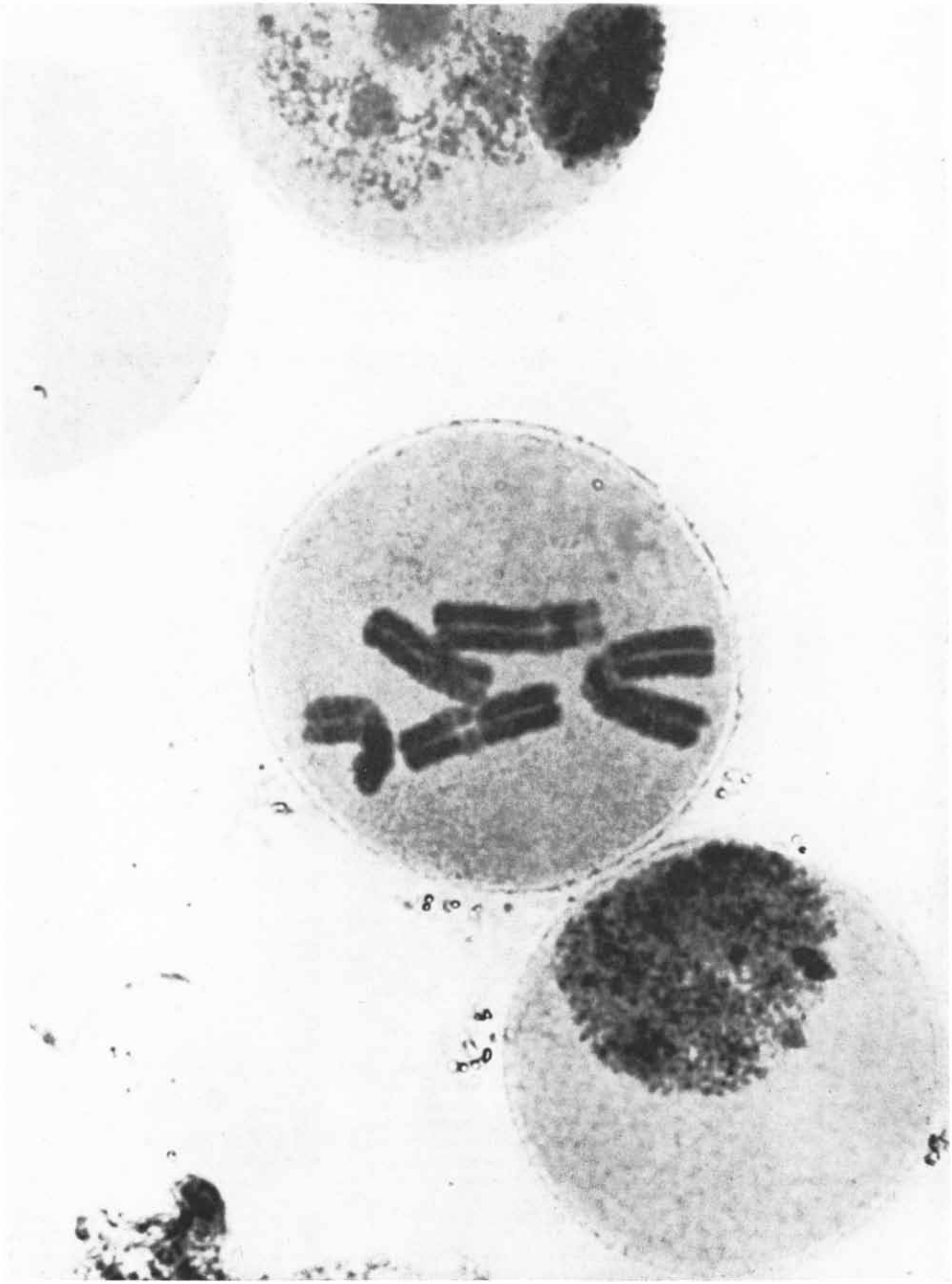
Thus, by division after division, the new body is built. Every cell of our bodies—each liver cell, brain cell, kidney cell—carries chromosomes and genes from both parents. In the fruit fly, *Drosophila*, we can see the phenomenon distinctly under the microscope. The chromosomes in the salivary gland cells of fruit-fly larvae are so large that we can make out their structural details and see that hereditary factors contributed by both parents are present in each pair of chromosomes.

The Potent Nucleus

Knowledge of the relation between chromosomes and heredity has come from two lines of investigation—breeding experiments and microscopic observations. It was the breeding experiments that showed that chromosomes carry hereditary factors. In recent years such experiments on the bread mold neurospora have shown most beautifully that hereditary factors in chromosomes have a precise controlling influence on many chemical processes in the cell.

The simplest and most direct evidence of the nucleus' far-reaching effect on the cell was provided by certain experiments made by the German biologist Joachim Hämmerling in 1931. He performed these experiments on Acetabularia, a little green plant consisting of a single large cell. It has the form of an umbrella, with the exceedingly small nucleus near the tip of the handle. If the hat-like top of the umbrella is cut off, a new one forms, looking just like the one removed. There are many varieties of Acetabularia, each having a distinctively shaped "hat." What Hämmerling found was that if he cut off the "hat" and the nucleus of one of these plants, and then planted in the remaining stump a nucleus taken from another variety of Acetabularia, the new "hat" that formed was like that of the second variety. It was the nucleus that decided what fashion "hat" was made. Hämmerling was even able to graft two different nuclei into the bottom of one "umbrella"; when he did so, the new "hat" was a compromise between the different shapes associated with the two nuclei.

The decisive influence of the nucleus has also been investigated by removing the nucleus from the amoeba, another single-celled organism. It has been known for many years that this operation slows down the metabolism of the cell. Recently Daniel Mazia of the University of California made such an investigation with tracer isotopes of phosphorus—an element well known to play a central role in cell metabolism. The speed with which the "tagged" atoms



CHROMOSOMES appear as dark rods in a spore cell of the plant Trillium in this photomicrograph by A. H. Sparrow. Trillium has five chromosomes; here they are shown in the process of division. The chromosomes have split lengthwise; later they pull apart, leaving a full complement of them for each new daughter cell.

enter into new combinations in the cell measures the cell's rate of phosphorus metabolism. Mazia cut a number of amoebae in half, one half of the cell containing the nucleus and the other lacking a nucleus. He put the halves containing nuclei in one vessel and the enucleated cell halves in another. Then he supplied tagged phosphate to both lots for the same length of time. He found that the halves with nuclei took tagged phosphorus into their complex phosphorus-containing substances at a normal rate, but the nonnuclear halves took up much less phosphorus. This experiment again showed that the nucleus, though only a minute part of the amoeba, has a decisive influence on the phosphorus metabolism of the whole cell.

DNA

Naturally one is led to wonder whether the chemical apparatus by which the chromosomes control all these activities can be related to some special substance in them.

The chromosomes do indeed possess a special substance: desoxyribonucleic acid, called DNA for short. DNA is peculiar to the chromosomes; it is not found in any other part of the nucleus or in the cytoplasm. This was shown many years ago by the well-known "Feulgen reaction." The German biochemist Robert Feulgen had discovered that when DNA is warmed with strong acid and then treated in a certain way with acid fuchsin, it turns a brilliant crimson. He performed this experiment in a test tube and did not apply his test to living cells until some 10 years later. When he did so, he found to his joy that the chemical treatment had not disintegrated the cells and that the network of chromosomes in each nucleus was boldly revealed in brilliant color. The rest of the cell was colorless. Ever since this experiment microscopists have been using the Feulgen reaction on all kinds of plant and animal cells. They have demonstrated that, in general, chromosomes are "Feulgen positive" and nothing else in a cell is. This means that DNA is present in chromosomes and not in other parts of the cell, or, strictly speaking, not in sufficient concentration to be Feulgen positive.

There is another remarkable fact about DNA. The various cells of the body differ greatly in chemical composition: the cells of the liver, kidney, heart, spleen and so on vary in the kind and amount of substances they contain. But every body cell, regardless of type, has the same amount of DNA in its nucleus. And the egg and sperm cells, containing only half as many chromosomes as body cells, have just one half as much DNA.

How does one measure the quantity of DNA in a nucleus? It was first done in domestic fowl in this way: One takes a specimen of blood from, say, a rooster and counts the number of red cells in a given volume. The amount of DNA in that volume is then measured and divided by the number of cells. This gives the quantity of DNA per red-cell nucleus: for the rooster it is 2.3 hundred-millionths of a milligram per nucleus. The sperm cells of a rooster, similarly analyzed, turn out to have half that amount—1.2 hundred-millionths of a milligram. To count the cells of solid tissues of the body, such as the liver, spleen, kidney or the like, the cells must first be dispersed in a fluid. To accomplish this, a piece of liver, for example, is immersed in citric acid and then disintegrated in a high-speed mixer. The cells are broken, but the nuclei remain intact. The nuclei, being heavier than the cell debris, can be separated by centrifugation. The clean nuclei are then dispersed in citric acid and counted. Once this has been done, the quantity of DNA per nucleus is calculated in the same way as in the case of red blood cells.

Such measurements have been made for the various tissues of a number of animals. In any one species of animal the quantity of DNA per nucleus is always about the same (within an error of 10 per cent), whether the cells come from the liver, pancreas, spleen or blood. But each species has its own characteristic DNA quota. In the frog, for instance, it is 15 hundred-millionths of a milligram per nucleus; in the shad, 2 hundred-millionths; in the green turtle, 5.3 hundred-millionths.

The Stuff of the Chromosomes

The experiments just described were done independently by two groups of investigators—in Strasbourg by the late André Boivin and his collaborators R. and C. Vendreley, and at the Rockefeller Institute for Medical Research by Hans Ris and myself. Ris and I have developed another method which measures the quantity of DNA in a single nucleus, rather than the average in a mass of nuclei. In this way some information can be had which is not obtainable by mass analysis.

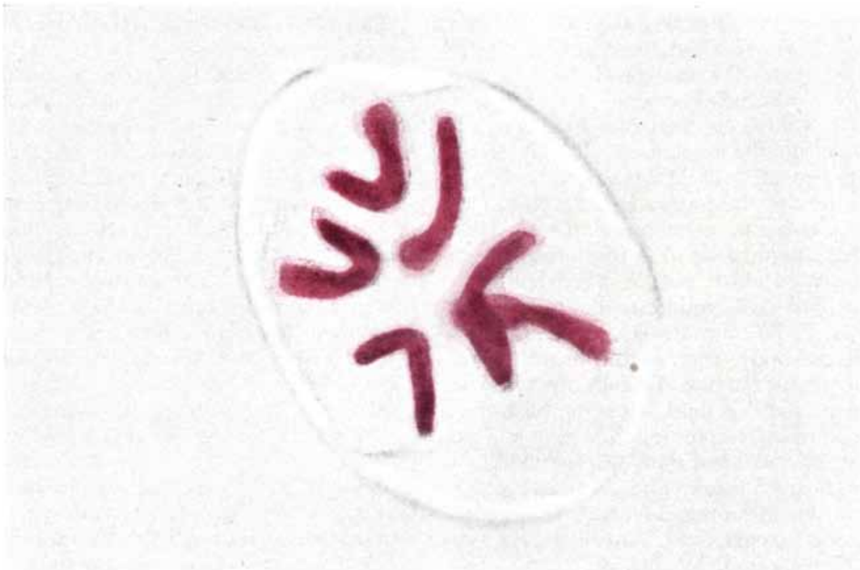
The procedure depends upon the Feulgen reaction. Cells with nuclei colored by the Feulgen reaction are placed on a microscope slide, and a photoelectric cell is inserted in the eyepiece of the microscope to measure the amount of light absorbed by the pigment in the nucleus. By grading the amounts of light absorption registered for a series of nuclei of known DNA content, one gets a set of standards which relates the amount of DNA in a nucleus to the amount of light absorption. With this index it becomes possible to measure the DNA content of certain nuclei which could not otherwise be investigated.

There are, for example, some nuclei in the body which contain two or four sets of chromosome pairs instead of the usual one. They are called polyploid nuclei. These should, according to the rule, have respectively two and four times as much DNA as ordinary nuclei in the same animal. And the light-absorption analysis of individual cells shows that this is indeed the case. For instance, cells of the rat liver with one-set, two-set and four-set nuclei are found to have DNA contents in the same ratios—1:2:4.

There is, then, a certain quantity of DNA in each set of chromosomes, whether in the egg or sperm, twice this quantity in the sets of chromosome pairs present in most body cells and correspondingly more in the double and quadruple sets of chromosome pairs found in some cells. All this shows that DNA is closely associated with the hereditary factors of chromosomes and most likely forms part of the stuff of which the hereditary factors are made. The chromosomes of course contain other substances besides DNA (*e.g.*, various proteins), but none of those other known constituents is distributed in nuclei in the same regular way.

It should be said that some investigators are convinced that certain cells of a developing embryo contain more than the normal amount of DNA for the organism. But at present it cannot be said whether their measurements are correct or are thrown off by some unconsidered technical point in the procedure. Even if such exceptions to the rule of DNA distribution do exist, they should not occasion surprise, considering how great are the possibilities for cell variation.

To the rule that DNA is restricted to the cell nucleus there is a clearly established exception, but it is an exception which may be said to prove the rule. DNA or something closely related to it has been found in the cytoplasm of egg cells of many organisms; indeed, these cells have far more of the substance in the cytoplasm than in the nucleus. Most egg cells are large with materials required for growth of the embryo. Long before fertilization these materials are fed into the egg from surrounding cells called "nurse cells." In 1936 M. Konopacki, a Polish biologist, showed that in certain animals the nurse cells produce DNA, which is passed into the egg cell along with other nutrient materials. It remains in the cytoplasm until an embryo forms. Recently D. C. Cooper at the University of Wisconsin found that the nurse cells in plants do the same thing, and he showed that the DNA was derived from the nuclei of the nurse cells. The DNA in the cytoplasm of an egg cell comes, then, from the nuclei of nurse cells and is destined ultimately for the nuclei of the embryo's cells. In other words, the DNA in egg cytoplasm



FEULGEN STAIN colors the six chromosomes in a cell of the herb Tradescantia in this photomicrograph by A. H. Sparrow. This fuchsia-colored stain is the standard means of testing for the presence of desoxyribonucleic acid.

is on its way from one nucleus to another. There is enough of this material in the cytoplasm of one egg cell, according to recent experiments of E. Zeuthen and E. Hoff-Jorgensen in Copenhagen, to supply the nuclei of the thousands of cells that will develop by division from the single fertilized egg.

DNA's Role

Now let us consider some experiments which illuminate the dynamic role played by the DNA in the chromosomes. It all began with certain curious observations made by the English bacteriologist Fred Griffith. He was working with pneumococci, the bacteria that cause pneumonia. There are many varieties of pneumococci, and they are classified according to the chemical make-up of the gummy capsule that surrounds the cell, which is different for each type of pneumococcus. Each type reproduces its own kind of capsular gum. When grown under certain conditions, however, pneumococci lose their capsules and reproduce cells that lack capsules. What Griffith did was this: He used two cultures of pneumococci, one of encapsulated cells of type III, and another that had had capsules of type I but had lost the capsules. He killed the encapsulated type III cells by heating them in water. Then he injected these dead cells together with living non-encapsulated cells of type I into a mouse. After a suitable time Griffith examined the mouse and found that pneumococci of encapsulated type III were now growing at a great rate in its tissues! Surely the killed type III cells that had been injected into the mouse could not have multiplied. To make sure of this Griffith injected heat-killed encapsulated type I cells into many mice; in no instance did they multiply. The conclusion to be drawn was clear: It was the living, non-encapsulated type I cells that had multiplied, but they had been converted into encapsulated type III. The dead encapsulated cells had somehow transmitted their hereditary constitution to the living non-encapsulated cells. They must have passed along to the type I cells the ability to make type III capsular gum.

Griffith's results were confirmed by Martin Dawson at the Rockefeller Institute. He found a way of doing the experiment in a test tube: the mixed heat-killed and living cells were placed in a nutrient solution in a test tube and there, as well as in the mouse, the encapsulated, heat-killed cells transmitted their hereditary constitution to the living, non-encapsulated ones. Another important step was made by James L. Alloway, also at the Rockefeller Institute. Pneumococcus cells disintegrate when placed in bile salts; they seem to dissolve, and the fluid in the tube clears. Alloway found that the heat-killed encapsulated cells could transmit their hereditary constitution even after they had been dissolved. In short, it looked very much as if some substance in the cell, rather than the cell as a whole, was responsible for transmitting its hereditary constitution.

The problem now was to hunt for that substance in the disintegrated and dissolved debris of the cell. This problem was undertaken by O. T. Avery, Maclyn McCarty and Colin MacLeod at the Rockefeller Institute. They quickly eliminated the capsular gum itself as a possibility; when they destroyed the gum with an enzyme which decomposes it, the cell debris was still able to transmit the hereditary property of forming a capsule. The investigators then removed from the debris the protein, which makes up the great bulk of material in the cell. They did so by a procedure which leaves the remaining compounds in the solution undamaged. That operation eliminated the protein as a suspect, for what was left of the heat-killed and decimated cell could still transmit its heredity.

With the capsular gum and cell protein out of the way, it became apparent that the effective substance might well be DNA. And further experiments indicated that indeed it was. When the DNA in the remaining material of the cell was decomposed by a purified enzyme known to act specifically on DNA, the debris finally lost its ability to promote the manufacture of capsular gum.

The action of DNA is highly specific. If the DNA derived from another type of pneumococcus is added to non-encapsulated cells, the cells that finally multiply are of the type from which the DNA was derived. There must be a special kind of DNA in each type of pneumococcus.

Transmission of hereditary characteristics in pneumococci by means of DNA provides a beautiful example of one of the fundamental principles of heredity. What is transmitted in us from one generation to the next is not a characteristic eye pigment or blood type or other hereditary trait. Rather, it is a set of factors in chromosomes which are able to influence the activities of the cells so that certain eye pigments and certain substances responsible for blood types are produced. In the pneumococcus the DNA of the pneumococcal chromosomes influences the cell in which it is placed to make a particular kind of capsular gum.

DNA's Composition

What is the chemical nature of this potent substance? DNA was first discovered in the nucleus by the Swiss biochemist Friedrich Miescher in 1869. He was working with pus cells in the laboratory of Felix Hoppe-Seyler, one of the leading biochemists of the time. At first he had done some experiments on these cells along a line suggested by his teacher. When they did not turn out well, he investigated on the same cells the effect of pepsin, the enzyme of gastric juice which digests proteins. Unlike most biochemists, then or now, Miescher made a practice of examining carefully under a microscope the cells from which he extracted substances. As the pepsin in dilute acid decomposed the proteins of the pus cells, Miescher saw under the microscope that while the structure of the cell as a whole disintegrated, the nucleus remained essentially intact, though it shrank in size. When the peptic digestion was complete, most of the materials of the pus cells had gone into solution. Miescher made a chemical analysis of the residue, consisting of shrunken cell nuclei, and found its composition different from anything else that had previously been prepared from cells. He called the material "nuclein," because it was located in the cell nucleus.

Hoppe-Seyler, at first skeptical about the discovery, soon convinced himself that the work was sound. He himself prepared from yeast cells a substance similar to nuclein. In the meantime Miescher had returned to his native Swiss city, Basel, and there continued his study of nuclein. Basel was fortunately a most suitable place for chemical investigation of the cell nucleus. At that time the Atlantic salmon still swam up the Rhine as far as the falls just above Basel. The fish came up the river to spawn, and when they reached Basel their testes were large with sperm. Nearly every spring Miescher would conduct a sperm-collecting campaign, for salmon sperm are in many respects the most suitable cells for chemical investigation of the nucleus. They are exceedingly rich in DNA; it makes up 50 per cent of their dry weight.

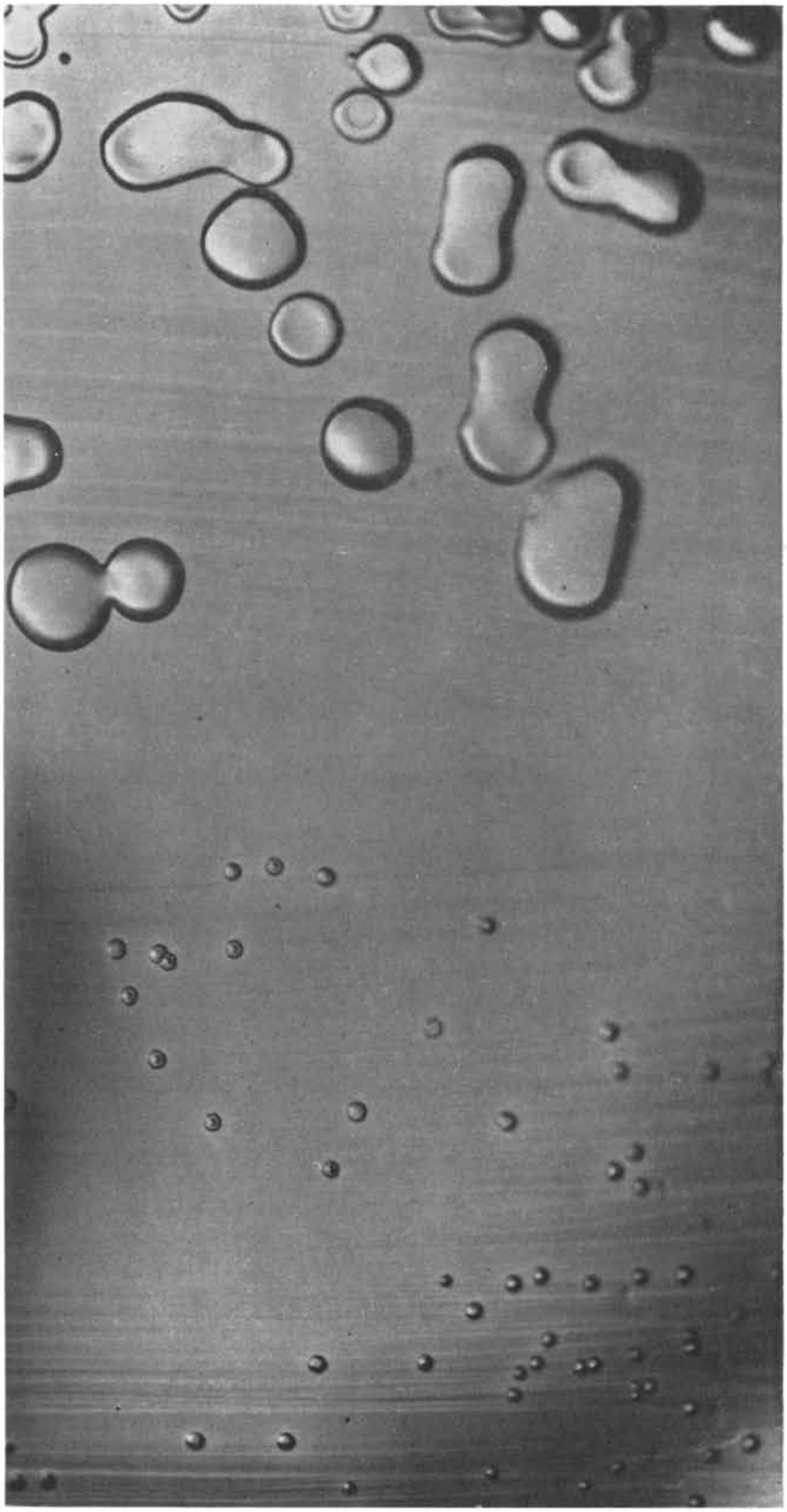
With this favorable material Miescher soon began to make great progress. He found that he could remove the cytoplasm from the sperm cells by immersing them in dilute acid, thereby obtaining clean, well-formed nuclei. It was no difficult matter to extract from the nuclei pure, protein-free DNA. Miescher determined its content of nitrogen, phosphorus, carbon, oxygen and hydrogen. By this time it was clear that "nuclein" was an acid, and another investigator suggested that the protein-free substance be called "nucleic acid."

Miescher was a thorough investigator, not easily satisfied with his own achievements, and when he died in middle age much of his experimental work was found unpublished in his notebooks. In 1897 friends gathered these notes, along with his published papers, into a volume which investigators in this field find well worth poring over today.

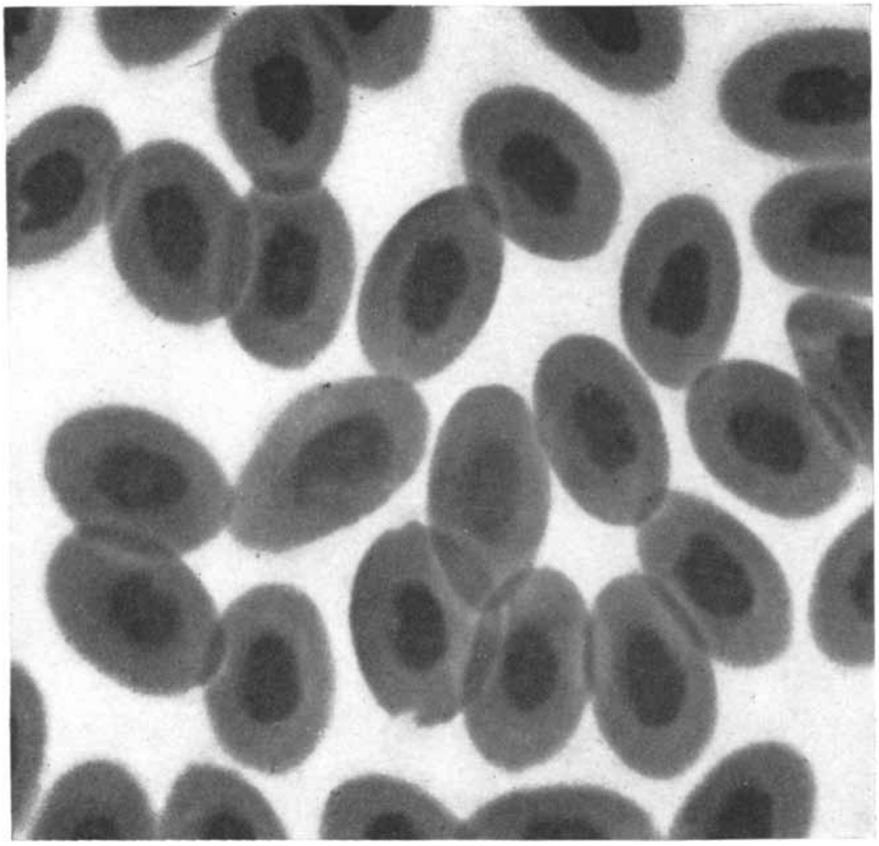
Of the other biochemists who entered the field of investigation of the cell nucleus during Miescher's time, two of the most notable were Albrecht Kossel in Heidelberg and P. A. Levene at the Rockefeller Institute. In contrast to Miescher, who worked by himself, both Kossel and Levene had large laboratories and many collaborators—and for the type of problem which now came under investigation, many collaborators were needed.

DNA's Structure

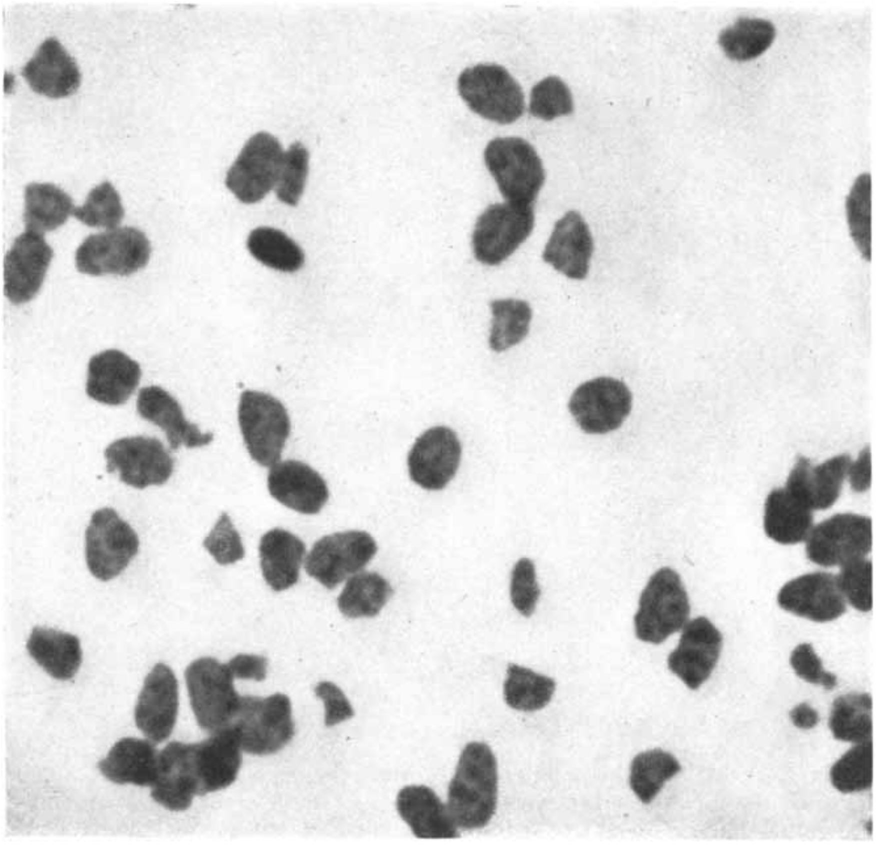
These investigators, all skillful organic chemists, set themselves the task of unraveling the structure of the nucleic acid molecule. It is a large molecule,



PNEUMOCOCCI in the colonies at the top of this photograph have a coat of gum; those in the colonies at the bottom have no coat. The top colonies are descendants of those at the bottom; their pneumococci developed coats when they were treated with nucleic acid from a coated strain. This photograph of the colonies was made by Joseph Haulenbeek for a paper by O. T. Avery, Maclyn McCarty and Colin MacLeod of the Rockefeller Institute.



RED BLOOD CELLS of a chicken are shown in this photomicrograph by Vincent Allfrey. The nucleus of each cell is the dark area in its center.



RED BLOOD CELL NUCLEI are separated from the rest of the cell. The nuclei can now be investigated by relatively large-scale chemical means.

consisting of half a dozen different, moderate-sized molecules joined together. The first problem was to take apart the large nucleic acid molecule and identify its component molecules. This had to be done gently, for the smaller molecules are themselves quite complex, and rough handling might decompose them. The safest way is to use enzymes, the tools that the organism employs. For some purposes it is possible to use a relatively rough procedure, such as treatment with hot, strong acid.

When the submolecules had been separated, they were examined to see whether they accounted for all the elements found in the large molecule. All the nitrogen could be accounted for by a group of nitrogenous submolecules, of a kind related to uric acid and caffeine. Four of these nitrogenous molecules were found, distinctly different from one another but belonging to the same family of substances. The phosphorus of DNA could be accounted for by the presence of phosphoric acid, which also explains why DNA is an acid. Another submolecule found in DNA is a 5-carbon sugar. From these three types of submolecules DNA is constructed in this way: The 5-carbon sugar molecules are linked together in chains by phosphoric acid links, and to each sugar molecule in the chain is attached one or another of the four nitrogen-containing submolecules. (A fifth nitrogen-containing molecule has recently been found; the amount varies strikingly in different kinds of DNA.)

An intact molecule of DNA is a very large, complicated structure: it may contain as many as 3,000 molecules of the 5-carbon sugar. DNA is an example of what is nowadays called a high polymer. Familiar examples of high polymers are nylon and other substances of which fibers are formed. The characteristic of a high polymer is that some chemical unit is linked together repeatedly to form a big structure. In nylon the unit is relatively simple, there being but one type of submolecule. In DNA the units are far more complex. To learn how they are polymerized to form a giant molecule is a formidable task which has not yet been accomplished. When it is, we shall understand better how DNA functions in the chromosome.

The success of the Feulgen reaction in making chromosomes visible depends upon the fact that DNA is a polymer. When subjected to the procedure of the Feulgen reaction, the polymerized DNA remains insoluble and so becomes stained where it is located in the cell. When DNA that has been depolymerized (*i.e.*, partly decomposed) is treated by the same procedure, it goes into solution; if it were not a polymer it would be washed out of the cell by the Feulgen process.

The effectiveness of DNA as a transmitter of heredity also depends upon its

CHROMOSOMES also can be separated from the rest of the cell. These, photographed by H. Ris, are from the cells in the thymus gland of a calf.

being polymerized. This can be seen in experiments with pneumococci. When the DNA of the heat-killed encapsulated pneumococcus is depolymerized, its ability to transmit the hereditary constitution of the cell is lost.

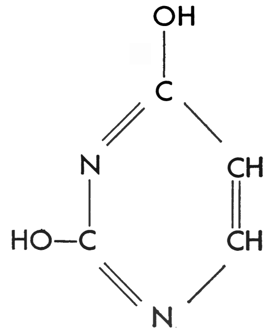
RNA

Besides DNA, every cell possesses another type of nucleic acid. It is known as ribonucleic acid (RNA). Like DNA, it is composed of phosphoric acid, nitrogen submolecules and a 5-carbon sugar. But RNA's sugar molecule (called ribose) is very different from DNA's (called desoxyribose). It has one more oxygen atom, and this has a big effect on the molecule's properties. Since as much as 48 per cent of a nucleic acid is sugar, and the sugar occupies a central position in the molecule's structure, the difference between the sugars probably is responsible for the many differences between the behavior of RNA and that of DNA.

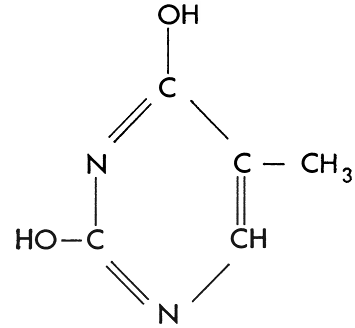
RNA has a different location in the cell and seems to be concerned with quite different biological functions. It is located largely in the cytoplasm, and it seems to be concerned with synthesis of protein. Protein synthesis is of course one of the central problems in biology, because proteins constitute a large part of living matter, because in the form of enzymes they control nearly all the dynamic processes of the cell, and because they are so complex that they have so far defied all efforts of chemists to solve the riddle of how they are made. Hence RNA is of intense interest to chemists and biologists.

RNA was found in yeast soon after Miescher's discovery of DNA. Since DNA was usually prepared from the cells of animals (fish sperm and the calf thymus gland), while RNA was usually prepared from plant cells (yeast), for many years DNA was known as animal nucleic acid and RNA was known as plant nucleic acid. The first step toward correcting this error came when Feulgen applied his color reaction and found that the nuclei both of plant cells and of animal cells contained DNA. He also stained cells in other ways to try to detect RNA, and he concluded that RNA also probably was present in both plant and animal cells, in this case in the cytoplasm.

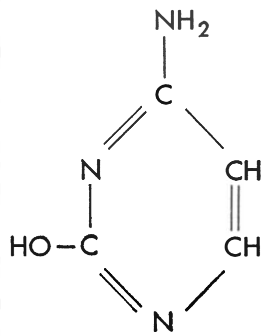
To settle more definitely the question of where DNA and RNA are located in cells, Feulgen's pupil Martin Behrens made preparations of isolated nuclei and



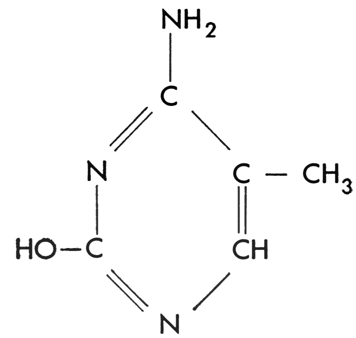
Uracil



Thymine



Cytosine



5-methyl cytosine

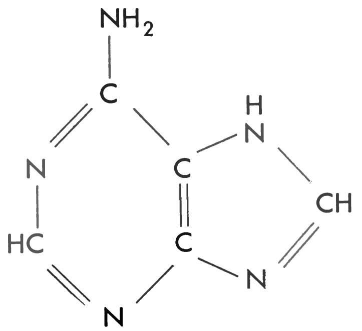
PYRIMIDINES are a group of nitrogen-containing submolecules that are found in nucleic acids. They are characterized by a single-ring structure.

isolated cytoplasm. For this experiment he used, among other cells, those of the embryo of the rye plant. In order to avoid losing or transferring any of the substances from the nucleus or the cytoplasm while he was separating them, he decided to carry out the separation in the absence of water. He began by freezing the tissue and drying it in a vacuum while frozen. Then he ground the material in a nonaqueous fluid to break up the cells and release the nuclei from the cytoplasm in which they were embedded. Cell walls break more readily than nuclear walls, so it is possible to break up most of the cells without much breakage of nuclei. Next Behrens suspended the disintegrated material in a series of fluids of different density, first floating away the lighter debris and then floating the nuclei away from the heavier debris. This is a laborious process, but Behrens was patient and skillful. Finally he evaporated the fluids and found at last that he had obtained clean nuclei free of cytoplasm and cytoplasm free of nuclei. Those who have repeated his procedure know that it must have given him great satisfaction to put the powders consisting of separated nuclei and of cytoplasm into vials and label them. To have such preparations, in powdered form and in neatly labeled vials, is the dream of every chemist.

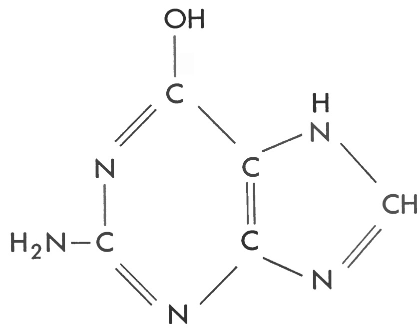
From these separated parts of the cell Feulgen and Behrens proceeded to extract nucleic acids and to identify them chemically. They found DNA in the nuclei and RNA in the cytoplasm. It was clear that DNA is in general confined to the nucleus and that at least the bulk of RNA is in the cytoplasm of both animal and plant cells.

Maker of Proteins

For a more precise localization of nucleic acids in the cell further microscopic observations were required, and these were soon made by Jean Brachet in Brussels and Torbjörn Caspersson in Stockholm. They located the nucleic acids, as Feulgen had, by means of chemical properties which can be detected in a minute amount of material under the microscope. Brachet's method depended upon the presence of phosphoric acid in nucleic acids, Caspersson's on the presence of nitrogen containing submolecules. After investigating many different kinds of cells, they found that there is some RNA in the nucleus, especially in a body called the nucleolus which is attached to a certain chromosome, and that the chromo-

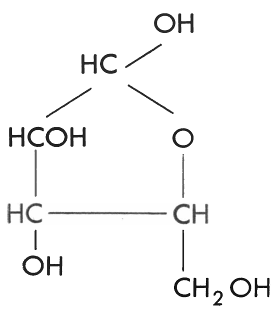


Adenine

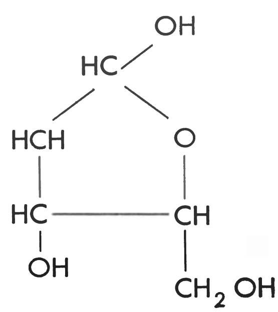


Guanine

PURINES are another group of nitrogen-containing submolecules that are found in nucleic acids. They are characterized by double-ring structures.



d-ribose



d-2-desoxyribose

SUGARS of nucleic acid have five carbon atoms. The structure at the left is from ribonucleic acid; that at the right, from desoxyribonucleic acid.

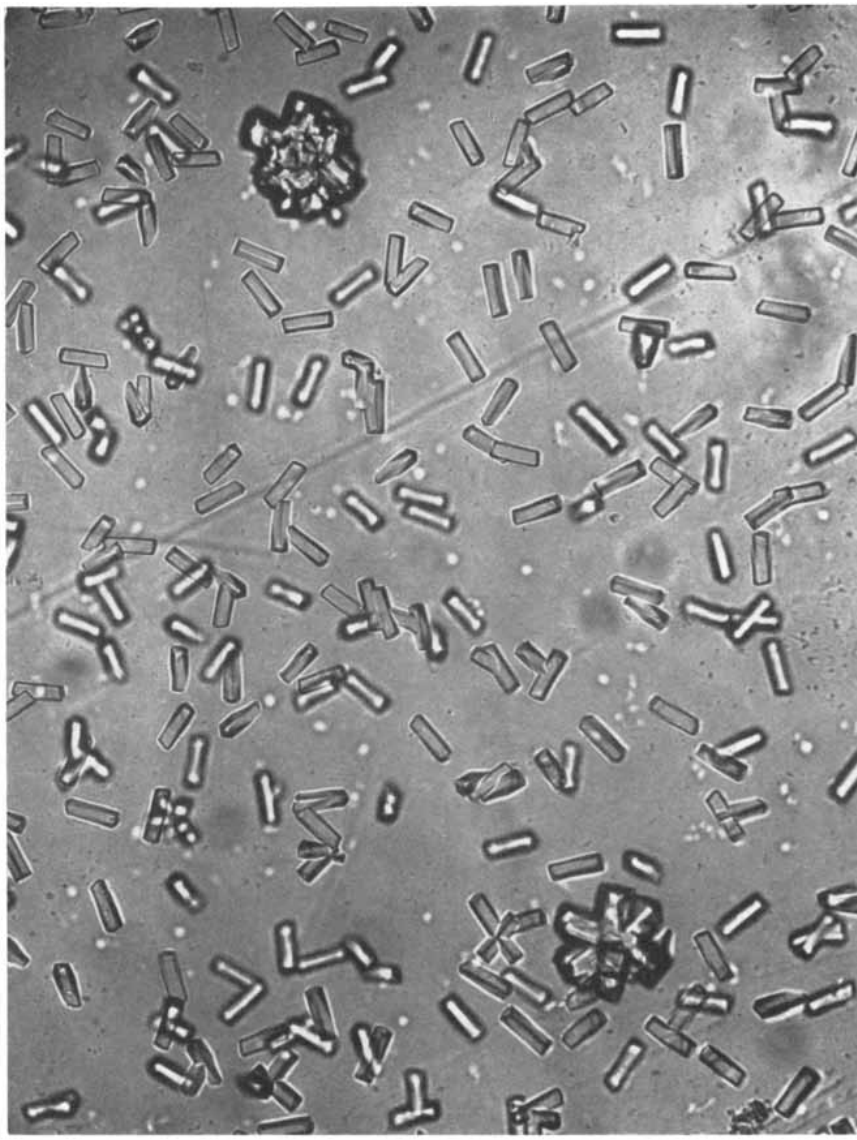
somes themselves contain some RNA. The amount of RNA in the nucleolus and cytoplasm varies considerably from cell to cell, and in a highly significant way. Certain physiologically active cells, such as those of the heart, skeletal muscles and kidney, contain very little. But cells active in the synthesis of protein, such as those of the glands and those growing rapidly, have a high concentration of RNA in the nucleolus and cytoplasm. Of the large cells lining the stomach those that synthesize pepsin (a protein) have a large amount of RNA, whereas those that form hydrochloric acid have little.

All this certainly indicates very strongly that in some way, not yet understood, RNA plays a part in the synthesis of protein. And this seems especially true of the RNA of the nucleus. Holger Hydén in Sweden has seen under the microscope evidence that in the living cell RNA moves out of the nucleus into the cytoplasm. This may well be one of the mechanisms by which the nucleus influences the surrounding cytoplasm. The clearest sign that the RNA of the nucleus is particularly active comes from an experiment done by R. Jeener in Brussels. He exposed cells to phosphate containing tagged phosphorus and determined that much more phosphorus was incorporated in the RNA of the nucleus than in that of the cytoplasm.

The extreme variation in the amount of RNA contained in an organism's various cells is in striking contrast to the constancy of DNA in the nuclei. The cells of the pancreas of a fowl, for example, have several times as much RNA as do those of the kidney, whereas the nuclei of the two kinds of cells have the same amount of DNA.

DNA's Protein Partner

Nucleic acids in a cell are not unattached. They are combined with proteins. Very little is known about the protein combinations of RNA. The proteins attached to DNA, on the other hand, were investigated by Miescher and by those who followed him. In the salmon sperm nucleus Miescher discovered, combined with the phosphoric acid of DNA, an unusual protein—far more basic and much simpler in construction than other proteins. It lacked many of the amino acids that are present in most protein molecules. The name of this protein is familiar to diabetics: it is protamine, which is now added to insulin to keep that substance in the blood for a longer period. This is an excellent ex-



ENZYME which acts upon desoxyribonucleic acid is desoxyribonuclease. These crystals were isolated by M. Kunitz of the Rockefeller Institute.

ample of how unpredictable the applications of science frequently are. Who could have anticipated that the strange protein which Miescher discovered in salmon sperm would be combined with a hormone of the pancreas for the treatment of diabetes?

Kossel made an extensive study of the protamines in fish sperm. His work on these simple proteins had a considerable influence on our understanding of proteins in general. Kossel found other basic proteins in the nuclei of red blood cells and of calf thymus, and the author later found them in nuclei of liver, kidney, pancreas and other cells. They are probably present in all cell nuclei. Most of these proteins are somewhat less basic, more complex and larger than those in sperm. During the formation of sperm cells in the testes, the more complex basic proteins in the cells from which they are made are replaced by the simpler protamines. The functions of a sperm cell are to reach the egg and transmit hereditary factors; all the equipment not essential to those functions is trimmed down to a minimum. In fact, the sperm nucleus consists of little more than DNA and its attached basic protein. Even the basic protein is trimmed down to essentials; in the fully formed sperm all that remains of it is the basic part that combines with the phosphoric acid of DNA.

The linear arrangement of the hereditary factors in a chromosome implies that DNA, which is an essential part of these factors, is held in a chromosome in a definite and precise manner. We have found that it is attached to a protein which forms part of the structure of the chromosome. From a mass of isolated chromosomes in a test tube it is possible to extract all the strongly basic protein. This is done with concentrated saline, made slightly acid. Even with the basic protein missing, the chromosomes appear unchanged when examined under the microscope, and they retain their DNA when immersed in a neutral medium. This shows clearly that the DNA is still attached to something in the chromosomes, for in this medium it is freely soluble. If it were not so bound, the DNA would simply float away from the chromosomes. That the material to which the DNA is bound is a protein was proved by treating the chromosomes with pure crystalline trypsin, which digests protein. The polymerized DNA was set free and formed a thick gel. When, on the other hand, we broke down the DNA in chromosomes with an enzyme which digests the nucleic acid, there was left a protein which could be seen as a mass of minute coiled threads, quite unlike chromosomes in appearance. It had been deformed and condensed by its separation from DNA. It is the combination of this protein with DNA (to which basic protein also is attached) that forms the chromosome as seen under the microscope. If either DNA or the structural protein is digested, the structure of the chromosome disintegrates.

The amount of structural protein in the chromosomes, unlike that of DNA, is not constant but depends on the over-all activity of the cell. Cells with abundant, metabolically active cytoplasm (*e.g.*, those of the liver or kidney) have a relatively large amount of structural protein in their chromosomes. On the other hand, a cell such as the lymphocyte, with only a scanty layer of cytoplasm around its nucleus, has only one fifth as much. The metabolically sluggish red blood cell contains less than one tenth as much.

The fact that the quantity of structural protein in the chromosomes is related to the over-all metabolism of the cell suggests that the structural protein may itself be metabolically active. Experiments show that this is indeed the case. The metabolic activity of the protein was measured by supplying tagged nitrogen, built into an amino acid (glycine). The amino acid can be injected into rats or mice and the fate of the tagged atoms followed in their cells. Einar Hammarsten in Stockholm found that the tagged nitrogen was taken up by the nuclear proteins much more rapidly than by DNA. In our laboratory, carrying the experiment a step further, we showed that structural protein took up nitrogen much more rapidly than did basic protein.

Since the amount of the metabolically active structural protein varies considerably in different nuclei of an organism, it follows that the chromosomes of the different cells must vary in their activity. This also has been confirmed with tagged nitrogen of glycine. Liver and kidney cells of a mouse, for example, have equal quantities of DNA, but the DNA in liver chromosomes takes up nitrogen three times as fast as that in the kidney. Even in the same cell chromosome activity varies during different physiological states. The cells of a digestive gland, such as the pancreas, become far more active when an animal is fed, and when the cells are more active, the DNA of their chromosomes takes up 50 per cent more tagged nitrogen. The degree of activity of a chromosome must depend on its surroundings.

Influence of the Cytoplasm

The immediate environment of the chromosomes is the cell nucleus. To understand how the chromosomes function we must know the conditions within the nucleus. The effects of chromosome activity are seen in the cytoplasm. The cytoplasm of each type of cell is especially equipped to carry out its specific functions: muscle-cell cytoplasm contains the contractile protein myosin; red-blood-cell cytoplasm has the oxygen-carrying pigment hemoglobin; pancreas-cell cytoplasm has the digestive enzyme trypsin, and so on. In each type of cell the chromosomes are acting on a differentiated cytoplasm. If such a system is to work effectively and harmoniously, the parts must be integrated; there is need for a feedback from the cytoplasm to chromosomes so that the latter's activity is adjusted to the cytoplasm's special requirements. The place to look for evidence of such a feedback is in the nuclear composition.

Does the differentiation of the cytoplasm change the nucleus? There is every indication that it does indeed. The enzymes in nuclei of different cell types of an organism vary, as do those in the cytoplasm. Even when the cytoplasm of a given type of cell has a special enzyme, the same enzyme can occasionally be found in the cell's nucleus as well. For example, the enzyme arginase, which enables liver cells to form urea, is present in both the cytoplasm and the nuclei of those cells. Since changes in the cell environment may produce marked changes in the cytoplasm, it follows that they may also alter the composition of the nucleus, and this has in fact been found to be the case.

Thus the relationship between the nucleus and the cytoplasm is a two-way affair. The hereditary factors in the chromosomes govern the cell as a whole, but the cell in turn influences conditions within the nucleus and so modifies the activity of its chromosomes. Our knowledge of this reciprocal influence, and of the chemistry of the interaction between nucleus and cytoplasm, is still vague, but obviously this is a central problem for our understanding of the cell.

A. E. Mirsky is a member of the Rockefeller Institute for Medical Research.

INCRIMINATING STAINS

The police laboratory uses a variety of scientific techniques. Not the least is the theory of probability, which brings new insight to the proof of guilt and the vindication of innocence

by Charles E. O'Hara and James W. Osterburg

MYSTERY story writers have always been partial to evidence in the form of stains or spots. The goat blood *qua* human blood on Joseph's coat (which would not have fooled a modern police laboratory for long) is perhaps the earliest recorded instance of this type of clue. Sherlock Holmes was seldom so impressive as when deducing a client's occupation, habits and recent whereabouts from the assorted spots and debris on his person and the color of the mud on his boots. The ingenuity and lightning speed of Holmes's inferences set a style for the mystery novel.

Within the last 15 years the fictional sleuth has given up curbstone chemistry and permitted his gleanings to be sent to a laboratory. From a literary viewpoint this is a step backward. Yet it is an inevitable and realistic recognition of the facts of life. In modern crime detection the man in the armchair has yielded to the man in the white gown.

Joseph's coat and Holmes's boots illustrate the two major questions which the police ask about a stain: (1) What is it? (2) Where did it come from, and can it be connected with a suspect? The latter is a classic problem of criminalistics, and the successful association of an incriminating material with a suspect constitutes scientific evidence *par excellence* —often preferable to casual eyewitness testimony.

Some spots—narcotics, chloral hydrate (knockout drops), poisons—may themselves constitute the *corpus delicti*. Sometimes stains provide a running story of the crime. For example, recently the police were able to reconstruct how a killing had taken place by examining an apartment generously splashed with the blood of the killer and of his two victims. Again, identification of a telltale stain such as printer's ink or confectioner's sugar may lead to the criminal. And of course there is the conclusive evidence of a spot on a suspect that may be linked to a substance at the scene of a crime: a white smudge on the shoes of a burglary suspect, for instance, may be identified as insulating material from a particular broken safe.

These, in brief, are the kinds of stories stains may tell. The finding and analysis of stains or spots are, however, complicated problems.

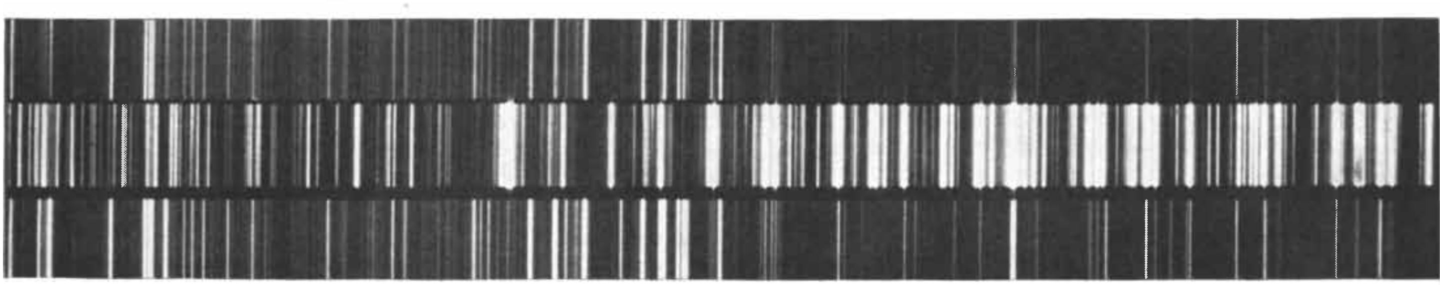
THE first step in attempting to solve a crime by the stains left behind is to search likely places for spots or smears. The garments of the victim or suspect are commonly the first objects inspected. If the crime is one of violence, the police look for excretory fluids: blood, sweat, saliva and semen are frequently emitted during a criminal struggle. These fluids can usually be classified: blood can always be, if the stain is reasonably large and fresh, and the other three fluids can be for about 80 per cent of the population.

Of the four, blood is by far the most important to police work. It possesses three of the qualities of a good identification medium: everyone has it in generous quantities, it is often left at the scene of a crime and it has specific characteristics. A crime laboratory performs tests to answer this series of questions: Is it blood? Is it human blood? What is its type?

Even a dried bloodstain, if it is large enough (the size of a half-dollar) and not too old, can usually be identified according to its major group: O, A, B or AB. Fresh blood can be classified much more specifically; considering its Rh type and other identifying characteristics it may be placed in one of many thousands of subdivisions.

Bloodstains on the person or clothing are less useful for discovering a suspect than most laymen and many policemen suppose. A prolonged scrutiny of almost anyone's clothes may reveal minute specks of blood. The finger nails are a favorite area of exploration for enthusiastic district attorneys, but blood found there usually has a discouragingly innocent explanation; it is a common result of manual labor or routine hygienic performances. More often than not such "invisible" bloodstains put investigators on a false track.

Once a lead has been established, however, blood can provide important corroborating evidence. By the same token, it is often valuable in clearing the guiltless; the vindication of innocence has historically been an important function of blood examination. Many a lynching might have been prevented



SPECTRA were employed to identify paint stains on a "jimmy," the tool used by burglars to open doors or windows. At the top is the spectrum of the paint on the jimmy. In the middle, for comparison, is the specsimply by a blood test. For instance, not long ago a farmer's wife was found murdered in the South, and a Negro picked up in the neighborhood was found to have blood on the sleeve of his jacket. He attributed it to a recent hunting expedition. After a mob had lynched him, an examination of his jacket proved that the stain was animal blood. Eventually it was found that the woman had been killed by her husband.

Semen is the second most important serological stain. As corroboratory evidence of rape or sodomy, it is looked for on garments of the victim. The police scientist first examines the garment under ultraviolet light, because semen is fluorescent. If he finds fluorescent spots, he dissolves some of the stain and examines the extract under a microscope; the presence of spermatozoa will then identify it as semen.

Serological stains are seldom of more than routine interest to the crime laboratory. More challenging are the stains of other types, which are not only more common but usually more difficult to identify and trace.

For example, motor-vehicle homicides (usually hit-and-run cases) number about 30,000 a year and are a far greater problem to the police of a large city than the few hundred murders that make the headlines. In a typical hit-and-run case bits of paint from the missing car may be found on the buttons or belt of the victim. As soon as a car is picked up on suspicion, the men working on the case will send a sample of its paint to the laboratory for comparison by spectroscope. While in most paints the main ingredients are the same, a specific batch of paint may be identified by its content of trace elements, or impurities. Here the police scientist resorts to the theory of probability. If, to take an over-simplified case, we assume that the probability of finding a specific impurity in a given batch of paint is one in 10, and if we find 10 such impurities, the probability that just this combination of impurities will be found in any other batch of paint is only one chance in 10 billion. Obviously such a coincidence is far beyond the leeway provided by reasonable doubt; the chances of finding two identical batches of paint of this composition are even smaller than of finding two human fingerprints exactly alike. In practice the situation is not usually so clear-cut. Some elements are more common than others, some tend to run in groups. The probability calculation is often exceedingly complex, and part of the technician's job is to phrase the results in accurate terms that are comprehensible in the courtroom.

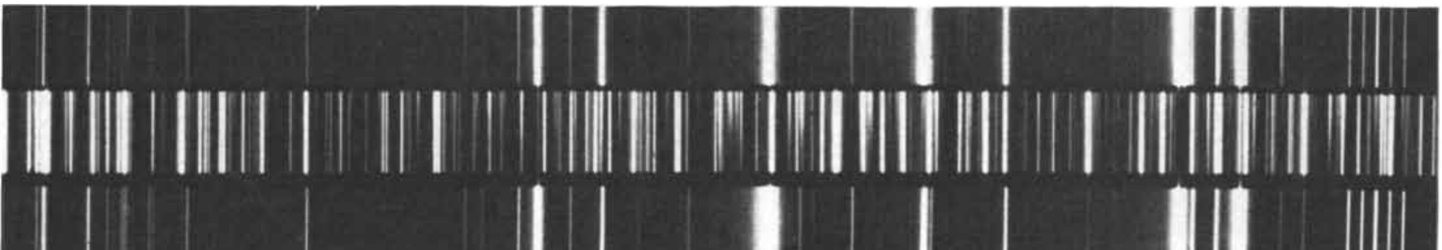
POLICE work has been enormously helped by the spectrograph and other rapid instruments of chemical and physical analysis. They can deal with minute samples, which are frequently all that the case affords, and they can reveal physical or chemical characteristics so great in number, so diverse in nature or so rare in occurrence as to preclude all but a negligible probability of duplication by coincidence. They permit analysis without disturbing the sample, thus making it possible to keep the evidence intact for presentation in court and for tests by the defense. Moreover, with these instruments a police technician does not have to be an expert in every branch of chemical analysis. A reasonable familiarity with the techniques, the basic materials, the fillers and the accidental trace elements of the industries from which his samples come is enough for effective use of his instruments.

The instruments serve first of all to locate the clues. Just as fluorescence will call attention to semen stains, X-rays will disclose gunpowder marks. When a gun is discharged at short range, a halo of smoke is deposited on the target. On dark cloth this effect is hard to see, but soft X-rays show the lead fouling and give some indication of the distance from which the weapon was fired. Infrared radiation is useful for distinguishing stains which otherwise look alike. It is even more valuable for exposing something that has been blotted out. Thus on a bloodstained document the writing under the stain can often be restored to legibility by an infrared photograph. Inks vary in their opacity to infrared rays, and a message that has been scored out can sometimes be deciphered by this method if the two inks are of different composition.

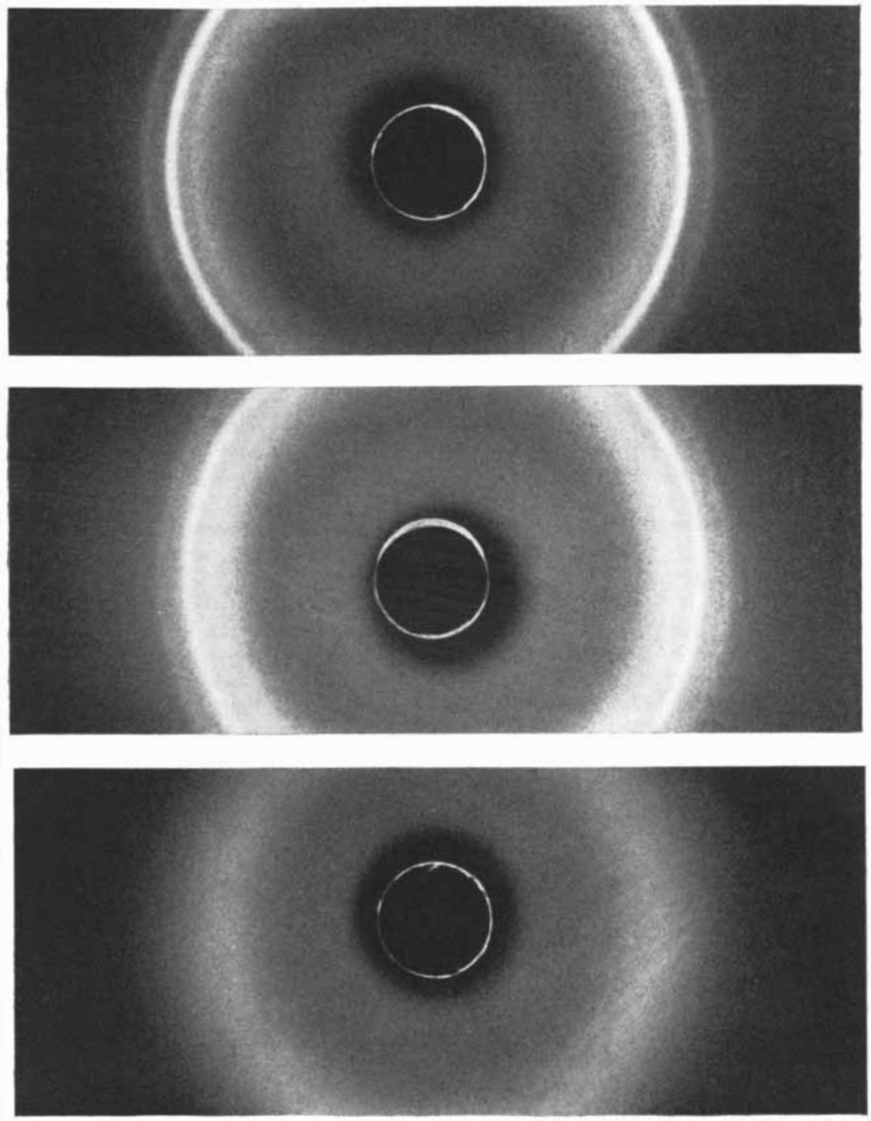
The spectrophotometer also has proved its worth in crime detection. It can detect tiny differences in inks, dyes, lipsticks and some other materials. Moreover, it provides evidence in precise, objective mathematical terms and is especially valuable in court. The spectrophotometer was used effectively in a recent mugging case. A woman walking home from the subway was gripped from behind by an assailant who clapped his hand over her mouth, grabbed her handbag and ran. She screamed for help. A few minutes later a man was picked up by the police three blocks from the scene. The woman had not seen the thief's face, and there was no evidence to link the suspect to the crime except his proximity, his suspicious behavior and a red smear on the palm of his left hand. But a spectrophotometric analysis showed that the substance on his hand had the same absorption spectrum as the woman's lipstick. This, with supporting evidence, was sufficient to convict him.

WHEN a stain can be made to yield crystals, or at least a substance which is not truly amorphous, it may be analyzed by X-ray diffraction. An X-ray diffraction camera can distinguish substances identical in chemical constituency but differing in atomic arrangement. Not long ago a man was found dead on the ground beneath the window of his garret room. It was supposed that he had committed suicide. But on the low, slanting ceiling near the window were some black smudges. An X-ray diffraction picture showed that the material was the same as in the heels of the deceased's shoes. The smudges could hardly have been made on the ceiling if he had jumped; he must have been picked up and pushed out. After further investigation two casual acquaintances of the man were arrested, and they admitted they had been with him.

X-ray diffraction is used to identify and compare barbiturates, which are ordinarily distinguishable only by their melting points. Grease stains also can be recognized by this device. In one case the prosecution claimed that the stain on a defendant's clothing was kitchen grease from the scene of the crime. The defense maintained that it was auto grease. X-ray diffraction analysis of the



trum of iron. At the bottom is the spectrum of paint from a door that had been opened with a jimmy. The similarity of the top and bottom spectra indicates that the door had been opened with the jimmy in question.



X-RAY DIFFRACTION was used to identify the origin of grease on the coat of a man suspected of breaking into a restaurant by way of a kitchen ventilator. At the top is the diffraction pattern of grease from the ventilator. In the middle is the pattern of grease from the suspect's coat. At the bottom is the pattern of grease from the suspect's car, which he claimed was the origin of the stain. The similarity of the first two diffraction patterns and the dissimilarity of the third suggested that the suspect was guilty.

sample, less than a milligram, proved that the stain was kitchen grease.

The electron microscope promises to yield valuable information from such clue materials as dust, metals, fibers, inks and other materials whose particle size and distribution cannot be differentiated by less sensitive instruments. It was used effectively two years ago in connection with the murder of a woman by a burglar. A suspect was "developed," but the police could discover no stolen property in his possession, nor could they trace his activities on the night in question. They did, however, find in his room a towel bearing a pink stain. The laboratory determined that this small stain was face powder, and under the electron microscope it was identified with powder in the woman's compact. Faced with this evidence, the suspect confessed to the crime.

Often the police can assure that a thief will pick up an incriminating stain at the scene of the crime. Where there has been a systematic series of petty thefts, they may plant a "detective dye," such as rhodamine B or eosine, which is hard to wash off. Rhodamine B may be brushed on a brown wallet, or a green dye on greenbacks. For a thief this is "nonprotective coloration." When he touches the wallet or the bills, perspiration dissolves the dye and leaves a brilliant stain on his hand. Surveillance of nearby washrooms often catches the thief. When a continuous vigil is impracticable, a small quantity of fluorescent powder can be sprinkled on the object. The powder will be spread on the hands and

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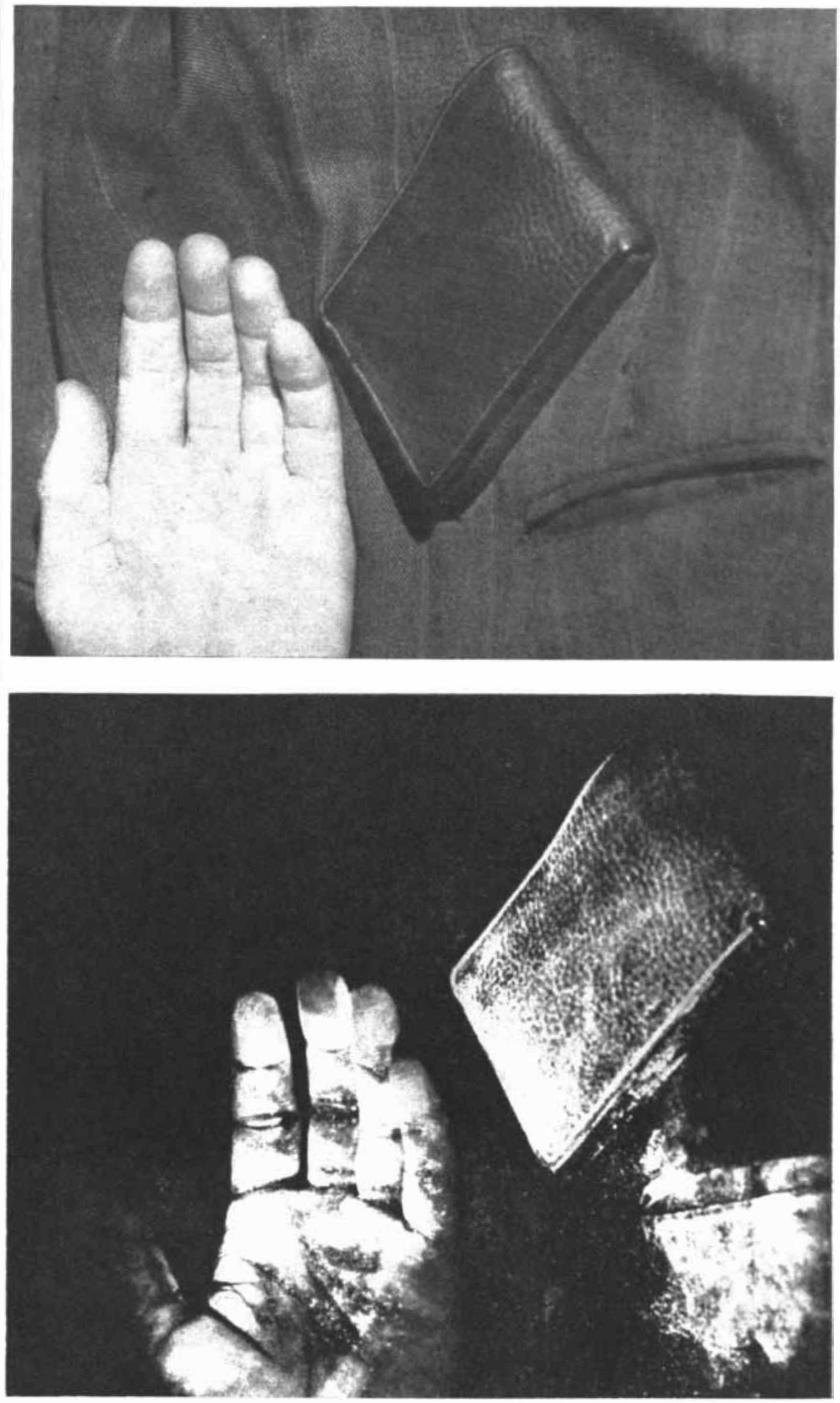
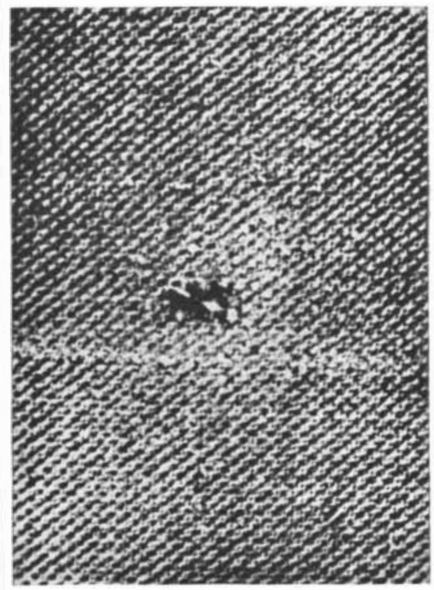
THE labeling technique should have a big future in crime detection, now that we have radioactive isotopes to add to the other labeling substances. Fingerprints have always been an ideal means of placing a criminal at the scene of the crime, but unfortunately criminals know that as well as the police. Already it has become the practice to tag some materials that figure frequently in crimes with radioisotopes, fluorescent substances or rare elements. Radioactive substances have been employed to label "company" gasoline and prevent pilfering. Pari-mutuel tickets are sometimes

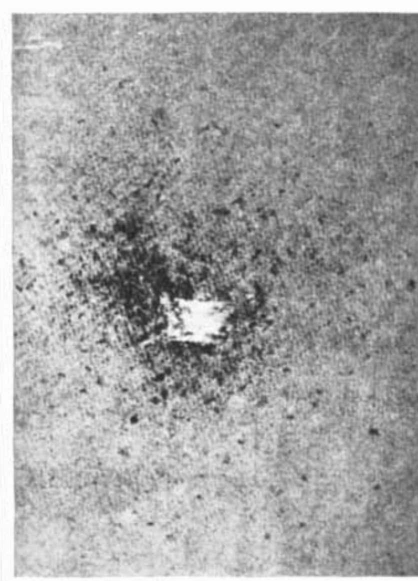


FLUORESCENT POWDER can be used to label the perpetrator of a theft. At the top objects labeled with such a powder are seen under ordinary light. At the bottom the same objects are photographed under ultraviolet light.

impregnated with a fluorescent dye for identification; the cashier looks at them under an ultraviolet lamp to make sure they are genuine. During the last war ration coupons were similarly treated to detect forgeries.

To extend this method of attack on crime would require the cooperation of the manufacturers of common clue materials. Two outstanding examples are bullets and lipsticks. Trace elements placed in a bullet or lipstick could tell us three things: the name of the maker, the area of distribution and the year of manufacture. That knowledge would go a long way toward making it easier to solve crimes involving guns or women. So far manufacturers have rejected the suggestion, arguing that labeling could only rarely be useful to the police and it





SOFT X-RAYS reveal powder stains around a bullet hole in a trouser leg. Top: the bullet hole in ordinary light. Bottom: a radiograph of the hole that was made with soft X-rays.

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Technical Service Data Sheet

Subject: HOW *GRANODIZING* PROTECTS STEEL DRUM SURFACES FROM RUST AND IMPROVES PAINT ADHESION

NEW DEVELOPMENT IN CONTAINER INDUSTRY

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They are free of mill-scale. United States Steel Products is the first steel drum manufacturer to remove harmful mill scale completely ahead of the zinc phosphate coating stage.

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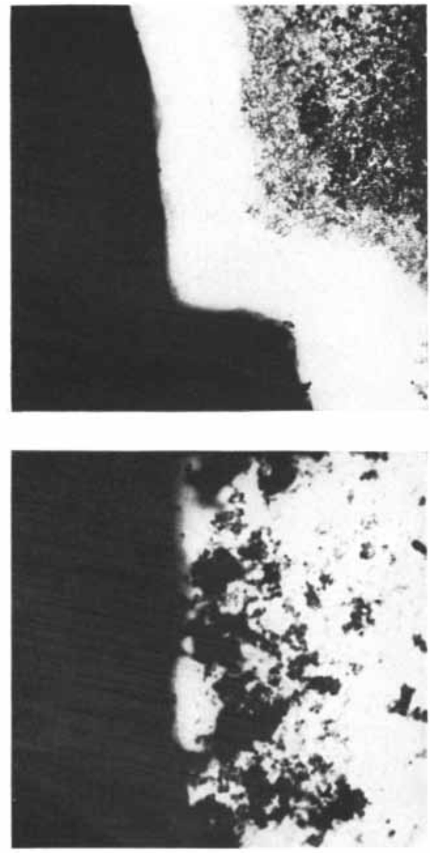
CHEMICALS ACP PROCESSES



BLOOD GROUP of a bloodstain on an axe is determined by agglutination. In the photomicrograph at the top the dark area is the stain; the small particles are the red cells in blood of a known group. At the bottom the cells have agglutinated.

would not contribute to the commercial success of their products. Some manufacturers of wire do label their product with tracers, but primarily to prevent mislabeling and protect their own reputations. Most of the manufacturers of cosmetics have even refused to tell the police confidentially the ingredients of their lipsticks, on the ground of protecting themselves from imitation. On investigation it was discovered that those who refused were for the most part selling lipsticks obtained from "superwholesalers"; many employ the same source and in fact the same lipstick, but give it their own name and their own highly individual claims.

These failures do not dismay the scientific criminologist. He has been similarly blocked in other utopian projects. Nor would he seek to compel manufacturers to cooperate, since compulsion would negate his function, which is to guarantee in his own small way the people's freedom in the lawful pursuit of their ways of life.

Charles E. O'Hara and James W. Osterburg are the authors of the book An Introduction to Criminalistics.

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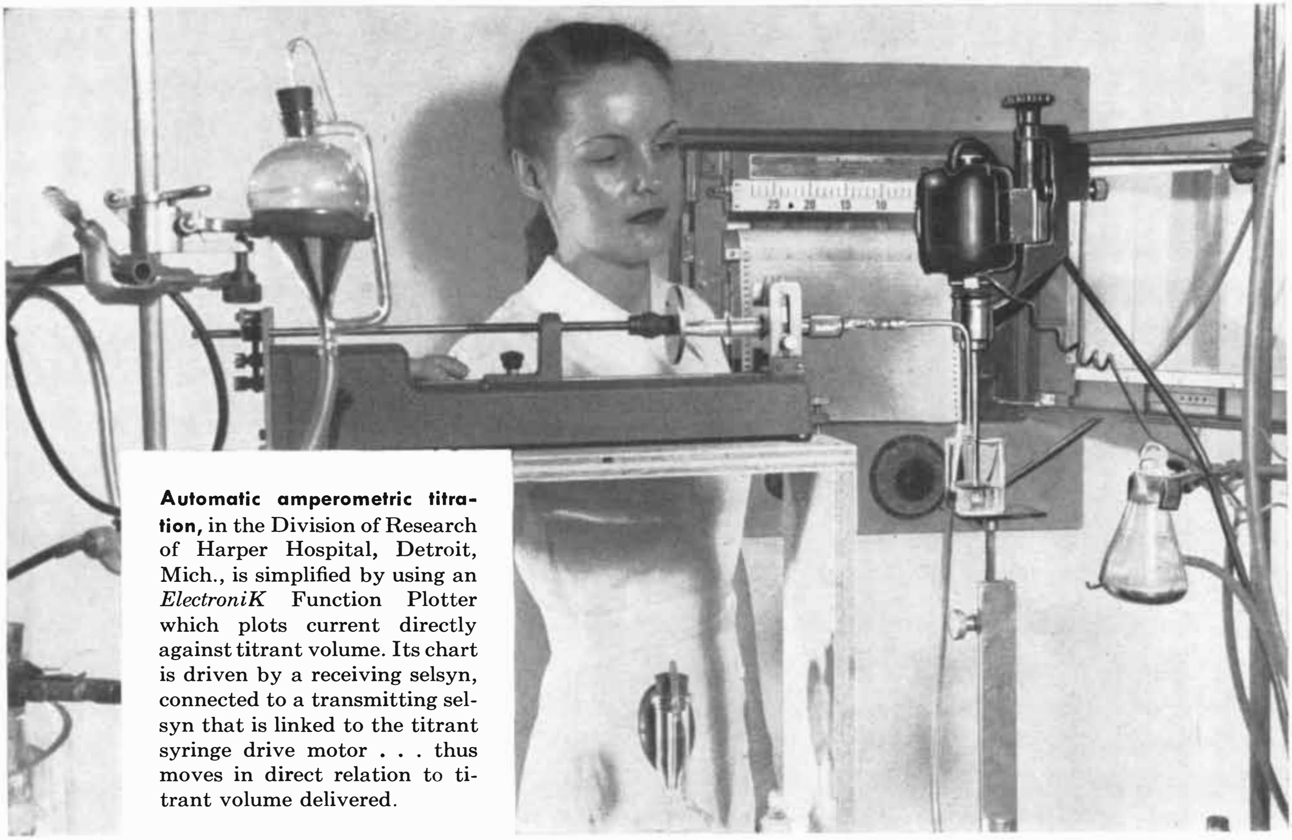

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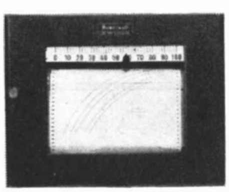

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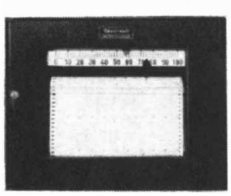

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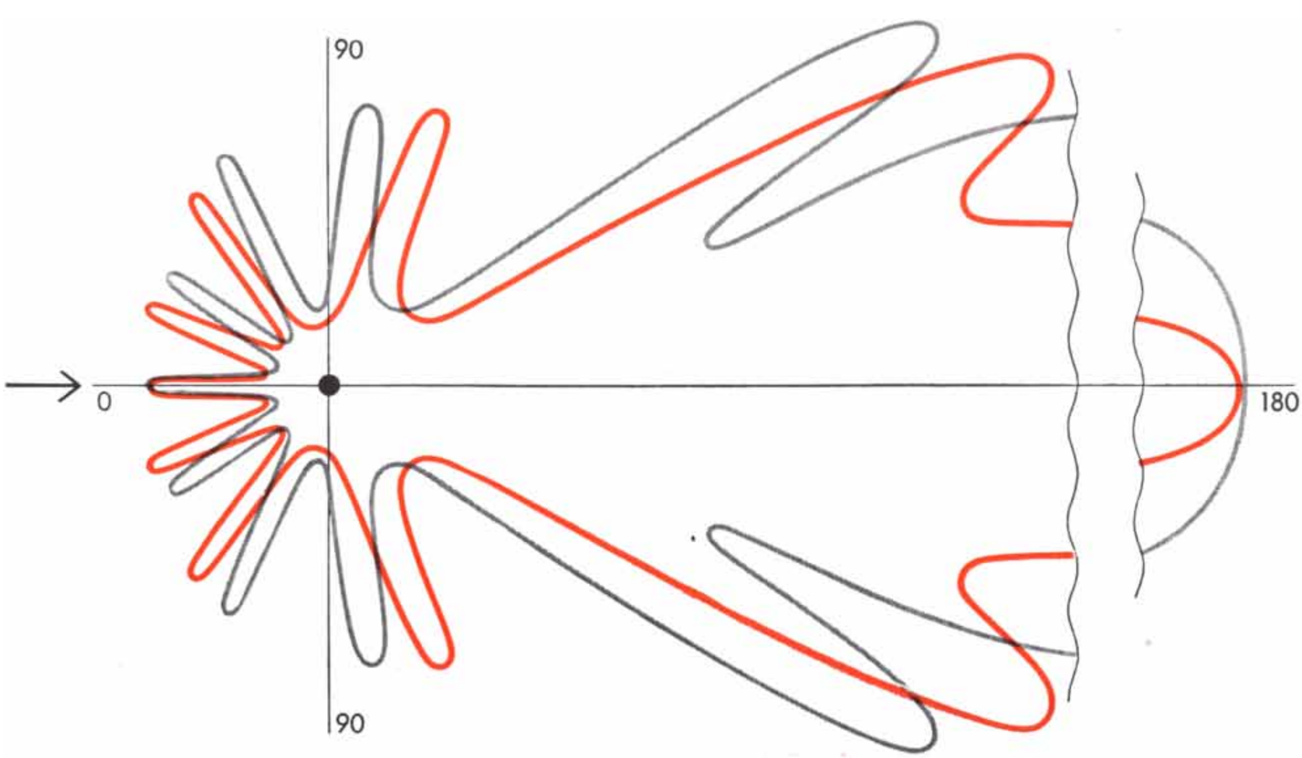
LIGHT SCATTERED BY PARTICLES

A laboratory procedure that measures the size of colloidal particles in liquids or gases utilizes the same phenomenon that causes the blue of the sky and the red of the sunset

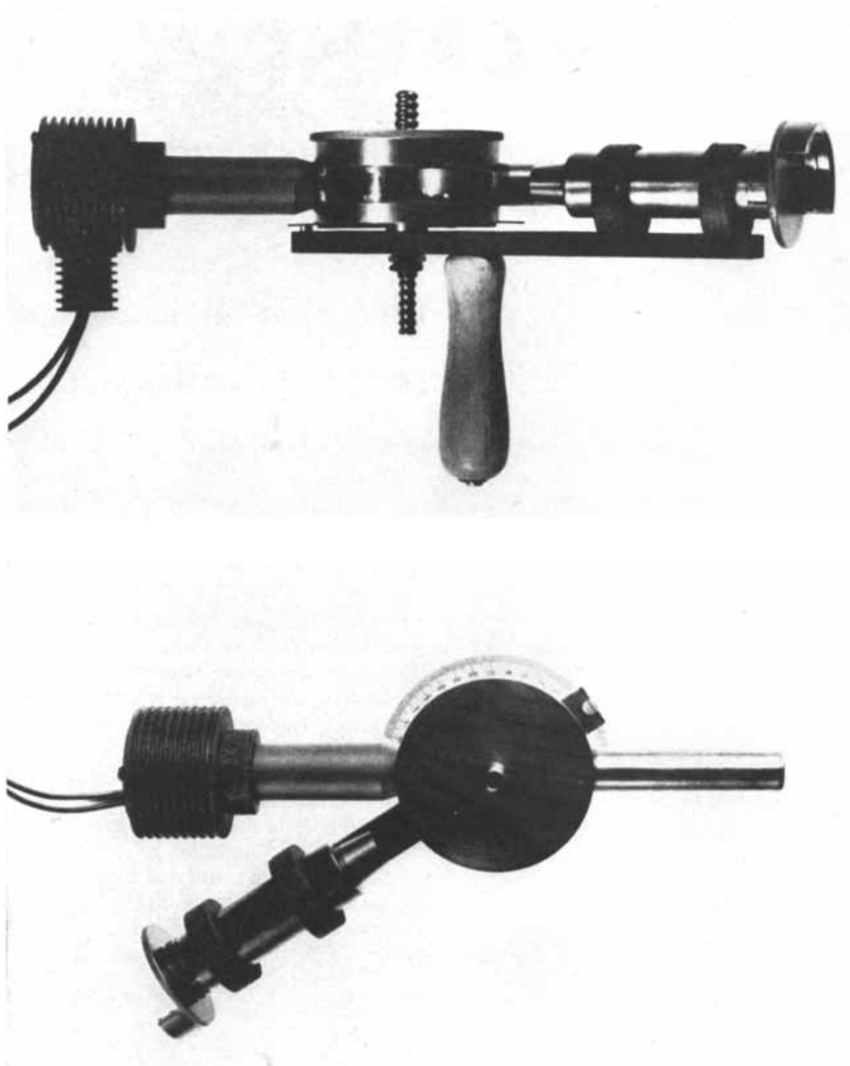
by Victor K. La Mer and Milton Kerker

THE "witchery of the soft blue sky," in Wordsworth's phrase, has fascinated scientists as well as poets. Why, after all, should the sky be blue? Until fairly recently many scientists believed that the blue of the sky must be its intrinsic color, as a paint pigment has a color. As they learned more about the nature of light, however, they came to realize that the color of the sky is entirely a light-scattering effect; were it not for this, the heavens would be black. Something close to the correct explanation was suggested more than four centuries ago by the remarkably prescient genius Leonardo da Vinci. He wrote in his notebook: "I say that the blueness we see in the atmosphere is not intrinsic color, but is caused by warm vapor evaporated in minute and insensible atoms on which the solar rays fall, rendering them luminous against the infinite darkness of the fiery sphere which lies beyond and includes it. . . . If you produce a small quantity of smoke from dry wood and the rays of the sun fall on this smoke and if you place [behind it] a piece of black velvet on which the sun does not shine, you will see that the black stuff will appear of a beautiful blue color. . . . Water violently ejected in a fine spray and in a dark chamber where the sunbeams are admitted produces then blue rays. . . . Hence it follows, as I say, that the atmosphere assumes this azure hue by reason of the particles of moisture which catch the rays of the sun."

In 1869 the British physicist John Tyndall performed a famous and beautiful series of experiments which confirmed the essence of Leonardo's idea.



SCATTERING OF LIGHT by a particle with a radius of .5 micron is plotted in this diagram. When white light (*arrow*) strikes the particle (*dot*), the red and green components of the light are scattered in different directions. The intensity of the red is indicated by the red line; that of the green, by the gray line. The radius of the particle in microns is indicated by the number of red bands in 180 degrees divided by 10.



"OWL," one of the instruments that utilizes light-scattering, is seen from the side (*top*) and the top (*bottom*). At the left is a light source that shines a beam through the particle-containing chamber in the center. The bands of color are counted by means of a viewer that can be rotated around the chamber. The device was furnished by the firm of Process and Instruments.

He passed white light through air containing fine suspended particles and showed that much of the light was scattered away from the path of the beam. In most cases the scattered light was a milky white, but when the particles were very small, it was blue. The transmitted beam, lacking the blue wavelengths, took on a reddish-yellow hue. Tyndall reasoned that atmospheric dusts would produce the same effects on sunlight and would account for the redness of the setting sun: in the long horizontal travel of the sun rays through the atmosphere much of their blue light was scattered, leaving the transmitted light reddish.

That light is scattered by particles in the air is a matter of common knowledge today; everyone knows, for instance, that fog makes a searchlight beam highly visible because its water droplets scatter the light. But it is not very widely known that as a result of new discoveries since 1940 light-scattering has become an important analytical tool with many applications, from biochemistry to astronomy. It is used to measure the size of particles and even to determine the weights of molecules. The scattering of light by particles has been worked out in precise mathematical terms.

After Tyndall's demonstrations, his contemporary Lord Rayleigh undertook a theoretical study of light-scattering on the basis of Maxwell's recently developed electromagnetic theory. He proved mathematically that particles with a diameter less than one tenth a wavelength of light must scatter short wavelengths (blue light) much more strongly than long wavelengths (red light). He also pointed out that the oxygen and nitrogen molecules of the air, as well as dust particles, should scatter sunlight; experiments with dust-free

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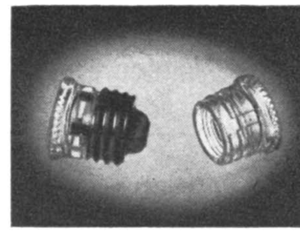

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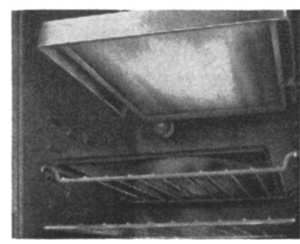

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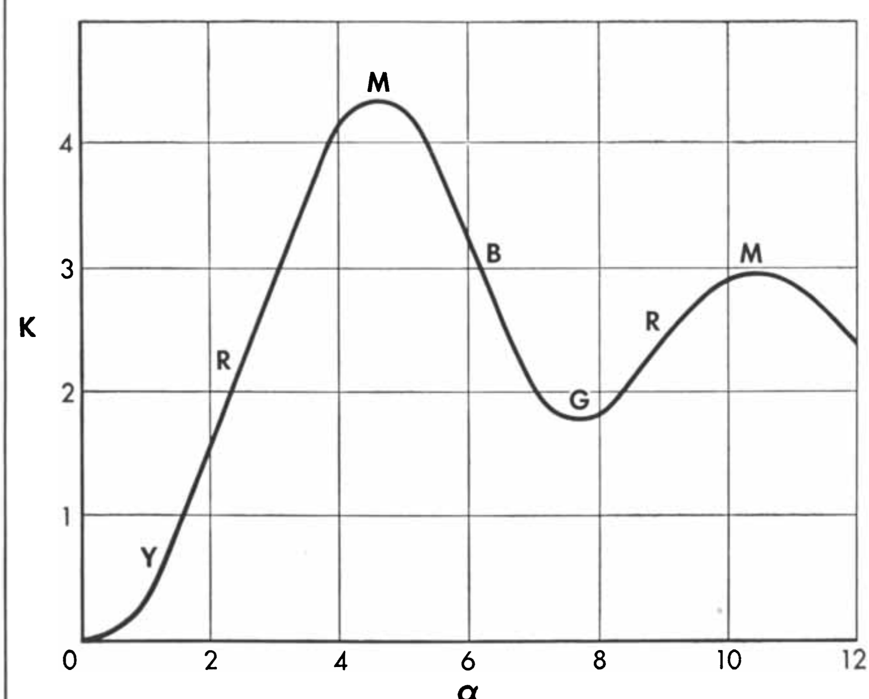
gases confirmed this prediction. Indeed, it is now known, from studies at Mount Wilson Observatory, that most of the intensity of sky radiation comes from molecular scattering; scattering by dust particles is important only at lower levels. Rayleigh concluded that the blueness of the sky was due mainly to scattering by air molecules.

The German physicist Gustav Mie extended Rayleigh's work much further. He was able to write equations which can be used to describe the pattern of light-scattering not only by Rayleigh's small particles but by spherical particles of any size. The pattern depends on the size of the sphere and the wavelength of the light that strikes it. Thus in theory it became possible to determine the size of minute particles by observing their scattering effect on light. In other words, every particle provides a fingerprint of itself. Two difficulties, however, stood in the way of applying Mie's equations. First, the labor involved in computing his mathematical functions was too great. Second, the method was applicable only to collections of particles of uniform size, since a mixture of particles of different sizes produces a smeared out pattern which cannot be resolved to find the sizes of the various particles in the mixture.

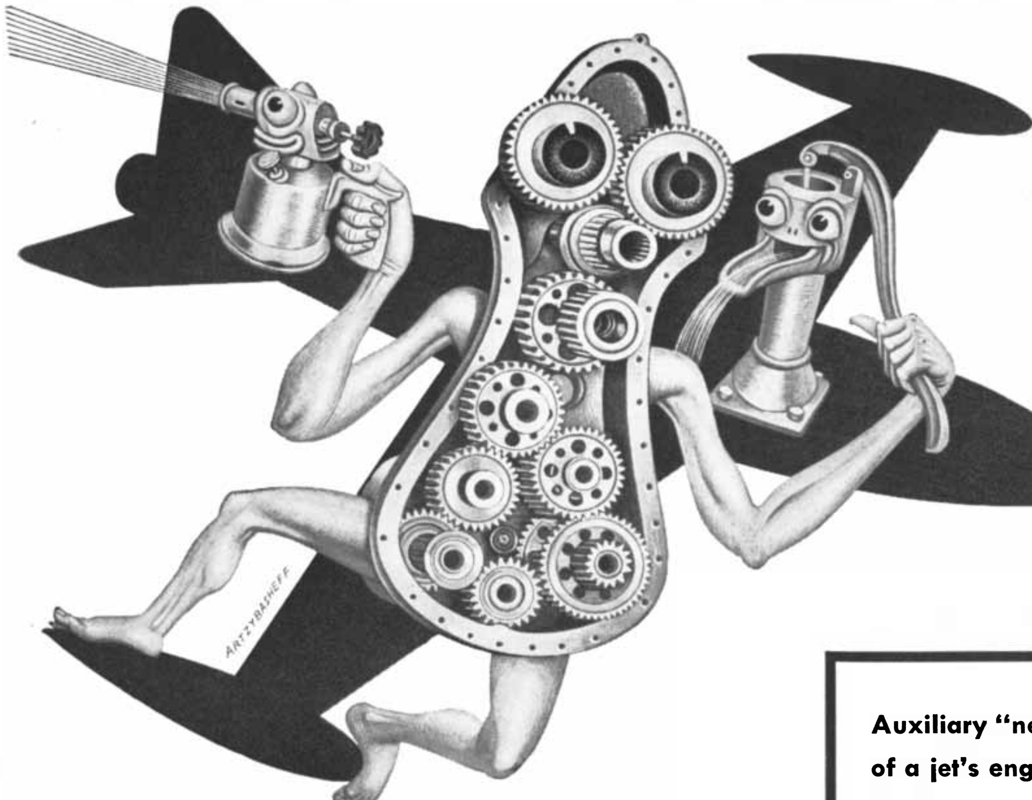
Within the past decade both difficulties have been overcome. High-speed electronic calculators made Mie's computations feasible, and ways were found to produce suspensions with uniformly sized particles. Victor K. La Mer (one of the authors of this article) and David Sinclair were working at Columbia University on the project of producing aerosols (fogs) with uniform-sized particles for the Chemical Warfare Service. They were experimenting with a column of dense cigarette smoke whose temperature was carefully controlled to avoid convection currents. A shaft of light sent across this column of smoke gave at first the familiar milky Tyndall beam. In a few minutes the upper part of the beam became blue. Then, after 15 to 20 minutes, there came a display of spectacularly beautiful colors—red, blue, green and orange. The color of the beam varied with its height in the column and the angle at which it was observed, as well as with the elapsed time. It was immediately obvious that this new phenomenon was due to the fact that the particles of different sizes in the mixture were falling at different rates and separating into homogeneous layers. Each layer was giving the characteristic scattering pattern of its particle size.

With the aid of this test for homogeneity of particle size, La Mer and Sinclair were able to devise a new type of smoke generator with which they could produce at will uniform aerosols of particles of any given size. Shortly afterward La Mer and Marion Barnes made a liquid suspension (hydrosol) of sulfur particles, also of uniform size, with which scattering experiments could be performed more conveniently. The preparation of this suspension is very simple. Solutions of sodium thiosulfate



COLOR transmitted by a suspension of uniform particles is related to particle size. K is a measure of scattering as it is related to particle size and wavelength by means of the function alpha. The symbols on the curve are Y=yellow, R=red, M=magenta, B=blue and G=green.

How a jet engine runs on its "nerves"



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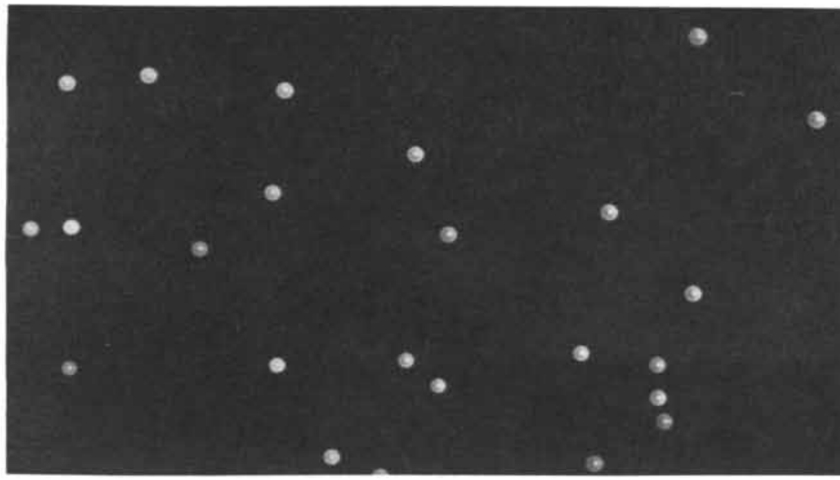

UNIFORM PARTICLES are required to produce colors. This photomicrograph, made by P. K. Lee, shows the uniform diffraction circles of such particles made by the regulated cooling of dioctylphthalate vapor.

and of acid, both very dilute, are mixed together. The mixture remains crystal clear for about an hour. Then a blue Tyndall beam suddenly appears. This means that very fine sulfur particles have formed. The beam gradually grows brighter and becomes gray in color, showing that the sulfur particles are getting bigger. They continue to grow, and after another hour a red band appears to an observer watching the beam at a certain angle. Thereafter more bands, alternately red and green, appear at half-hour intervals. The growth of the sulfur particles can be stopped at any point by adding a dilute iodine solution.

WHEN an observer looks at a beam of white light sent through a uniform aerosol or hydrosol, the color of the beam changes as he changes the angle of observation. [The photograph on the cover shows beams of light entering a hydrosol at three different angles.] Starting from the head-on view and moving around 180 degrees to behind the beam, he alternately sees red and green bands. He may see as many as nine of each, the number depending on the size of the particles in the given suspension. Divide the number of red bands by 10, and you have roughly the radius (half the diameter) of the particles in microns, one micron being four hundred-thousandths of an inch. A more exact measure is given by the exact angular position of the bands. Thus these so-called "higher-order Tyndall spectra" provide a facile and rapid method for measuring small particles. The method is especially useful in studying particles too small to be resolved by the light microscope and too large for the electron microscope.

The phenomena we have discussed so far involve only spherical particles. Other shapes also scatter light, but the laws governing the effect are more complex. Peter J. W. Debye of Cornell University has worked out scattering equations for rod-shaped particles, and he has used these equations to study large molecules such as proteins and viruses. The light-scattering measurements of molecule sizes agree very closely with those obtained with the electron microscope. Thus they provide a rapid, easy method of determining the molecular weight of a large molecule.

If the giant molecules can be seen with the electron microscope, why bother with light-scattering? The answer is that it not only provides a valuable check on the microscope but makes possible measurement of the molecules without disturbing their normal condition. To prepare a virus for observation under the electron microscope involves such drastic treatment that there is often considerable doubt whether the prepared sample is much like the original object, whereas a light beam passed through a suspension of viruses leaves them unharmed. Besides this, the light-scattering method is faster, cheaper and simpler to carry out.

THE LIGHT transmitted through a suspension, as well as that scattered away from the beam, gives valuable information about particle sizes. Rayleigh's calculations predicted that a beam of natural white light transmitted through very small particles should be yellow, its blue light being scattered most. As the particles grow bigger the transmitted light should turn red and then magenta. This latter color corresponds to the particle size that gives the maximum scattering (mostly of green light) and hence the minimum light transmission. For still larger particles the transmitted beam becomes blue and finally green. The big particles actually scatter red light more than blue.

These transmission effects, which were implicit in Mie's equations, were not actually calculated until 1942. After

the computations had been made, Seymore Hochberg of Columbia University tested them with some oil smokes of uniform particle size. He found that the light transmitted through droplets of .5-micron radius was a deep azure, just as the theory predicted. For .6-micron droplets the beam was pure green.

The results were put to immediate military use. At the General Electric Company laboratories Irving Langmuir and Vincent Schaefer were then developing generators to make smoke screens against aerial bombing. To assure that the smoke would have maximum obscuring power, the operators of the generators were instructed simply to observe the color of the sun's disk when it was almost completely hidden by the smoke from the generator. If it looked yellow or red, the smoke particles were too small for most effective screening; if blue or green, the particles were too large. The generator was adjusted until the sun's disk was magenta, which meant that the smoke was of just the right size for maximum screening.

The Mie-equation computations explained the old mystery of why the moon, on rare occasions, looks blue or even green: large dust particles in the atmosphere account for it. They also explained the extraordinarily brilliant sunsets and other weird color displays which were seen all over the world for three years after the great volcanic explosion at Krakatoa in 1883. In 1950 there was a similar effect when tremendous smoke clouds from forest fires in Canada floated across the Atlantic to Europe, causing the sun, moon and stars to turn blue.

ASTRONOMERS are gaining from light-scattering theory important information on the density and distribution of matter in the universe. Interstellar dust scatters starlight as it passes through space. The scattered light itself is much too faint to be detected, but the transmitted beams that reach us from the stars can give a clue as to the nature and amount of dust through which they have passed. Calculations show that interstellar dust is composed mainly of particles about half a micron in radius.

Although light-scattering is a very new tool, it has come into wide use for analyzing the size and structure of such diverse substances as viruses, smokes, rubber, proteins, smog, soap, blood platelets and gels. Many university and industrial laboratories now do light-scattering measurements of colloidal and macromolecular systems as a matter of daily routine.

Victor K. La Mer is professor of chemistry at Columbia University. Milton Kerker is assistant professor of chemistry at the Clarkson College of Technology.

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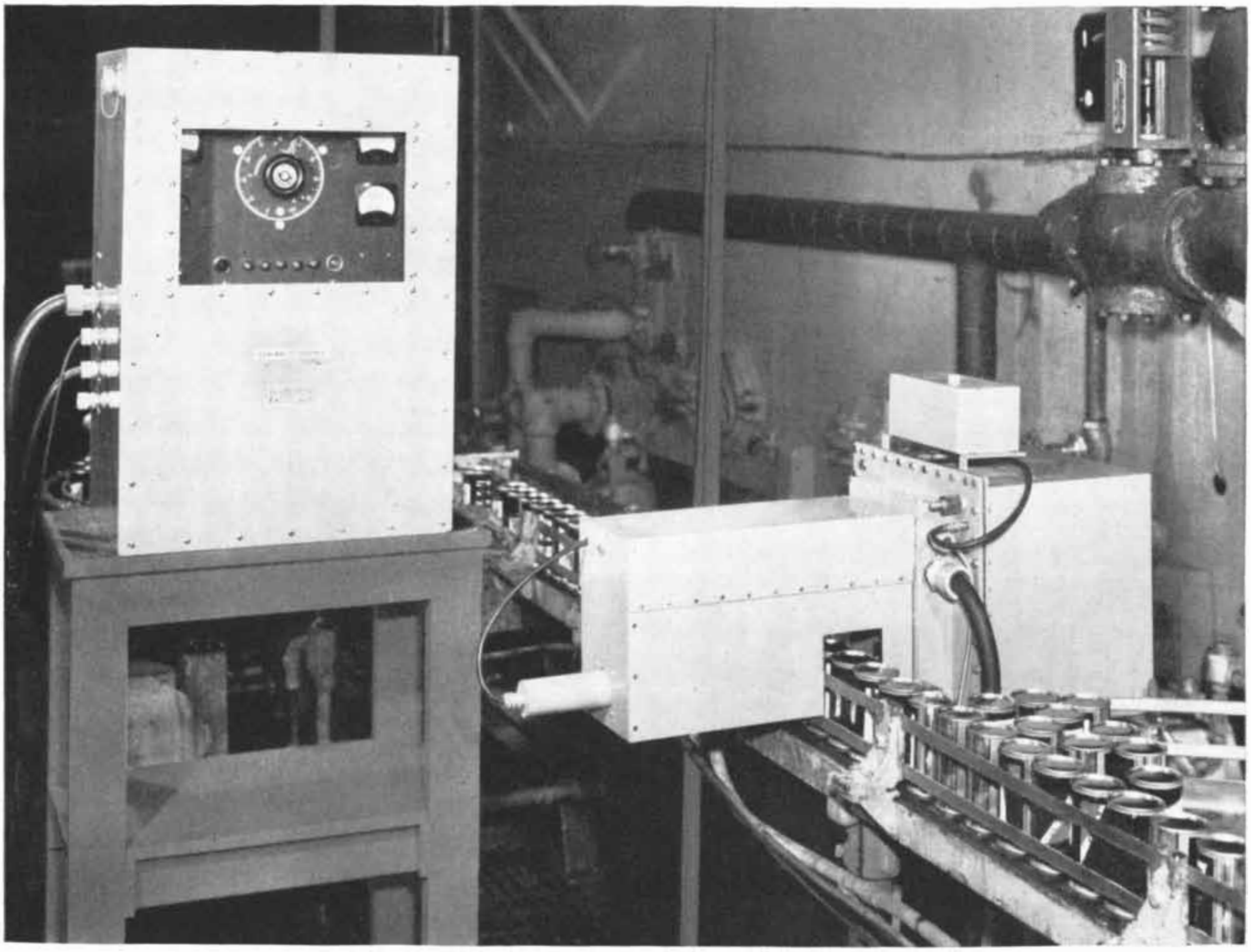

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GENERAL ELECTRIC

William Kingdon Clifford

He was a brilliant participant in the mathematical revolution of the 19th century, and is a memorable example for the popularizer and citizen of science

by James R. Newman

A FEW YEARS ago I was asked to prepare a new edition of a small 19th-century classic in mathematics: *The Common Sense of the Exact Sciences.* Seeking details about its author, William Kingdon Clifford, for the introduction to the volume, I discovered to my surprise that very few were available. The only published material on Clifford's life was a few scattered articles and obituaries and a brief biographical preface to his collected lectures and essays written by a contemporary, the barrister and legal historian Sir Frederick Pollock.

This neglect of Clifford is difficult to explain. He was not only one of the great mathematicians of his century but an original philosopher and a leader of British intellectual life in the Victorian age. Much of Clifford's thinking was ahead of his time. His mathematical work was prophetic, and its merit is still untouched after three quarters of a century of immense progress in mathematics; his philosophical ideas were rational and humane; he possessed an art of clarity, as Bertrand Russell has said, "that comes of profound and orderly understanding by virtue of which principles become luminous and deductions look easy." An inspiring faith in the power of reason and in human progress guided Clifford's remarkably productive but tragically short life of 35 years.

He was born in Exeter May 4, 1845. His father was a man of status in the town, serving as justice of the peace. His mother, a sensitive woman of intellectual tastes and delicate health, died when he was a boy—of the same disease to which Clifford was to fall victim. Clifford, a precocious youngster, produced at the age of 18 two original papers in geometry which led his tutor at Cambridge University to prophesy that he would gain a place among the leaders of science. As an undergraduate in Trinity College he read widely in philosophy, classical literature and modern history; he enjoyed companionship and participated in endless debates with his fellows and tutors on subjects ranging from Catholic doctrine to chemistry, from Thomas Aquinas to Darwin and Spencer. It was Clifford's good fortune to be a student at a time when long-accepted beliefs in science and logic were beginning to crumble under the assaults of new theories and discoveries. Cambridge was a center of this revolution, and Clifford shared in its excitement and its "daring" talk. At first a High-churchman, "fond of supporting Catholic doctrines by ingenious scientific analogies," he turned gradually into a bitter enemy of organized religion, especially what he called "priestcraft." Clifford was a whirlwind in argument; when he let loose his tongue, "the pace was tremendous." His brilliance in conversation in the Grote Club at Cambridge was remembered half a century later by Alfred Marshall, a fellow member who became a famous economist. Marshall wrote of him with immense admiration, though he felt that Clifford was "too fond of astonishing people."

Clifford enthusiastically studied French, German and Spanish (to help him in his work); Arabic, Greek and Sanskrit (because they were difficult); hieroglyphics (because they were a riddle); shorthand and the Morse code (because he was interested "in all methods of conveying thought"). Every branch of mathematical and scientific literature appealed to his eclectic appetite. He won an assortment of literary, scientific and oratorical prizes. He was proudest, however, of his athletic achievements: the crown of his undergraduate career was hanging by his toes from the crossbar on the weathercock of a church steeple—a quaint Cambridge antic not usually fatal in its consequences. He also finished second in the arduous competitive examinations known as the tripos, thus matching the achievement, in their day, of Lord Kelvin and the incomparable James Clerk Maxwell.

HIS TRAINING had been good and his record outstanding, and in 1868 he was elected to a fellowship at Trinity. He was already turning out a steady output of three or four first-class mathematical papers a year. His first important public lecture was called "Conditions of Mental Development." Like every other important scientist, philosopher and man of letters in the 19th century, he took to the lecture platform to help popularize learning. Clifford excelled in making hard concepts understandable, and he enjoyed the effort. His ability to turn the abstract into the concrete gave his lectures a lucidity and charm which even the lapse of time and transfer to print do not diminish.

Clifford spent two years as a fellow at Cambridge teaching, doing research, developing his ideas—alone and in commerce with other original and provocative minds. Then in 1870 he joined an English expedition to observe an eclipse. The ship carrying the party was wrecked off Sicily, but fortunately all hands and even the instruments were saved. Clifford took the mishap with his customary good humor. Shortly after the shipwreck he wrote from Florence to Lady Pollock, the wife of his friend Sir Frederick:

"At Catania, orange groves and telescopes; thence to camp at Augusta; Jonadab, son of Rechab, great fun, natives kept off camp by a white cord; 200 always to see us wash in the morning—a performance which never lost its charm—only five seconds totality free from cloud, found polarisation on moon's disc, agree with Pickering, other people successful. . . . At Rome 2½ days, pictures, statues, Coliseum by moonlight. Both of us sneezed awfully next morning. This morning arrived in Florence—Pitti Palace—spent all my money, and shall get stranded between Cologne and Ostend unless I can live on one egg every other day, and thereout suck no small advantage—be better off in Paris."

Clifford left Cambridge in 1871 to be professor of applied mathematics at University College, London. Clerk Maxwell was among those who strongly recommended him for the post, stressing the freshness and breadth of his research, as opposed to the "mere elaboration of abstruse theorems by ingenious calculation." In the next two years Clifford gave several of his best-known lectures and published a considerable number of mathematical articles, including a paper on biquaternions, dealing with the generalized conceptions of space, which stands high in the literature of mathematics. Two of these lectures, before the British Association for the Advancement of Science in 1872 and before the Royal Institution in 1873, afford admirable examples of Clifford's singular powers.

THE FIRST was "On the Aims and Instruments of Scientific Thought." It touched upon the profound re-evaluation of Euclidean geometry which had been forced by the researches of mathematicians who were taking a fresh look at the foundations of geometry. Up to that time the universality and the eternal verity of Euclid's theorems had never been doubted, just as they had never been tested. The non-Euclidean heresy put an end to this placid confidence.

Clifford illuminated the problem in masterly fashion. Advance in scientific thought, he said, depends on the hypothesis that the order we see in natural events holds good beyond our experience. Although human observation is limited, with the aid of the hypothesis of uniformity we can "infer things that we have not seen from things that we have seen." The hypothesis must be sharply defined, however; we must decide whether the uniformity on which inferences are based is mathematically exact. The mechanistic interpretation of the universe, magnificently elaborated in the 18th century, rested on the conviction that "if we knew all about it, Nature would be found universally subject to exact numerical laws." But the mathematicians themselves had shown that the issue as to whether nature obeyed such laws was far from settled.

"I shall be told, no doubt," said Clifford, "that we do possess a great deal of knowledge of this [exact] kind, in the form of geometry and mechanics; and that it is just the example of these sciences that has led men to look for exactness in other quarters. If this had been said to me in the last century, I should not have known what to reply. But it happens that at about the beginning of the present century the foundations of geometry were criticized independently by two mathematicians, Lobachevski and the immortal Gauss, whose results have been extended and generalized more recently by Riemann and Helmholtz. And the conclusion to which these investigations lead us is that, although the assumptions which were very properly made by the ancient geometers are practically exact—that is to say, more exact than experiment can be—for such finite things as we have to

Clifford among his students

deal with, and such portions of space as we can reach; yet the truth of them for very much larger things, or very much smaller things, or parts of space which are at present beyond our reach, is a matter to be decided by experiment, when its powers are considerably increased. I want to make as clear as possible the real state of this question at present, because it is often supposed to be a question of words or metaphysics, whereas it is a very distinct and simple question of fact."

Clifford thus firmly allied himself with Georg Friedrich Riemann, one of the greatest mathematicians of the century, in the view that geometry as applied to the world of experience is an experimental science, a proper part of physics. Geometry according to this view remains an exact science but ceases to be a universal one. For a law is true universally only if it is true of all cases whatever, "and this is what we do not know of any law at all." Therefore geometry is an exact science only within a limited field.

Today this is a familiar idea—that geometry is a formal exercise in logic when considered as a pure science of ideal space, and that when it is considered as applied mathematics, purporting to describe actual space (within the atom or out towards Betelgeuse) it is an experimental discipline like cooking or entomology, subject to verification and change as we probe further. But in 1870 this idea was neither familiar nor generally acceptable; indeed, it flagrantly contradicted the main body of accredited mathematics and philosophy. Clifford's opinions were a challenge to the belief that Euclidean geometry was the perfect description, for all times, of all parts of actual space—and the challenge eventually led to the modern conceptions of space, time, energy and matter. From the standpoint of philosophy Clifford's view contested the doctrine, advanced in Kant's transcendental esthetic, that the long-accepted notions of space were immutable because they were determined by our mode of perception, or by the structure of the mind.

CLIFFORD'S second lecture, "The Philosophy of the Pure Sciences," offers a penetrating, at times almost lyrical, survey of the revolution in science, the "changes in the conception of the Cosmos" wrought by the inventors of non-Euclidean geometry.

"What Vesalius was to Galen, what Copernicus was to Ptolemy, that was Lobachevski to Euclid. . . . Before the time of Copernicus, men knew all about the Universe. They could tell you in the schools, pat off by heart, all that it was, and what it had been, and what it would be. There was the flat earth, with the blue vault of heaven resting on it like the dome of a cathedral, and the bright cold stars stuck into it; while the sun and planets moved between. Or, among the better informed, the earth was a globe in the center of the universe, heaven a sphere concentric with it; intermediate machinery as before. At any rate, if there was anything beyond heaven, it was a void space that needed no further description. The history of all this could be traced back to a certain definite time, when it began; behind that was a changeless eternity, which was fully accounted for and described. But in any case the Universe was a known thing. Now the enormous effect of the Copernican system, and of the astronomical discoveries that have followed it, is that, in place of this knowledge of a little, which was called knowledge of the Universe, of Eternity and Immensity, we have now got knowledge of a great deal more; but we only call it the knowledge of Here and Now. We can tell a great deal about the solar system; but, after all, it is our house, and not the city. We can tell something about the star system to which our sun belongs; but, after all, it is our star system, and not the Universe. We are talking about Here with the consciousness of a There beyond it, which we may know some time, but do not at all know now.

"This, then, was the change effected by Copernicus in the idea of the Universe. But there was left another to be made. For the laws of space and motion . . . implied an infinite space and infinite duration, about whose properties as space and time everything was accurately known. The very constitution of those parts of it which are at an infinite distance from us, 'geometry upon the plane at infinity,' is just as well known, if the Euclidean assumptions are true, as the geometry of any portion of this room. . . . So that here we have real knowledge of something at least that concerns the Cosmos; something that is true throughout the Immensities and Eternities. That something Lobachevski and his successors have taken away. The geometer of today knows nothing about the nature of actually existing space at an infinite distance; he knows nothing about the properties of this present space in a past or future eternity. He knows, indeed, that the laws assumed by Euclid are true with an accuracy that no direct experiment can approach . . . but he knows this as of Here and Now; beyond his range is a There and Then of which he knows nothing at present, but may ultimately come to know more. So, you see, there is a real parallel between the work of Copernicus and his successors on the one hand, and the work of Lobachevski and his successors on the other."

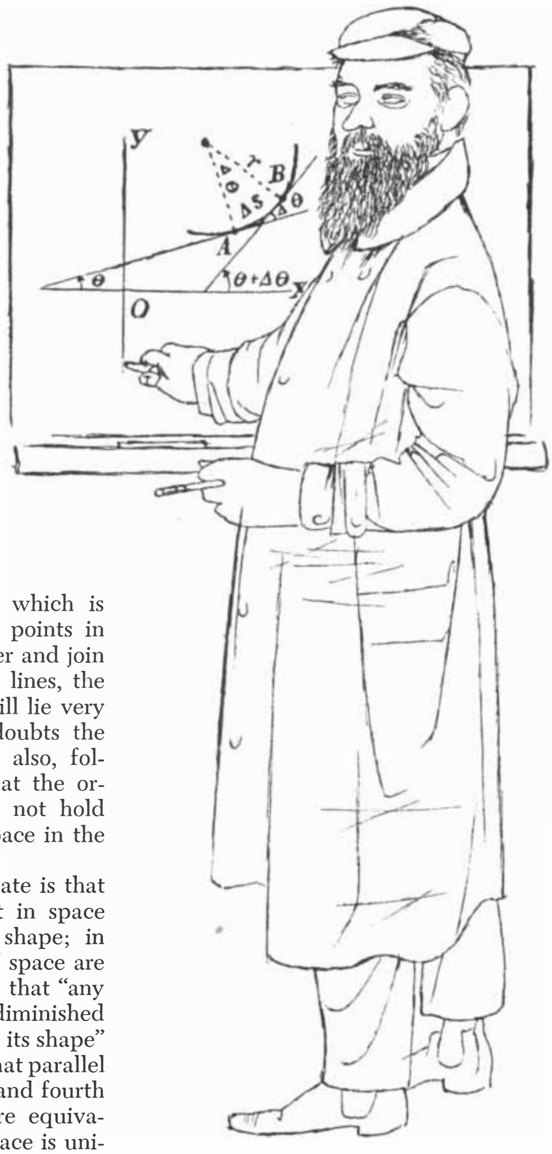
THE ORDINARY Euclidean conception of space rests on four fundamental postulates, and Clifford lucidly analyzes each in turn. The first states that space is continuous, without breaks or gaps of any kind. But continuity, Clifford points out, is an impression gathered from our senses, and they may deceive us. With the instruments of physics and chemistry we can see that objects which seem smooth and unbroken break down into atoms or other separate units. What proof have we that space is not of the same nature, smooth in appearance but actually crisscrossed, say, by a lacework of tiny fissures? The Euclidean postulate of continuous space therefore waits upon experience.

The second postulate assumes "the flatness of space in its smallest parts," which is to say that if we take three points in space very close to one another and join them by the shortest possible lines, the triangular figure so formed will lie very nearly in a plane. Clifford doubts the universality of this postulate also, following Riemann's opinion that the ordinary rules of geometry do not hold for "the metric relations of space in the infinitely small."

The third Euclidean postulate is that a body can be moved about in space without altering its size or shape; in other words, that "all parts of space are alike." The fourth postulate is that "any figure may be magnified or diminished in any degree without altering its shape" (which implies Euclid's rule that parallel lines never meet). The third and fourth postulates, taken together, are equivalent to the assumption that space is uniformly of zero curvature. Clifford finds these two postulates vulnerable on the side of the "very great," just as the first two could be attacked on the side of the "very small." That is to say, just as very small regions of space might turn out to be discontinuous, very large regions might turn out to be curved. Extraordinarily complicated *ad hoc* geometries may be required to describe any deviations of a given space from the standard of elementary flatness. These are closely tied to modern concepts of physics, suggesting that all phenomena, even matter itself, may consist of wrinkles or changes of curvature in space.

If the fourth postulate of "similarity," insofar as it relates to parallels, is abandoned, the way is open for a non-Euclidean geometry, such as the hyperbolic, which holds that the sum of the angles of every triangle is less than 180 degrees, or the elliptic, which makes the sum of the angles greater than 180 degrees. The space of elliptic, or Riemannian, geometry, proposing a large but curved and finite universe, appealed to Clifford: "I do not mind confessing that I personally have often found relief from the dreary infinities of homaloidal space in the consoling hope that, after all, this other may be the true state of things."

IN 1874 Clifford was elected a Fellow of the Royal Society, having declined to have his name put forward earlier on the ground that he "did not want to be respectable yet." He was in good health, energetically occupied with teaching and turning out papers on his latest researches, yet not too busy to continue his lectures on popular science as well as on social and ethical philosophy. He put forward some metaphysical theories of "mind-stuff" and the "tribal self" which are obscure and lifeless. But his ethical precepts embody all the warmth, the hatred of intolerance and the faith in reason that characterized his personality. The framework of his ethics was founded on the new doctrines of evolution. Freedom, independence, acting from "one's own inner conviction," he



Clifford at the blackboard

held, were the essential values of society: "There is one thing in the world more wicked than the desire to command, and that is the will to obey." He attempted to develop his ethical theories on the same objective basis as underlay his philosophy of science. It would not have entered his head that moral and religious values could be supported by any arguments other than reason and the teachings of experience. He was no more prepared to accept eternal values in ethics than in geometry.

In Clifford's personal life there was never a trace of cant, hypocrisy or self-righteousness. Writing to Lady Pollock on his "ideal theory" of behavior, he concluded: "All this, by the way, is only theory; my practice is just like other people's." Free from pretentiousness himself, Clifford was sharp in criticizing it in others. Of an acquaintance about to undertake a work in philosophy he remarked:

"He is writing a book on metaphysics, and is really cut out for it; the clearness with which he thinks he understands things and his total inability to express what little he knows will make his fortune as a philosopher."

But he was incapable of malice or personal enmity. Once he wrote:

"A great misfortune has fallen upon me; I shook hands with ———. I believe if all the murderers and all the priests and all the liars in the world were united into one man, and he came suddenly upon me round a corner and said, 'How do you do?' in a smiling way, I could not be rude to him upon the instant."

On April 7, 1875, Clifford married Lucy Lane. When he took leave from University College on this occasion, he informed his class that "he was obliged to be absent on important business which would probably not occur again." His wife became a well-known novelist and playwright, writing under the name Lucy Clifford, and she outlived him by half a century. Two daughters were born to them and brought Clifford great joy. He loved all children and delighted in making up games, fairy tales and poems. Some of his fables he contributed to a collection, *The Little People*. He had a scheme to issue a series of little school manuals whose lessons would be designed to help "kids find out things for themselves."

Clifford's happiness with children and his deep concern with their problem of learning and growing up stand in poignant contrast to the brief period he lived to spend with his own. In 1876 the first alarming signs of tuberculosis appeared. All his life he had taxed his physical powers; he was athletic but essentially frail in constitution. Despite the symptoms of his grave illness Clifford did not let up in his work. In 1876 he published no fewer than nine mathematical papers and various other writings. One of the papers was a remark-

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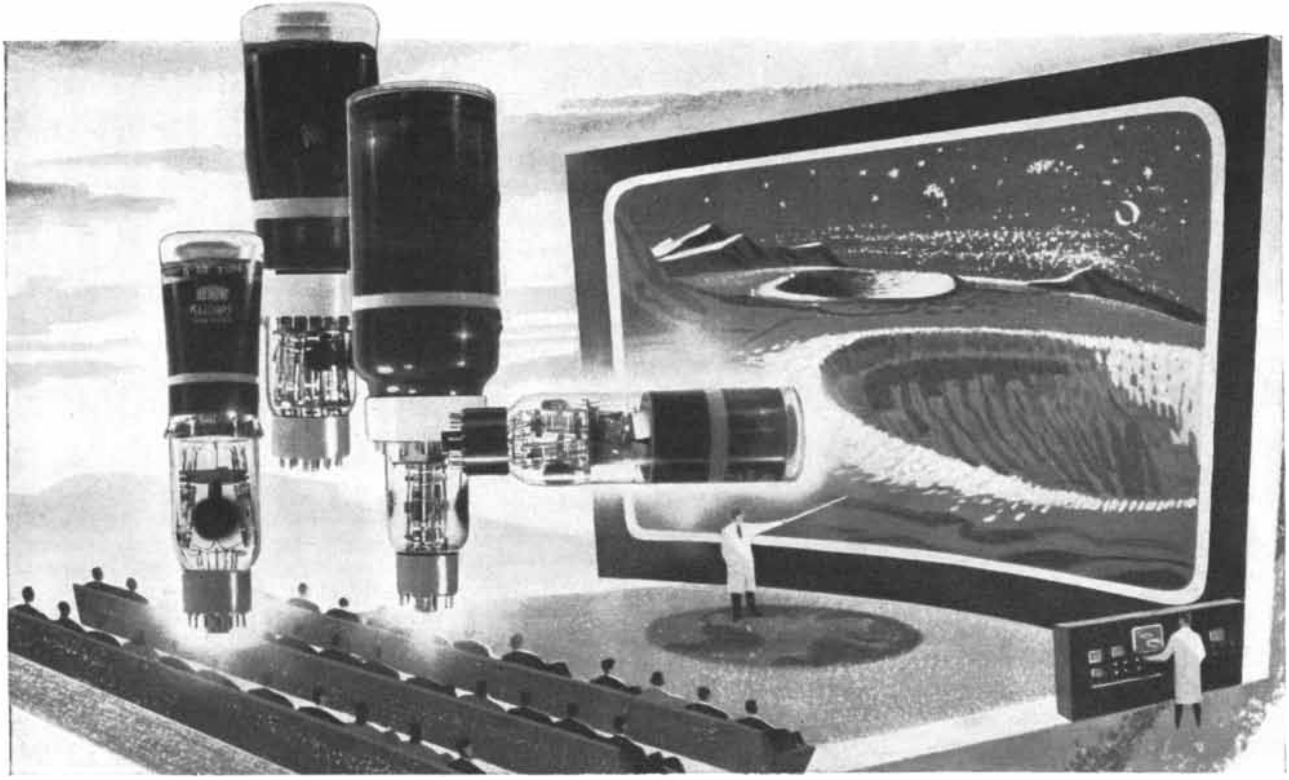

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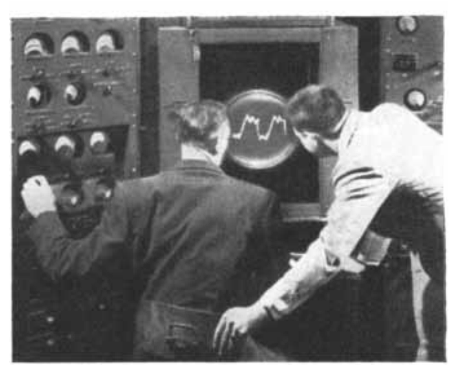

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Allen B. Du Mont Laboratories, Inc., 750 Bloomfield Ave., Clifton, New Jersey able contribution to the Cambridge Philosophical Society "On the Space Theory of Matter," in which he suggested that small portions of space are "analogous to little hills on a surface which is on the average flat . . . that this property of being curved or distorted is continually being passed on from one portion of space to another after the manner of a wave; that this variation of the curvature of space is what really happens in the *motion of matter* . . . that in the physical world nothing else takes place but this variation, subject (possibly) to the law of continuity. . . ." These words were published 40 years before Einstein announced his theory of gravitation.

IN THE FALL of 1876 Clifford agreed reluctantly to take a six months' leave of absence for his health, and spent it traveling with his wife in Algeria and Spain. He returned to England somewhat improved and in the next year and a half accelerated his work, issuing two of his most celebrated papers, along with other mathematical memoirs, an excellent volume on dynamics, a number of essays, lectures and reviews. Again there came a collapse, and he passed the spring and summer of 1878 in Italy, then returned to England, still looking very ill and feeble. At the beginning of 1879 he sailed for Madeira and there had a few days of peace in the fine sunshine. On March 3, 1879, he died.

"And this," wrote Sir Frederick Pollock, "is the witness of his ending, that as never man loved life more, so never man feared death less. He fulfilled well and truly that great saying of Spinoza, often in his mind and on his lips: *Homo liber de nulla re minus quam de morte cogitat* [There is nothing over which a free man ponders less than death]."

Clifford was not only a great professional mathematician, a distinguished philosopher and a brilliant writer, but a citizen of science. He ceaselessly strove to strengthen its foundations and organic unity and, by preaching the widest applicability of its methods, to promote the rational and confound the irrational. His was the spacious outlook of an elevated man: "Remember then that [scientific thought] is the guide of action; that the truth which it arrives at is not that which we can ideally contemplate without error, but that which we may act upon without fear; and you cannot fail to see that scientific thought is not an accompaniment or condition of human progress, but human progress itself." It is a maxim which our age, often mistaking valves and levers for science, would do well to recall.

James R. Newman is author, with Edward Kasner, of Mathematics and the Imagination. *He is an editor of this magazine.*

sci'ence (si'ens), n.(OF., fr. L. scire to know)

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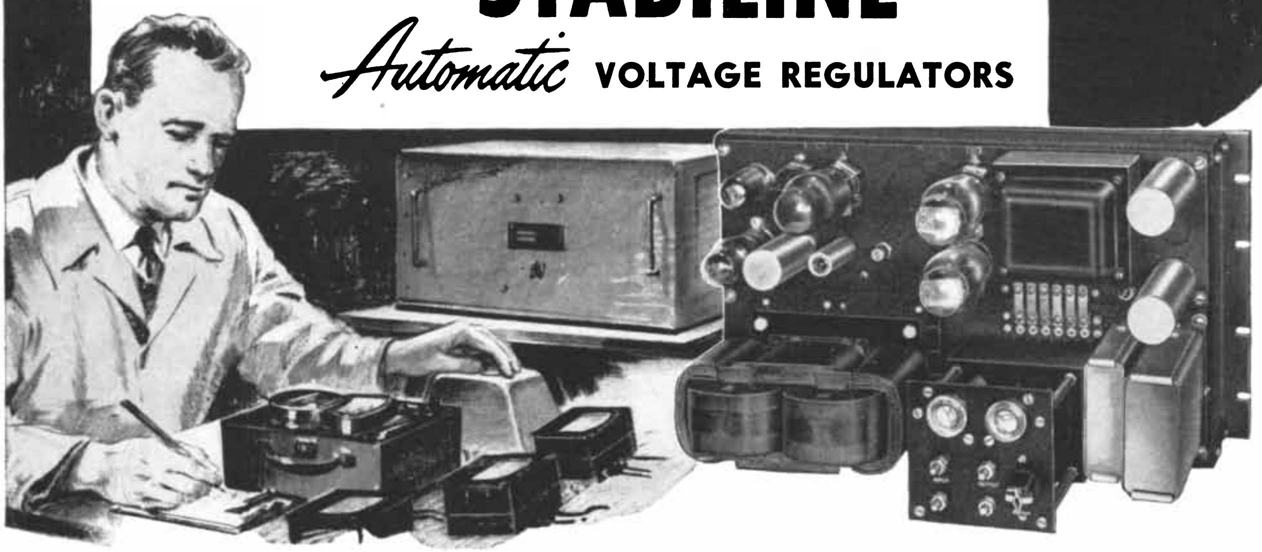

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TOXOPLASMOSIS

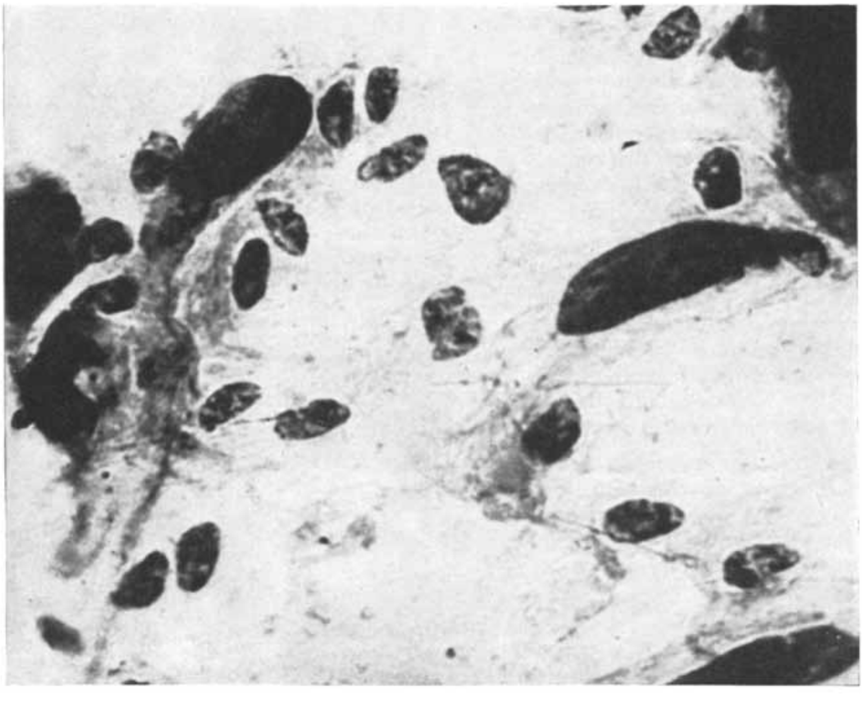
This little-known disease is surprisingly widespread and sometimes fatal. Although it has been studied for 50 years, it is still a medical and biological enigma

by Reginald D. Manwell and Hans Peter Drobeck

IN 1909 two French scientists named Nicolle and Manceaux described a strange new disease which they had found in a North African rodent called the gondi. It was caused by some kind of parasite, which they took to be a protozoon (one-celled animal), and they named it *Toxoplasma gondii*. The disease at first was thought to be rare, but as time went on it was found in many species of animals, mainly mammals and certain birds, notably the pigeon and the canary. By now toxoplasmosis has become a very intriguing disease indeed. In the first place, the infection is apparently widespread among human beings, and in its acute form it is often fatal. Secondly, it seems to be able to attack all, or nearly all, warm-blooded animals, which would make it unusual among parasites, for generally a parasite can live in only one or at most a few hosts. Finally, the disease presents an enigma and a baffling challenge to biology and medicine. Of few subjects in science can it be said, after almost half a century of research, that so little positive knowledge has been discovered.

Although toxoplasmosis is now known to occur rather commonly in man, we are in the dark as to just how prevalent it is. We do not know how it is spread, how it injures the body, why it is only occasionally serious or fatal, or how to prevent, treat or even diagnose it reliably. We cannot cultivate the organism successfully except in living cells. Worse still, we do not even know just what Toxoplasma is. Half a century of investigation has merely given us some fairly definite ideas about what it is not. Yet the inquiry has its own interest, and it has raised some stimulating questions about the nature of elementary forms of life.

The first question posed by Toxoplasma is: Is it an animal or a plant? Unfortunately the differences between animals and plants, which seem so clear to most of us, become less and less distinct as we go down the scale of living things, until finally they almost disappear. Toxoplasma seems to have some attributes of an animal and some of a plant. It is a minute, crescent-shaped organism, somewhat more pointed at one end than the other. It is slightly bigger than a red blood cell, which means that it is considerably larger than most bacteria. It seems to prefer to live within cells, especially cells of the brain, spleen and liver. A single cell will sometimes contain 20 or more parasites, so that little remains of the cell itself except the nucleus (which seems never to be invaded) and a thin envelope of cytoplasm.



TOXOPLASMA CELLS, which cause the disease toxoplasmosis, are shown in the brain of an experimentally infected mouse. They are the smaller dark objects. This photomicrograph enlarges the cells some 1,700 diameters.

ONE TEST of a plant is the ability to manufacture foodstuffs from such simple materials as carbon dioxide and water. Toxoplasma cannot do this. But then neither can the fungi, which are considered true plants. Many parasitic fungi can infect a wide range of species. The late protozoologist Charles Wenyon suggested that Toxoplasma might be related to the fungus *Histoplasma capsulatum*, which produces a human disease similar to toxoplasmosis [see "Histoplasmosis," by Martin Gumpert; SCIENTIFIC AMERICAN, June, 1948]. But Toxoplasma can scarcely be regarded as a fungus according to the usual criteria. It has a simple life history and appears only in the one crescent-shaped form, whereas fungi generally have a complex life history, with spores, hyphae, mycelia and often other stages. Furthermore Toxoplasma will not grow in the various media on which the fungi thrive. On the whole Toxoplasma does not fit readily into the fungus category, and its resemblance to Histoplasma seems confined to the name.

If mobility is a distinguishing attribute of animals, then on this score also Toxoplasma must be placed in the animal kingdom. For many years its ability to move independently was a matter of controversy, but anyone who has the patience to watch it for some time under the microscope can see it move. The crescent-shaped organism moves pointed end first, sometimes apparently exploring the surface of cells in the medium in which it is placed. Occasionally you may even see one enter a cell. But here again we have a mystery: What does it move with? Toxoplasma has no flagella, cilia, pseudopods or other visible means of locomotion, such as most one-celled animals possess. Certain Sporozoa, which are parasitic protozoa, are able to move at some stages of their life cycle though they lack such appendages. But Toxoplasma cannot belong to the class of Sporozoa, for those animals have complex life cycles with sexual stages, and they usually reproduce by multiple fission.

Toxoplasma has no known sexual phase, and apparently its only method of reproduction is to split in two. This last characteristic suggests a kinship to the flagellated protozoa, especially since one of the two large groups in this class also lacks a sexual phase. But where are the flagella? No one has yet been able to show conclusively that Toxoplasma has them, nor do stained preparations reveal any of the cell structures usually associated with these locomotor parts.

Another puzzle is Toxoplasma's ability to infect so many kinds of hosts. Such a remarkable capacity for adaptation to different kinds of internal environments is seldom found among protozoa. Viruses, fungi and some bacteria frequently possess it, but Toxoplasma is much too highly organized to be considered a virus or bacterium.

All in all we can do no better than place Toxoplasma among the protozoa, along with somewhat similar parasites known by such intriguing names as Hepatozoon, Encephalitozoon and Sarcocystis.

THE infection of man by Toxoplasma is usually so mild that it passes unnoticed. It may produce a fever and a rash, and it sometimes leaves lesions of the lungs or, more often, of the eyes, and cerebral calcifications. It is these signs, and the presence of antibodies in the blood, that have mainly identified the disease and led to the conclusion that the infection is widespread. Blood tests of large groups have indicated that it may be present in 40 per cent or more of some populations. It is probable that most of us are exposed sooner or later and that our bodies produce enough antibodies to check the disease before it makes itself felt.

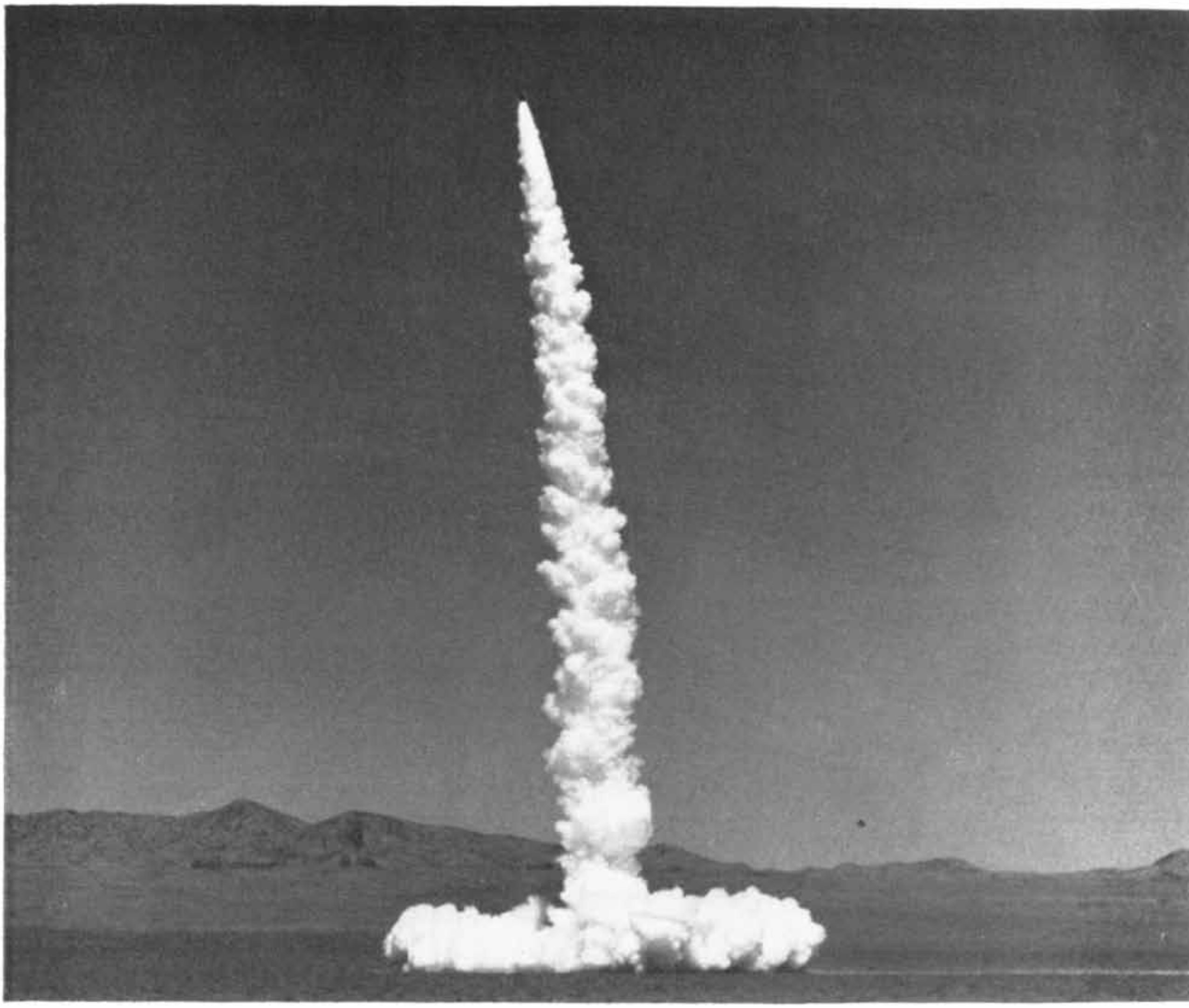
In its acute form the disease attacks the central nervous system and causes

GROUP OF PARASITES are photographed in the peritoneal fluid of a mouse infected with toxoplasmosis.

encephalitis. Most of the acute cases have occurred in very young children or in infants. Many drugs have been tried on experimentally infected animals, and we have found several (notably certain sulfa compounds, endochin, aureomycin, promin) which somewhat prolong life. But no substance yet tested has shown any dependable ability to eradicate the infection.

As toxoplasmosis becomes more widely known, more cases are reported, but the disease is still difficult to recognize, particularly in the early stages when therapy might be effective. The search for better methods of diagnosis is being vigorously pushed, and not without progress. Skin tests based on the presence of antibodies have been devised. There are several blood tests, of which the most widely used is one originated by Albert B. Sabin of the University of Cincinnati Medical School and Harry A. Feldman of the New York State College of Medicine at Syracuse University. Their unique test employs methylene blue, and it is based on the somewhat chance observation that the dye will not stain the cytoplasm of the parasite cells when a sufficient concentration of Toxoplasma antibodies is present. But blood tests are not very useful until the antibodies develop, and in acute cases death is likely to occur first. Parasites are almost always present in the blood of experimentally infected animals during the early stages of the disease, and this is no doubt true of human cases. Thus the inoculation of animals with blood from suspected cases could be used as a test, as in polio, but by the time the animals had developed the infection the patient might well have died.

We have as yet no satisfactory explanation of how the disease is transmitted. The first proved cases of human toxoplasmosis were found in newborn infants, who died within the first month or two of life. These infections must have come from the mother. In



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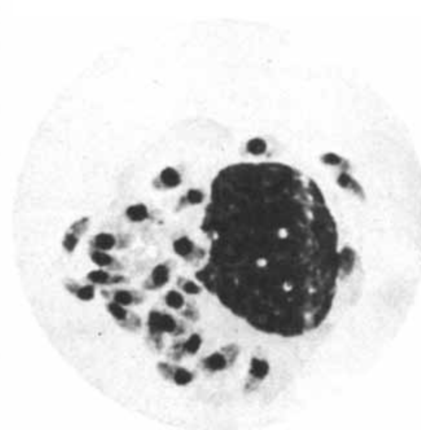
nearly every case the mothers appeared to be healthy, but blood tests revealed that most of them had been infected. Although the organisms must have passed to the child from the placenta, we still have no real proof of the route by which they were transmitted. The placenta is a barrier to most infectious agents, and experiments on mice show that toxoplasmosis is seldom transmitted within the uterus or in the mother's milk unless the mother is suffering from an acute infection. In few, if any, human cases have the mothers had an acute infection during pregnancy. Of course it is possible that toxoplasmosis is more easily transmitted in human beings than in mice.

Does Toxoplasma enter through the respiratory tract? The frequent lung lesions suggest that it may, and yet acute toxoplasmosis is so rare that the danger of infection by this route cannot be great.

It seems likely that many people get the infection from contacts with animals. Dogs, rats and pigeons are among the most likely sources of infection. Several cases of human toxoplasmosis in which the family dog was proved to have suffered from the disease have recently been reported from Germany. Some time ago a test examination of rats caught around Savannah, Ga., showed that almost 9 per cent harbored the organism, and this incidence is probably typical. But if animals are a source, how do they transmit the disease to human beings? Toxoplasmosis is not very contagious: mice, which are among the most susceptible animals, can often be kept with infected cage mates for long periods without contracting it. Rats may acquire toxoplasmosis by eating one another's flesh, for it is known that the disease may be transmitted in this way, and cannibalism is common among rodents. Perhaps the dogs and cats that have been found with the disease became infected from killing rats, but it also seems entirely possible that they got the disease



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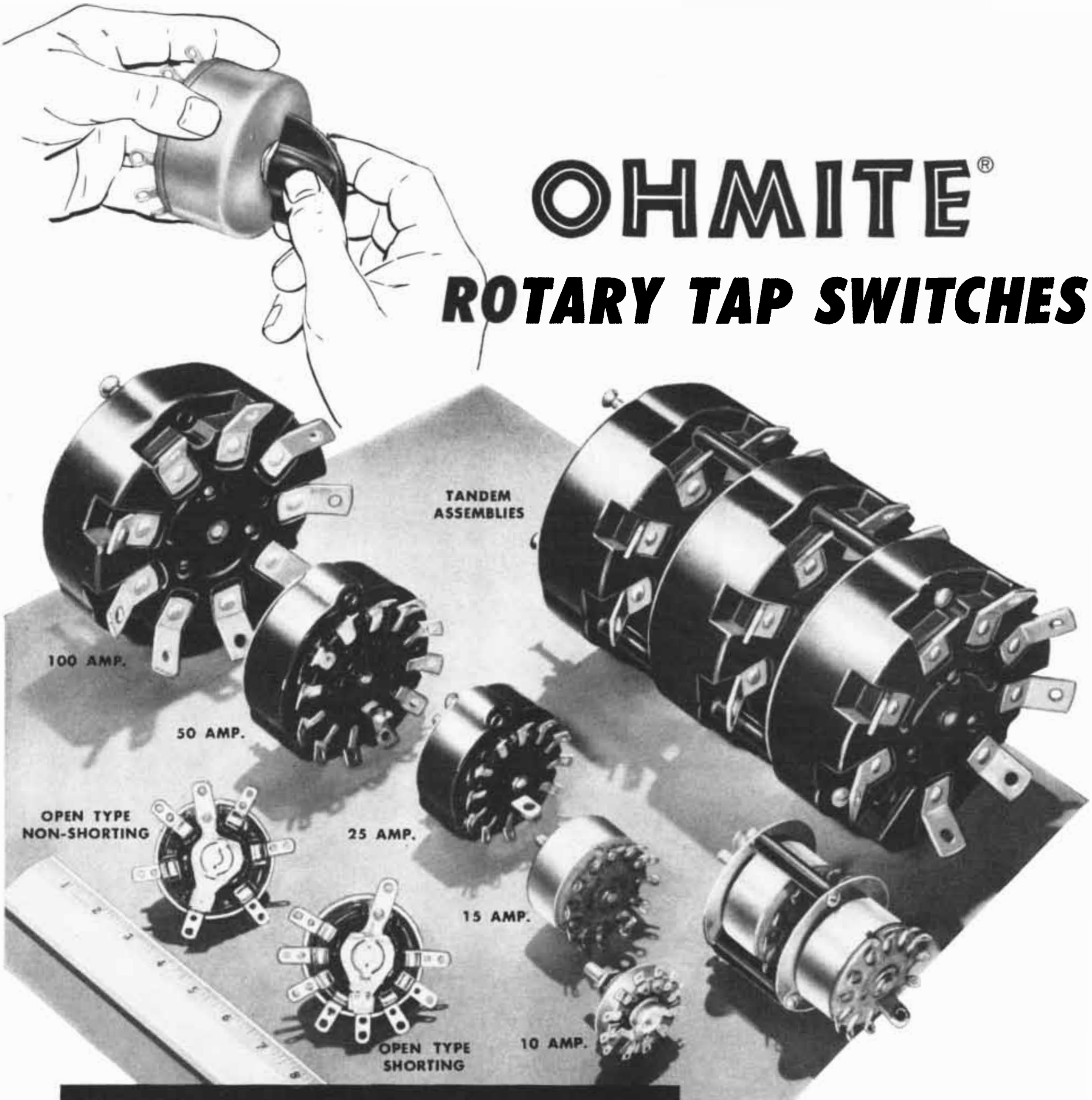

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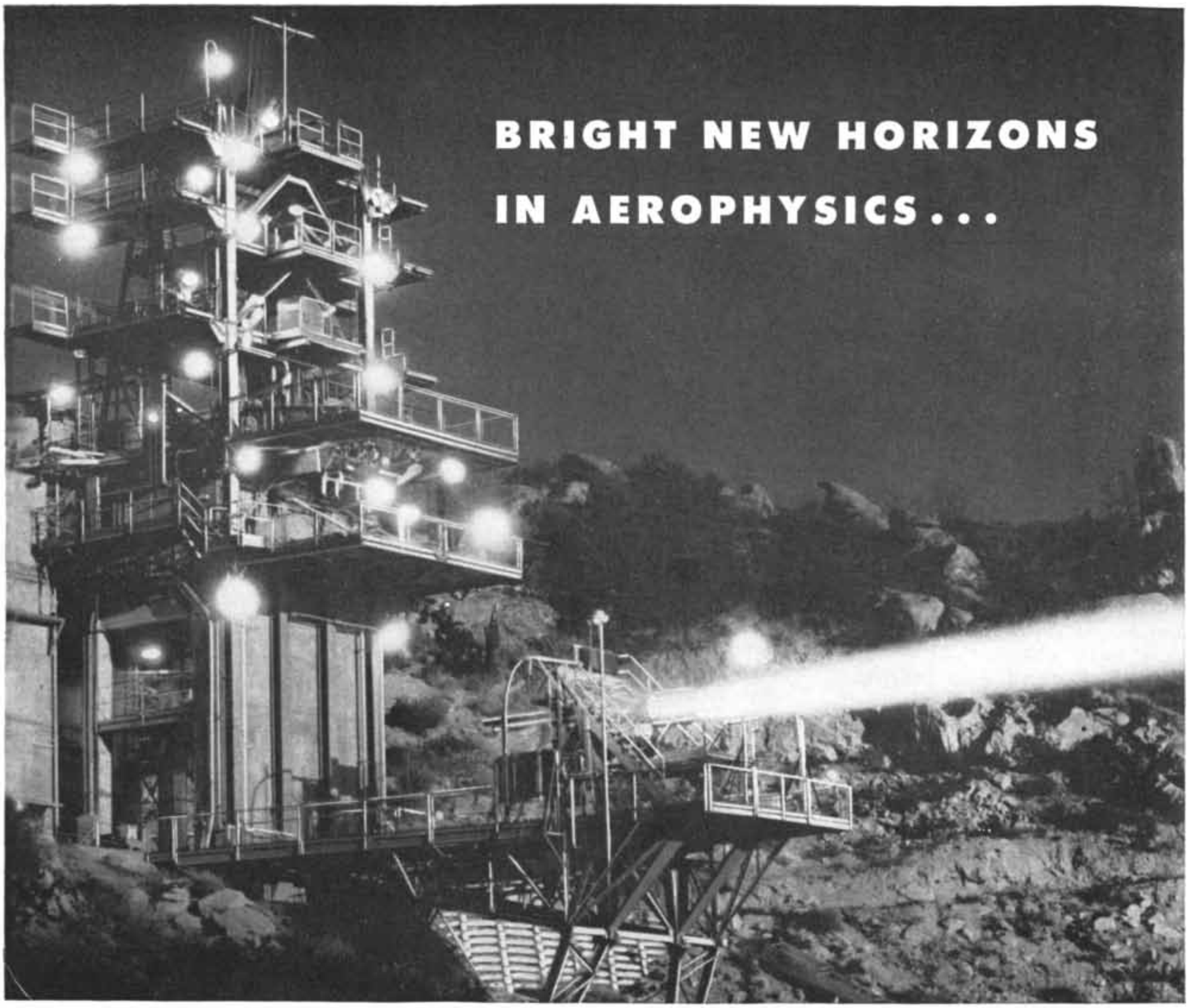
It is improbable that human beings contract the disease from contaminated meat. Toxoplasma is easily destroyed by drying, by weak disinfectants and by heat; a few minutes of exposure to a temperature of 122 degrees Fahrenheit is lethal. However, it is possible that people may be infected by handling diseased meat or by eating raw food soiled by the excrement of rodents or houseflies.

WHETHER Toxoplasma infects the lower vertebrates or the invertebrates in nature is still a moot question. There have been reports of toxoplasmosis in snakes, and some 40 years ago one investigator claimed to have infected frogs. None of these claims has been confirmed, and attempts to infect frogs with Toxoplasma of mammalian origin have failed. Nor has anyone successfully infected mammals with supposed "Toxoplasma" from any species of cold-blooded host. On the basis of small differences in size and other features, Toxoplasma organisms have often been divided into many different species, but today nearly all investigators agree that there is only one true species of the organism—Toxoplasma gondi. If this is actually the case, it emphasizes further the uniqueness of this organism. There are few genera in the plant or animal world in which there is but one species, and which seem to be so lacking in near relatives.

It has long been suspected that insects may harbor Toxoplasma, as they carry the organisms of typhus, sleeping sickness, Rocky Mountain spotted fever and other parasitical diseases. Proof is still lacking, however. In a few cases of human infection there has been a history of tick bite. Laboratory experiments have shown that Toxoplasma may live for more than 24 hours in certain species of ticks and biting bugs, and for as long as a week in the body louse. Thus it is entirely possible that in some parts of the world the body louse may transmit the infection. It is almost certain, however, that few cases in the U. S. or western Europe originate in this way.

If an invertebrate carrier were found, this would go far to explain the high frequency of toxoplasmosis and the wide variety of mammals and birds that it attacks. It might also help us to understand why the disease appears commonly in a subclinical form but occasionally as an acute and very serious illness. It would certainly aid us in developing a method of treating the disease and in taking measures to control its spread.

Reginald D. Manwell and Hans Peter Drobeck are members of the department of zoology at Syracuse University.



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Waste radioactive gases and smokes from the working areas are first passed through a "scrubber," in which a caustic solution washes out the larger radioactive particles as well as the more volatile components. Next they go through a high-efficiency filtering system, which removes more than 99.9 per cent of the small amount of radioactive material left. The air that remains is diluted, from a thousand to ten thousand times, with filtered air from the ventilating system of the building, and then is discharged through the stack.

Normal atmosphere contains measurable but harmless quantities of radioactive elements, and these produce radioactive particles which are also removed by the filtering process.

As a result, in many instances the effluent from our stack is cleaner than the atmosphere itself.

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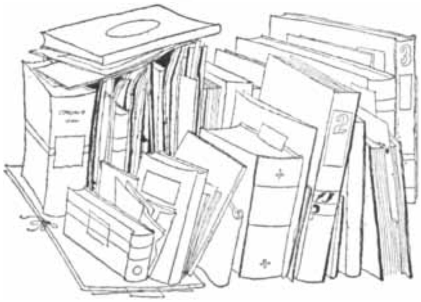


BOOKS

The first volume of a great new work about the place of science in history

by Herbert Butterfield

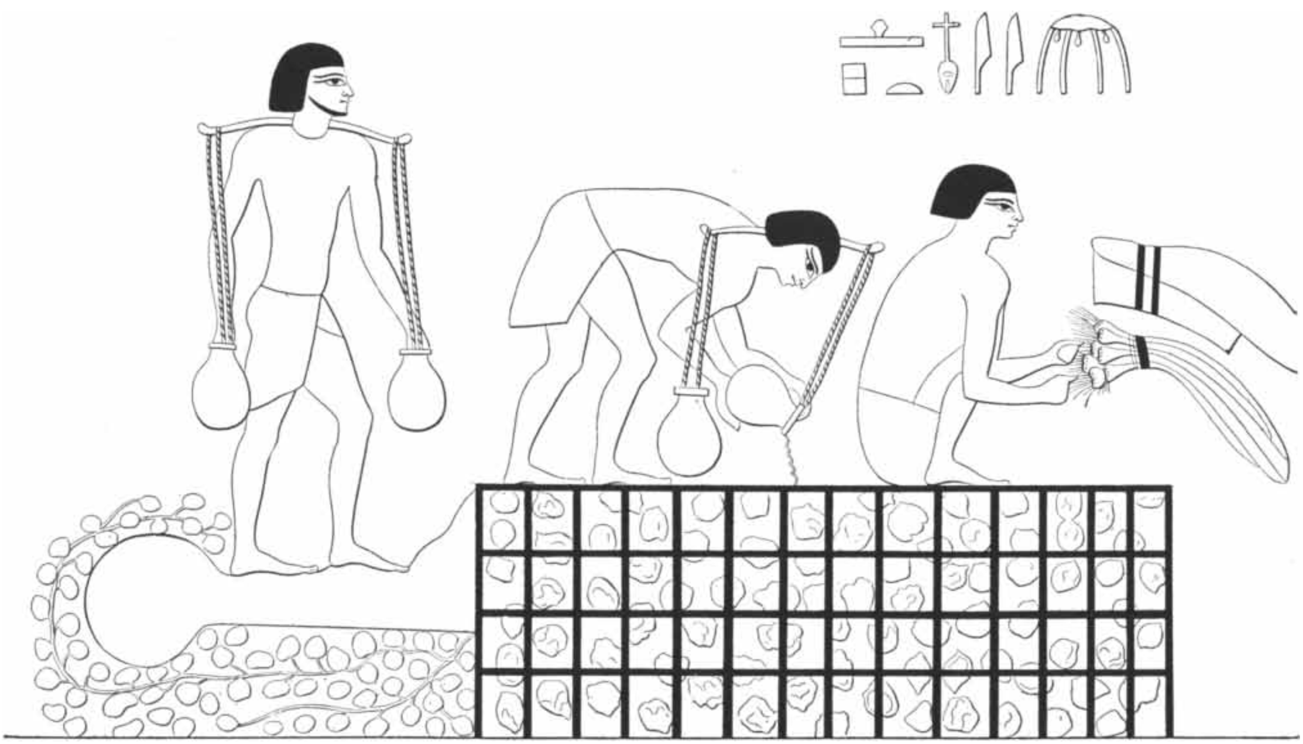
A HISTORY OF SCIENCE: ANCIENT SCIENCE THROUGH THE GOLDEN AGE OF GREECE, by George Sarton. Harvard University Press ($10.00).

DURING the last few decades the history of science has come to a rebirth as a branch of study. It has been brought to a higher degree of accuracy in its details and to a higher level of organization in its general discourse. Long a Cinderella in the world of learning, it now enjoys high recognition in academic circles and a lively interest among the general reading public. Moreover, it seems capable of becoming even more important in the future. As it develops, it may come to hold the strategic position in education and in scholarship generally. In these days of specialization the history of science is perhaps the only practicable bridge to link together the various sciences. It also affords a bridge between science and the humanities. Indeed, it is one of the most promising avenues we have for the unification of knowledge in our time.

We are fortunate in the fact that in recent decades the history of science has enjoyed the leadership of a man so catholic in his interests and so attractively endowed as Professor Sarton. He has given the subject great scope and warmth and put scholars deeply in his debt. By mastering an astonishing range of literature, by the magnificent spadework of his *Introduction to the History of Science*, by founding and editing the journal *Isis*, he has established the study of the history of science on a broad and solid basis. Now he has produced, for a wider public, the first volume of a history so grandly conceived that this installment of more than 600 pages carries us only to the time of Aristotle. What Professor Sarton has undertaken is not simply a history of scientific discovery but a large-scale history of civilization itself.

It has become the fashion to reject the idea that historical work of this magnitude can be done by one man, and to attempt it only on a cooperative basis, with a specialist assigned to handle each field separately. Sarton's work illustrates the advantages of single authorship. It displays a unity of plan and texture almost impossible in cooperative projects. And from the universality of his knowledge Sarton is able to bring to bear on all parts of the story a richness of comment that no mere specialist could ever achieve. He brings to the task a sixth organ of sense—an insight into the processes of history.

Professor Sarton has gained his universal viewpoint from a lifetime devoted to his subject. In this volume he begins with the invention of writing and of the alphabet and ranges over a background that embraces Babylonian irrigation, Assyrian bas-reliefs, Greek tragedy, the Book of Job. Insights learned from later periods in the history of science give him clues, or warnings, when he looks at the ancient world. He brings out the overtones of events by suggestive references to other periods of history and even to our own age. The result is no dry compendium of facts gathered by many hands, but the work of a mind constant-



Primitive technology: The cultivation of onions in Egypt ly trying to interpret history, seeing it not merely as a matter for narrative but as a matter for exposition. As a final contrast with syndicated history, his book is warmly written, intimately personal and charmingly self-revealing. For if in one sense historical inquiry necessitates that the heart stand still and the blood be cold as ice, there is a sense in which historical reconstruction and interpretation can be achieved only by a man willing to do his thinking through his sympathies.

Professor Sarton conceives the history of science as being in a fundamental sense the history of scientific thought. And this must be considered in the context of the history of human thought in general. Hence there is much more of the general history of thought in this book—and much less science per page—than the ordinary reader might expect. This approach is more fruitful than the one which starts by defining the history of science as the study of the relations between science and society. Those who study the history of scientific thought will reach in due course the question of the relations between that thought and the state of society. But a historian who starts with those relations often ends by taking the scientific thought for granted and relating it too directly to the contemporary economic and social world, without adequate evidence that the assumed linkages existed. This has been one of the main perils in the writing of the history of science.

That scientific thought may play a decisive role in the processes of history is self evident. As Francis Bacon recognized, there can be no knowledge more momentous for a civilization than the knowledge of how discovery takes place, how originality is achieved, how creative ideas are born. But it is not always realized that history, when its inquiries have been pursued to a microscopic degree for long periods, can often tell us more about the statesman than the statesman ever knew about himself, more about the poet's mind than the poet could ever express, more about Newton's achievement than he could have deduced from self-examination.

The study of the history of scientific thinking adds a new dimension to the mind of the scientist himself. It reveals the conditions and processes of scientific discovery, throws light on the genesis of hypotheses, shows the unconscious influence of contemporary patterns of thought and diagnoses the hidden factors that cause science to develop in a given direction. An intimate knowledge of the inner history of his field of study can enlarge a scientist's imaginative grasp and add to his flexibility of mind.

Where scientific ideas can be traced to their general historical causes, Professor Sarton is a master at assembling the evidence and the full richness of the background. He does an excellent job, for example, in explaining why the little island of Cos was so important in the history of medicine. Perhaps it would have been valuable to have given more of this kind of exposition. It is useful that we should constantly be reminded to ask ourselves why peoples like the Babylonians and the Greeks seemed destined to be the makers, while the Assyrians and the Romans were rather the carriers, of civilization. Professor Sarton does not avoid such fundamental issues. More than once he brings in a strategic argument against geographical determinism. He does not see all the Greeks as capable of abstract thought, but envisages a few daring thinkers amidst a people which in general was superstitiously religious. In the same way, instead of regarding the ancient Hebrews as peculiarly religious, we should see a few great prophets standing with their backs to the wall. The effect of this is to do more justice to the flexibility of the historical process, to see on how small a pivot world history often turns, and to realize that small minorities, working for long-term purposes, can achieve great things.

It is essential that historians of science should conceive the subject in Professor Sarton's liberal spirit and bring to it his great catholicity of mind. There have been periods when even religion promoted the sciences, when mysticism provided an impulse, when magic, alchemy and astrology were powerful allies. At other times, or at other levels, all these were obstructions, but the student of history must not regard them as inevitable enemies. During the Renaissance the visual arts made no small contribution to science, for scientists flocked to the artists' studios, and what they learned there helped in the development of observational accuracy.

In the 20th century we are prone to fail to appreciate that thousands of years ago there were human beings whose intellectual power, imagination, ingenuity and capacity for original achievement were not inferior to ours. They operated under different conditions, had different preoccupations, lacked our instruments and mental aids and were without the inventions and the experience which have been accumulated through the many intervening centuries. They could do great thinking which was wrong thinking—wrong at any rate from our point of view. While it is easy to dismiss these giants as creators of bad science, we must have misgivings when we try to imagine how some of the earliest inventions came about, how the first geometrical theorem was established, or how the ancients created those marvels of art which are relevant to Professor Sarton's discussion. Our misgivings must increase when we remember how men so distant from us reflected on human destiny, human personality and human relations with all the depth and the ingenuity which we today devote to the study of nature and material things.

To establish real contact with predecessors so far removed in time it is necessary to confront ourselves with the intellectual hurdles they had to face. This exceedingly difficult transplantation of oneself into the past is the activity which Professor Sarton most enjoys. He loves to find the way in which the human mind ultimately managed to get over the hurdles.

Though the subject matter of his book is ancient, the principal theme is of the greatest importance for the student of recent centuries. Ancient Greece not only lies at the root and genesis of our civilization but is planted fairly and squarely in the world of modern times. It took our Western world a thousand years to recover and assimilate the scientific achievements of ancient Greece. Our civilization took a great step forward when, in the Middle Ages, Aristotle was rediscovered as a master of scientific knowledge. The whole process of recovering ancient Greek science had to be completed (insofar as it was ever completed) before modern science could begin its development. Modern science was born out of men's wrestlings with ancient Greek thought. The controversies of the 17th-century scientific revolution, which overthrew the ancient methods, brought modern astronomy and mechanics to birth. Galileo and his allies can be understood only if we remember that they were carrying on a continuous debate with Aristotle. The period of Professor Sarton's first volume is therefore significant even for historians of modern investigation.

Comprehensive and knowing as Sarton's work is, there are points at which one might ask for more. Engineering probably played a bigger part in the evolution of scientific thought than it has ever been credited with playing. Before 1500 men who were doing things and making things were free to let their imaginations soar, whereas theorists were constricted by dependence on the intellectual systems of classical antiquity. Throughout the ages, moreover, men who needed harvests, imports, bridges and water supplies were obliged to practice the art of observation and to keep their vision at least partly unclouded by the prevailing myths. One might wish that Professor Sarton had told us more about them. But this would mean asking for a still bigger book, or wishing (what it is difficult to wish) that the author had curtailed his excursions into Homer, Greek tragedy and the like.

I am not quite sure that he has done entire justice to certain great spiritual movements which took place in the ancient world during the centuries that preceded the Christian era—movements which changed man's conception of the human drama, transforming, we might say, almost the place of man on the earth. A great shifting in the religious life of the world was establishing those views out of which our Western civilization and the things we call "Western values" were to develop. Modern systems which tend to make human beings the mere tools for a gigantic exploitation of the forces of nature are reversions which not only overthrow Christian tradition, but negate great achievements of the human mind accomplished in Greece and in parts of Asia in the half-dozen centuries before the birth of Christ. Professor Sarton's wide conception of his theme makes one wonder whether he did not have in his mind's eye the rise of this kind of civilization, as well as the emergence of science as such.

Herbert Butterfield, professor of modern history at Cambridge University, is author of The Origins of Modern Science.

PREHISTORIC EUROPE: THE ECONOMIC BASIS, by J. G. D. Clark. Philosophical Library ($12.00). Dr. Clark, University Lecturer in Archaeology at Cambridge, presents the first systematic study of how early man in Europe "managed not merely to survive but to raise his standards from those of savages to those of peasants ready to support the full weight of urban civilization." The story begins with the late glacial period and describes how in the coastal and inland regions men hunted, fished, cleared the land for cultivation, raised livestock, built homes, gathered in settlements, evolved in succession stone, bronze and iron technologies, and initiated trade and transport. It is a remarkably rich and comprehensive account, drawing not only upon the great store of archaeological remains but upon the sciences of geography, climatology, ecology and anthropology. Another vital source of Clark's survey is the existing folk culture, many elements of which have survived comparatively intact and are invaluable in the task of reconstructing prehistory. This is a masterly book, well written, copiously illustrated with maps, plates and line drawings, and supported by an admirable bibliography.

FOOD SCIENCE: A SYMPOSIUM ON QUALITY AND PRESERVATION OF FOODS, edited by E. C. Bate-Smith and T. N. Morris. Cambridge University Press ($8.00). This cooperative volume consists of lectures given in a summer course at Cambridge University in 1948. The science of food, a comparatively new academic subject, cuts across several established disciplines: biology, chemistry, physiology, agriculture, animal husbandry and the like. This symposium of 26 papers considers the problems of storing, preserving and transporting food. It also takes up the even more important question of how we might add to our food supply through new methods of cultivation, new sources and synthetic processes. The papers deal with various individual foodstuffs, the physical and chemical basis of quality in food, the role of microorganisms and sundry other interesting matters. One learns, for example, that meat from "fatigued" or "frightened" pigs deteriorates more rapidly (because the pH is higher) than meat from a composed and rested animal. It is also interesting to know that the experts feel the current enthusiasm for the deep freeze may be overplayed. Correcting the curious belief that foods kept in a freezer even for long periods retain all the qualities of perfect freshness, they emphasize that no known method of preservation can achieve this end.

LES INVENTEURS CELEBRES, published under the direction of Louis Leprince-Ringuet. Lucien Mazenod, Paris ($17.50). This sumptuous, encyclopedic volume, the sixth in the series *La Galerie des Hommes Célèbres*, presents biographical essays on nearly a hundred of the most famous inventors and discoverers in physical science and technology and 1,500 brief sketches of other eminent workers in this branch of knowledge. All the essays are in French, some translated to that language from English and German. The authors are themselves leading scientists, philosophers and historians of science. E. N. da C. Andrade writes on Hooke, Robert Millikan on Benjamin Franklin, C. Moeller on Oersted, Louis de Broglie on Fresnel, Paul Epstein on Willard Gibbs, Arnold Sommerfeld on Boltzmann, Jean Pelseneer on Gramme, Serge Korff on Morse, N. F. Mott on Maxwell, Irène Joliot-Curie on her parents, Max von Laue on Max Planck, John A. Wheeler on Niels Bohr, Sir George Thomson on J. J. Thomson, Carl D. Anderson on Millikan. For beauty, comprehensiveness and general interest this illustrated work must be counted an event in the literature of science.

BETWEEN PACIFIC TIDES, by Edward F. Ricketts and Jack Calvin; revised by Joel W. Hedgpeth. Stanford University Press ($6.00). The third edition of a book which describes in 500 pages the "conspicuous seashore invertebrates" inhabiting the rocky shores, tide pools and wharf pilings of the Pacific coast from Alaska to Mexico. The main author, the late Edward Ricketts, was the owner of a small biological supply business and spent most of his time wading along the shore observing small animals. He held no degree, not even a B.A., but he was a first-rate self-taught marine biologist. He had a wonderful eye, an unquenchable enthusiasm and the ability—with the help of Mr. Calvin—to communicate to ordinary readers his awareness that the world of giant horse mussels and polyclad flatworms is no less interesting than that of the mammals or the over-visited "social insects."

WEST AFRICAN EXPLORERS, edited by C. Howard. Oxford University Press ($2.00). The intrepid—and literate—19th-century travelers in West Africa explored the hostile land and hazardous waterways for profit and patriotism, for scientific and philanthropic motives, but mainly for the sheer joy of being the first to reach strange places. Mr. Howard has chosen skillfully from the superb travel journals of, among others, Mungo Park, Major Dixon Denham, Captain Hugh Clapperton, Richard Lander, René Caillié, Macgregor Laird and William Balfour Baikie. The last of the great 19th-century explorers was Mary H. Kingsley. "Controlling a canoe on the swift Ogowé River, traversing swamps and marshes up to her neck in water, falling into elephant traps—where she had reason to bless the voluminous petticoats which she continued to wear—mediating between her murderous followers and the equally evil natives of Fan villages, she preserved a calm matter-of-fact courage unrivaled by any other West African explorer." This tiny, fat, beautifully printed volume is a recent addition to the World's Classics "doubles." You can't get that much good reading elsewhere these days for five times the money.

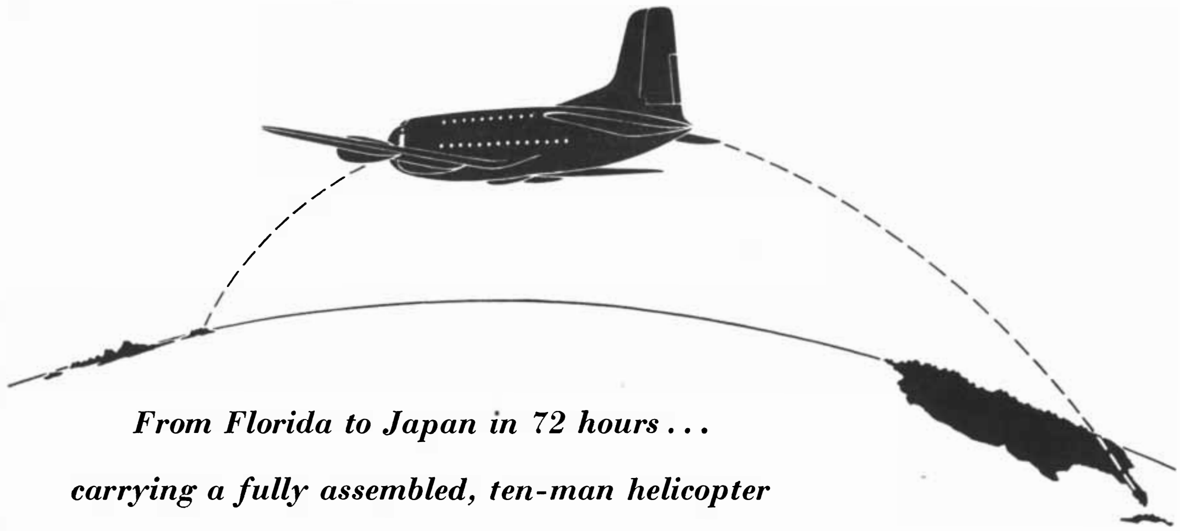
MAN AGAINST CANCER: THE STORY OF CANCER RESEARCH, by I. Berenblum. The Johns Hopkins Press ($3.00). Dr. Berenblum, head of the department of experimental biology at the Weizmann Institute in Rehovoth, Israel, is a leader in the study of cancer. His book explains what is known of the subject and describes the main directions that research is now taking. It is easily the best of the popular surveys: plain spoken, neither alarmist nor wholly reassuring, neither dogmatic nor full of confusing qualifications. It is also remarkably comprehensive. It answers a great many sensible as well as normally foolish questions.

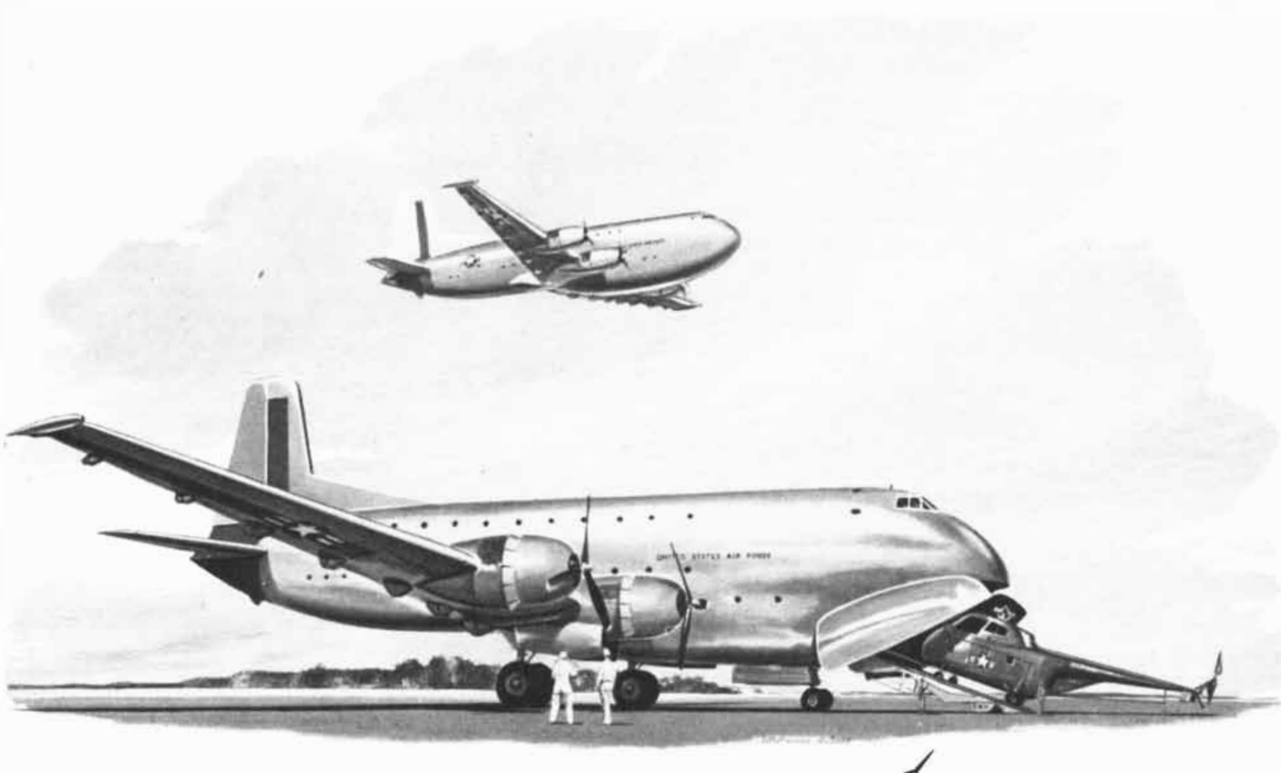
MAN AND EPIDEMICS, by C.-E. A. Winslow. Princeton University Press ($4.00). This is an unfailingly interesting survey, by an authority on public health, of the measures taken in the last 50 years to eliminate the scourge of such epidemic diseases as cholera, typhoid fever, bubonic plague, yellow fever and malaria. Dr. Winslow discusses the unceasing fight against filth, insect and rodent germ-carriers and other sources of infection. Water, milk and milk products have been the "chief causes of major epidemics spread over considerable areas." Standing water, contrary to popular opinion, purifies itself more effectively, and is therefore apt to be safer, than running water. "The substitution of the automobile for the horse has greatly decreased the fly problem in thickly settled areas"—with the result that the automobile now kills many more persons than typhoid fever. Dr. Winslow's tale of the war against infections celebrates one of the great constructive achievements of scientific thought and international cooperation.

TAXILA, by Sir John Marshall. Cambridge University Press (three volumes, $70.00). Taxila was an ancient city of India situated in the North-West Punjab, today part of Pakistan. Standing in a fertile and well-watered valley, the city had both the good and the ill fortune to bestride three trade routes carrying the bulk of the traffic between east and west. Taxila flourished because of its position, but it was also repeatedly overrun by invaders. During the 15 centuries between 500 B.C. and A.D. 1000 it enjoyed independence for less than 50 years. At various times it was ruled by Persians, Greeks, Scythians, Bactrians, Parthians and Kushans. The city was finally destroyed by the White Huns. In 1913 Sir John Marshall began at Taxila a program of archaeological investigations which continued until 1934. These handsome volumes are a complete report, in text and illustrations, of his labors. Besides giving a historical account of the city and a detailed description of its architectural remains and domestic utensils, Marshall has prepared a large group of maps and plans and a remarkable pictorial record of the many objects unearthed by his party. A monument of scholarship, worthy of the distinguished achievement it commemorates.

HANDBOOK OF ENGINEERING FUNDAMENTALS, edited by Ovid W. Eshbach. John Wiley and Sons, Inc. ($10.00). Second, revised edition—the first appeared in 1936—of a well-organized, ably written and richly stocked engineer's manual. The 14 sections range from mathematics, physics and chemistry to aerodynamics, metallurgy and engineering law. It is unfortunate that the author eliminated some of the simple but always useful refresher pages on mathematics that were in the first edition.

SOCIAL SCIENCE AND PSYCHOTHERAPY FOR CHILDREN, by Otto Pollak. Russell Sage Foundation ($4.00). This is a report of an investigation supported by the Russell Sage Foundation and the Jewish Board of Guardians and directed by Dr. Pollak. It is an admirable attempt to show the relationships between the social sciences and psychotherapy and to point out where each point of view can aid the other. The research covered work with children of various ages in various institutions and clinics.





THE AMATEUR SCIENTIST

About a portable terrestrial telescope and the enjoyment of chromatography

Conducted by Albert G. Ingalls

IN A PAPER exposing the rashness of claims for the deodorizing properties of chlorophyll [see "Science and the Citizen"], Alsoph H. Corwin of the Johns Hopkins University recently said: "Chlorophyll is indispensable to photosynthesis. It is highly esthetic in coloring the vistas from hills or mountains. For other purposes, we are not certain that it has any value except that it furnishes chemists, physiologists and other scientists with a lot of good, clean fun."

The principal point of Professor Corwin's paper did not astonish this department. Our circle of friends has included a number of goats whose intake of chlorophyll never seemed to make much change in their odor. But we were interested to learn how amateur scientists might have fun with the stuff. We did not have to look far. The first five neighborhoods we scouted turned up 17 individuals who are either working with chlorophyll or have done so recently. All of them are amateur chromatographers, and they are in various walks of life: one is a railway traffic agent in Chicago, another works for the local electric power company on Staten Island, N. Y., a third is a student at Princeton University, and so on.

William T. Beaver, the Princeton student, did a lot of work with chlorophyll a few years ago. The paper he subsequently wrote on plant pigments won a Westinghouse Science Talent Search award. "To have fun with chlorophyll," he says, "you first have to get some in the pure state. You won't find it in many drugstores, so you extract your own from green leaves. The easiest way to do that is to set up a chromatic column. You'll probably succeed in purifying both varieties of chlorophyll on the very first try. The chances are good you won't stick with chlorophyll very long. In addition to the chlorophylls you will get a number of other interesting leaf pigments—the carotenes and xanthophylls—and in the end you are likely to settle down to chromatography itself. A chromatic column is as fascinating as a microscope, and its range of subject matter about as broad."

Within the past 10 years, according to Beaver, the number of amateurs working with chromatography has grown enormously. Prior to that few had heard of "adsorption analysis," as the process is sometimes called. Despite the fact that the Russian botanist Michael Tswett described the chromatographic method in 1906, it did not come into general use even among professionals until 1930. In less than two decades chromatography has opened new avenues to knowledge, created new industries, expanded old ones and made substantial contributions to the health and well-being of millions.

No description of the chromatographic method has surpassed in clarity or conciseness that originally set down by Tswett: "If a petroleum ether solution of chlorophyll is filtered through a column of an adsorbent (I use mainly calcium carbonate which is stamped firmly into a narrow glass tube), then the pigments, according to the adsorption sequence, are resolved from top to bottom into various colored zones. . . . Like light rays in the spectrum, so the different components of a pigment mixture are resolved on the calcium carbonate column according to a law and can be estimated on it qualitatively and quantitatively. Such a preparation I term a chromatogram, and the corresponding method, the chromatographic method. It is self-evident that the adsorption phenomena described are not restricted to chlorophyll pigments, and one must assume that all kinds of colored and colorless chemical compounds are subject to the same laws."

In essence chromatography requires only three pieces of apparatus: a container for holding the sample, the chromatic column and a second container for catching the spent liquid as it drips from the bottom of the tube. After the column has been packed with adsorbing material, a portion of the sample solution is poured in at the top of the tube. This is allowed to percolate down the column for perhaps a tenth to a quarter of its length. In doing so it usually forms a solid band of color characteristic of the solution under investigation. Clear solvent is then washed down the column, and the process of separation begins. Each substance has a characteristic affinity for the solvent and for the adsorbent. Chromatographers commonly refer to this property as the adsorbent's or solvent's "activity." The activity ratio determines the position a particular substance will occupy on the column relative to others in the mixture from which it is being separated. Substances most weakly held in solution and most strongly attracted to the adsorbent will adhere to the uppermost particles of the column. Those less strongly attracted to the adsorbent will be washed down farther, the distance depending upon each substance's relative adsorption ratio, and the separated substances will form a characteristic pattern of bands in the column. Extracts prepared from some green leaves, for example, show more than 20 distinct bands, ranging from dark green through various shades of orange, pink, yellow and delicate violet to white, the colors identifying the various xanthophylls, flavoxanthins, luteins, carotenes and related pigments.

The operation of washing the column with clear solvent is known as "development." As fresh solvent flows down the column, some molecules detach themselves from the adsorbent, join the solution and move down to regions of less concentration. Here they are readsorbed. The activity of both the solvent and adsorbent appears to vary with the concentration of the substance under analysis; hence a given substance may pass out of and into solution many times in the course of its journey down the column. At first the bands are narrow and bunched near the top of the column. As development continues, all the bands progress toward the bottom and grow wider and more distinctly separated. A fully developed chromatogram displays a series of distinct, cleanly separated bands, varying in width in proportion to the amount of each substance in the mixture.

The separated, purified substances can then be extracted in one of two ways: either by washing the successive bands out of the bottom of the column with solvent, or by pushing the cylinder of adsorbent out of the tube, separating the bands with a knife and removing the substance with a solvent. If the chromatogram is sucked to dryness, it slips readily from the tube. Some workers scoop the adsorbent out of the tube one band at a time with a slender spatula.

Thousands of different adsorbents and

solvents have been tried. The selection of the most effective combination for each purpose remains largely a matter of cut and try. The following lists of adsorbents and solvents, which will resolve most of the mixtures the amateur is likely to prepare, have been drawn up by Beaver. The adsorbents are listed in approximate order of decreasing activity; the solvents, in the reverse order:

Adsorbents

1. Activated alumina
2. Charcoal
3. Magnesia
4. Silica gel
5. Lime
6. Magnesium carbonate
7. Calcium carbonate
8. Sodium carbonate
9. Talc
10. Powdered sugar

Solvents

1. Petroleum ether
2. Carbon tetrachloride
3. Carbon disulfide
4. Ether
5. Acetone
6. Benzene
7. Methyl or ethyl alcohol
8. Water
9. Organic acids
10. Aqueous solutions of acids or bases

Sometimes more than one solvent may be used, either in combination or successively. For example, a small amount of benzene may be mixed with the weakly active solvent petroleum ether to speed up the development of bands. Care must be exercised, however, not to make the solvent so active that it washes the bands from the column immediately. After the bands of a cylinder of adsorbent have been cut into blocks, they may be treated with a strongly active solvent for the swift and complete extraction of the principal substances. This is called elution, and the solvent or combination of solvents used for this purpose is the "eluent." Most of the common adsorbents and solvents are inexpensive; some are found in nearly every home. Beaver advises the beginner to purchase chromatographic supplies from a chemical supply house. Those found in the home are likely to be contaminated, and a minute amount of foreign matter can confuse the result. Chromatography is an extremely sensitive technique, comparable in its field with the classic knife-edge test used by amateur telescope makers.

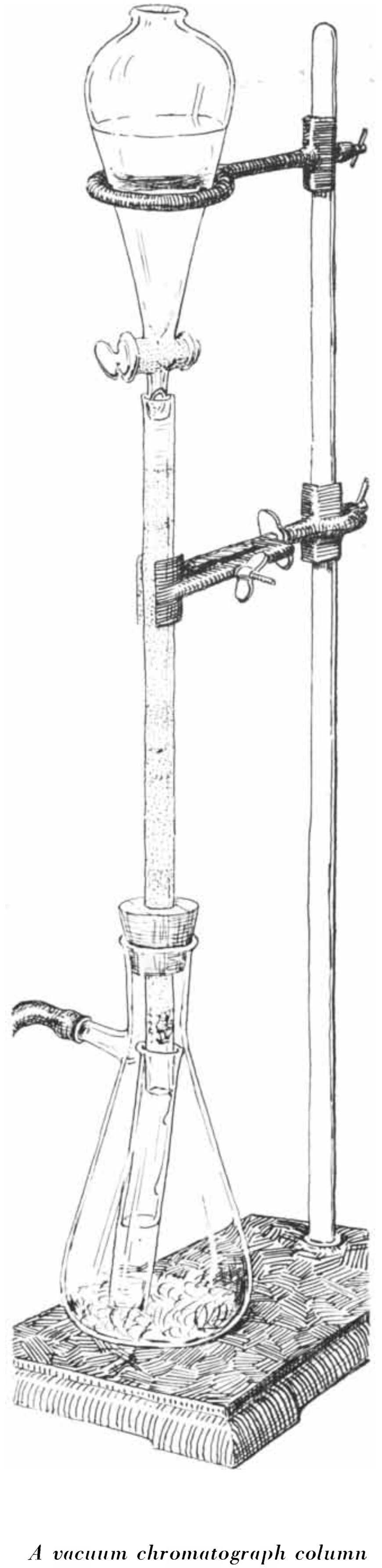
"The very fact," says Beaver, "that there are few fixed ground rules recommends chromatography as an avocation. Not even the most advanced professional can prescribe a hard and fast procedure for setting up and operating a chromatic column. The field is so new that it is open to all comers. The amateur has a good chance of making a worthwhile contribution to the technique."

The glass column may range from a fraction of an inch to several inches in diameter, depending upon the coarseness of the adsorbent, the nature of the substance to be adsorbed, the quantity of material available and like considerations. Most workers prefer to use tubes somewhat less than an inch in diameter. Usually the column is 10 times as high as it is wide. For the separation of some isotopes, however, slender tubes 100 feet or more in length have been used. The bottom of the tube is pinched in and stoppered with a tuft of cotton or glass wool to provide support for the adsorbent. Such tubes are available through most chemical supply houses, but they may be made readily at home from glass tubing.

Most of the difficulty experienced by beginners arises from failure to pack the column uniformly. Unless the adsorbent is evenly distributed, the bands are likely to be ragged and overlap. Tswett put in dry, powdered adsorbent a little at a time, and tamped each bit firmly into place until the column reached the desired length. Subsequent experience has modified his procedure in numerous ways. After a layer is packed into place, the surface may be loosened somewhat with a spatula so the succeeding one will join it more uniformly. Ordinary wooden dowel stock, squared at the end and slightly smaller than the inside diameter of the tubing, makes a good tamping tool. Some adsorbents settle into place satisfactorily if the tube is merely jarred while being slowly filled. Other adsorbents can be introduced in the form of a mud or paste, suction being applied simultaneously. Chromatographers agree that packing the column is an art. Like all arts, its mastery comes largely through experience.

Most workers use the standard tests that have been devised to choose appropriate solvents and adsorbents for specific jobs. One of the most popular consists in placing about a teaspoonful of adsorbent in a shallow dish, shaking it into a wedge-shaped layer on the bottom, dissolving the mixture to be tested in a weak solvent, putting a few drops of this on the thin edge of the adsorbent with a micropipette, and then trying various solvents and combinations of solvents in order of increasing activity.

Amateurs who get into this field will undoubtedly come sooner or later to paper chromatography, which makes the whole thing easier. The "column" in this case is a strip or sheet of paper, enclosed in a saturated atmosphere to prevent evaporation. The paper is moistened with solvent, and then a drop of the solution to be analyzed is applied to the upper edge or an upper corner of the sheet. The sheet is then bent over and



A vacuum chromatograph column

dipped into a shallow dish of the solvent to be used for development. The solvent flows down the hanging sheet by capillary action, carrying the substances to be resolved with it. These adsorb as spots along the paper—the counterparts of bands in the conventional column. When development has carried the lowest spot close to the bottom, the sheet may be removed from the solvent, rotated 90 degrees and reinserted. Each spot then becomes the point of origin for a new chromatogram. If the resolved fractions are comprised of subtle mixtures, the components of each fraction will array themselves across the sheet. What you have then is a "two-dimensional" chromatogram.

Tswett likened the bands on his column to the rays of colored light emerging from a prism in a series of colors. The two-dimensional chromatogram carries the analogy further by subjecting each "ray" to a second analysis, with increased resolution comparable with that achieved optically when physicists pass a colored light from one prism through a second. Many amateurs use the paper technique as a test method for identifying the fractions of a mixture qualitatively and follow it with a conventional column for quantitative determination.

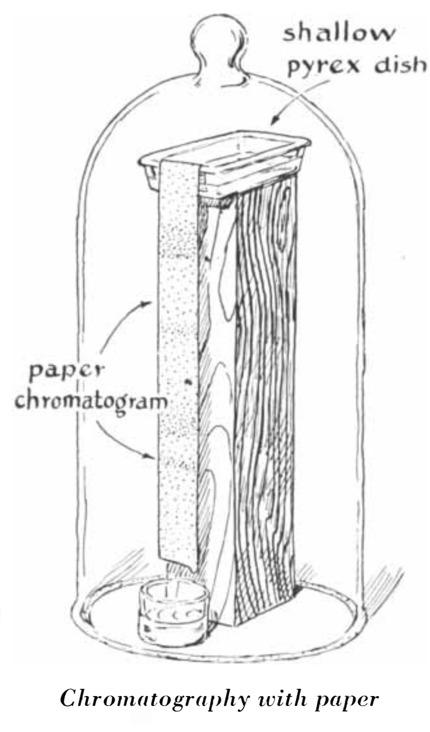
As Tswett predicted, the chromatographic method resolves colorless fractions just as readily as colored ones. During recent years much work has been done in colorless chromatography. Many techniques have been developed to make these substances visible. The presence of amino acids, for example, is detected by spraying the extruded adsorbent, or the paper chromatogram, with ninhydrin, which turns these normally colorless substances a light purple. Other substances fluoresce under ultraviolet light. If a drop of ordinary blue-black ink is placed on a strip of chromatographic paper and developed with alcohol, several bluish bands, representing the ink's content of iron compounds and dyestuffs, form along the length of the strip. Under an ultraviolet lamp the dried paper shows many other bands, ranging in color through the reds, oranges and greens. With a second chromatogram using a known substance as a control, one may identify an unknown (but suspected) substance by comparing the positions of the respective bands on the chromatograms. In a chromatographic column colorless fractions may also be detected by their differential bending of light transmitted through the column or by polarization of the light. Recently some substances have been tagged by radioactive isotopes and detected by photographic processes, but these techniques generally lie beyond reach of the facilities commanded by the average amateur.

Getting back to chlorophyll: How should the beginner prepare leaf pigments for analysis and what kind of a column should he set up? Beaver suggests some experiments, which, he emphasizes, should be made in a well-ventilated room, because the solvents are highly volatile and inflammable and poisonous wood alcohol is used.

Into columns made of 10-millimeter glass tubing about a foot long, fire-polished at one end and flared at the other to facilitate filling, is packed the adsorbent (Merck's alumina standardized according to Brockmann, of 80 to 200 mesh). It is packed in successive small portions while jarring the tube. Suction materially reduces the development time; Roger Hayward's drawing on the preceding page shows how to set up the column for use with a vacuum flask.

Ten grams of dried spinach leaves are steeped in 100 milliliters of wood alcohol for 24 hours. The material is then filtered and the residue is washed with an additional 50 milliliters of wood alcohol. This extract is shaken with 50 milliliters of petroleum ether; 100 milliliters of water are added, and the solution is placed in a separatory funnel. After a distinct separation has taken place, the lower alcohol-water layer is discarded, and the upper petroleum ether layer, containing the extract, is filtered.

You run about half of this extract into the column of alumina and then develop the column with benzene. The first fraction to pass down the column is a fairly narrow yellow-orange band of carotene. It is followed by much wider pink and yellow bands of xanthophylls. These are familiar pigments that cause wooded countrysides to take on the colors of fall after frost has killed the chlorophyll. Fractions of these pigments may be collected as they emerge from the bottom of the column and evaporated to dryness.



Chromatography with paper

The two groups (carotenes and xanthophylls) may then be further resolved into their components by dissolving them in a few milliliters of petroleum ether, passing them through fresh columns and developing with benzene-petroleum ether or, for greater eluent activity, with pure benzene.

In the column the chlorophylls form a dark green band. The band is scooped from the column; the pigments are washed out with five milliliters of wood alcohol, and the solution is filtered. The filtrate is put in a separatory funnel with five cubic centimeters of petroleum ether, and five milliliters of water is added. The petroleum ether extracts the chlorophylls, and the water and alcohol form a separate layer which can be poured off. Then the petroleum ether extract is washed several times with water and run through a column packed with powdered sugar (sucrose) in the form of a slurry with petroleum ether. Now you develop the column with petroleum ether. The chlorophylls separate into two components—a yellow-dark-green band of beta-chlorophyll near the top of the column and a bluish-green band of alpha-chlorophyll farther down.

Because of its vital role in photosynthesis, chlorophyll has become the glamor plant-pigment in popular imagination. But many amateur chromatographers find the carotenes just as interesting. Unlike the chlorophylls, which act as catalysts, the carotenes play a direct chemical role, both in animals and plants. They appear to be essential to the body's manufacture of vitamin A, and they play a part in the mechanisms of vision and sex. As the name implies they may be extracted from carrots.

To extract carotene you grind five grams of dried carrot root to dust in a mortar and then add 50 milliliters of a mixture of equal parts of wood alcohol and petroleum ether. Shake the mixture thoroughly, add five milliliters of water and pour into a separatory funnel. The carotenes, plus xanthophyll esters, are concentrated in the petroleum ether layer that forms at the top. Separate this layer and concentrate it by evaporating some of the fluid, leaving 20 milliliters. Then add three milliliters of a solution of 5 per cent sodium hydroxide in wood alcohol, which saponifies the xanthophyll esters so they can be removed by washing. Wash the mixture several times with 85 per cent wood alcohol in water; then wash several times with pure water to remove traces of wood alcohol. Now let the petroleum ether separate from the water and then filter it. The yellow-orange solution that remains bears the complex of carotenes. To separate them, pass about half of the solution into a column of alumina and develop the column with a mixture of benzene and petroleum ether in the ratio of 1 to 3. You will get three well-defined bands, containing, from the top down, gamma carotene, beta carotene and alpha carotene. You can recover the pigments either by washing them successively out of the column or by extracting them from the separate bands of adsorbent with wood alcohol.

Chromatography is a far more subtle method of separation than the traditional chemical techniques of distillation, precipitation with reagents, crystallization and so on. Fortunately for amateurs, it is also a method of beautiful simplicity.

At first glance the telescope shown on page 108 looks rather commonplace. But further examination discloses that it has several uncommon features. The most evident is its simple, neat solution of the tripod problem. The tripod consists of three pipes of one-inch internal diameter, screwed into a four-way pipe fixture called a "side outlet T," and a polar-axis extension screwed into the top of the same fixture. The length of the leg at the rear may be varied to bring the polar axis parallel with the axis of the earth in the observer's latitude. The legs may be unscrewed quickly by hand and the telescope detached from the mounting by unhooking the screen-door springs that hold it. You then have made it portable in less than one minute, instead of the several minutes a portable telescope often requires.

This telescope was planned and built by Clarence P. Cram of Avalon, Catalina Island, Calif. He writes that "the gap between the tube and the mirror cell gives room to insert a folding mirror-cover when the telescope is not in use. A system of locking thumbscrews makes the mirror cell easily adjustable." The mirror rests on three cork-tipped screws which extend through the curved lead counterweight, and it has three plastic hold-down clips on top. It is surrounded by a strip of cork.

"I cut several holes in the tube for inserting the eyepiece-prism unit," Cram continues, "but I find it simpler to just turn the tube within the screen-door springs to bring the eyepiece to a comfortable position. The eyepiece-prism unit is quickly detachable by pivoting its holding clips. I added the finder only because I happened to have it, but simple gunsights—a ring at the rear with a quarter-inch opening and a luminous painted forward stud—would serve as well. You need some kind of finder with a telescope like this, however, because the long-focus field is very narrow. Being a teacher, I found it natural to use blackboard paint for blackening the inside of the tube and other parts. It is rough and dull as desired."

It is only when you examine Roger Hayward's exploded drawing on page 110, detailing the Cram mounting, that you realize this telescope cannot be built without a lathe, though Cram points out that "all the lathe work is very elementary." It is not a simple mounting. In

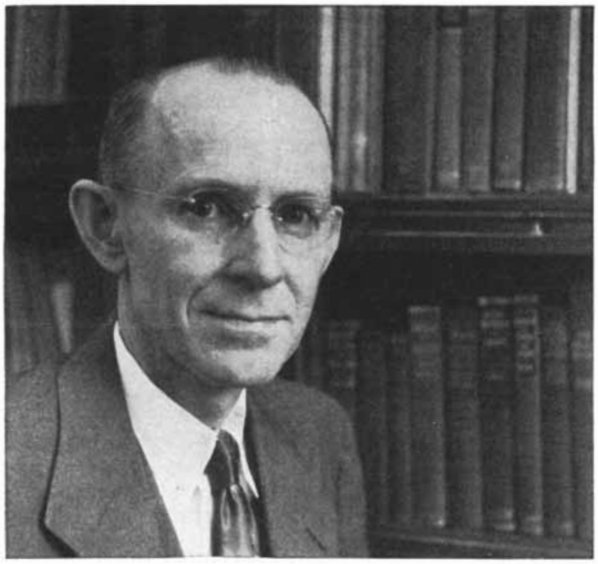
Testing solvents and adsorbents

fact, the drawing looks as confusing as a can of angleworms. Those who are familiar with the book *Amateur Telescope Making* will recognize in this mounting the friction-disk principle of the Springfield telescope invented by Russell W. Porter.

Porter assumed that the readers of *A. T. M.* and *Amateur Telescope Making Advanced* were mechanics and he did not insult their intelligence by describing his drawings in many words. He felt, as all engineers do, that a good drawing is a description, and that describing it is redundant. While this is true, it still is probable that some readers of these books have either had to spend time working out a clear conception of the principle (the method of learning that Porter called the best) or have not been able to state exactly how it works. It is also possible that many who have not studied these books cannot snap up instantly the explanation of the Cram variation in the drawings published here and may enjoy having their intelligence insulted. Hence we shall separate the several tangled worms and lay them in a row. This is exactly what Hayward has done in his drawings, but we shall redundantly describe his description.

The complication is the addition of a disk, a ring and a disk on both the upper and lower axes. Without these the mounting would be conventional, with the usual pair of axes mutually at right angles. The upper one is the declination axis, by means of which the telescope is tilted to the celestial latitude, or declination, of the object observed. The lower one is the polar axis, placed parallel with the axis of the earth and kept in slow rotation to offset the earth's rotation. The two are connected by two bearing blocks *c*, screwed to a round headplate into which the polar axis *k* is inserted.

Now for the added hardware. Referring first to the upper axis, there are two



Adventurers in Research

Dr. Arthur M. Wahl

SCIENTIST-ENGINEER

After graduation from Iowa State College in 1925, he enrolled in the Mechanical Design School of the Westinghouse Graduate Student Training Course. Upon completion of the course, he was appointed Research Engineer at the Research Laboratories, and in 1947 was made Advisory Engineer, his present position.

Back in 1929 a problem in spring design was turned over to Dr. Arthur M. Wahl of the Westinghouse Research Laboratories. It seemed that closely coiled helical springs subject to heavy repeated impacts were failing due to fatigue. "Why?" asked Westinghouse engineers.

Dr. Wahl proceeded to find out. His investigations disclosed that the springs were designed correctly in accordance with a long-established industry formula. But, being a man who likes to get at the root of a problem, Dr. Wahl dug deeper—and came up with a new formula for spring design. The "Wahl Formula" is now used throughout the spring industry, and the paper on this formula won for Dr. Wahl the Junior Award of the ASME.

He has developed formulas for practical calculations of stress in plates, diaphragms and disk springs. His book, *Mechanical Springs*, is considered the authority in the field. Over 50 papers and articles prepared by him have been published. Recently he was granted the Richards Memorial Award by the ASME for his achievements in mechanical engineering.

Dr. Wahl is equally at home in the laboratory, or out in the field. He combines practical engineering ability with a rare skill in mathematics. He is a key member of the Westinghouse Research team, for it has been found that research and engineering problems are often solved faster and to better advantage by means of mathematics. Problems of stress and vibration, for example, are particularly adaptable to mathematical solutions. Here, mathematics can become extensive and unmanageable. But Dr. Wahl is able to cut through such complications by his skill in simplification and approximation.

Where there's a problem at Westinghouse involving stress and vibration analysis, Dr. Wahl can be counted on to come up with a solution. His efforts have benefited nearly every division of the company.

His quiet and modest manner conceals an intense determination to see a job through. Evidence of this determination is found early in his career, when, with characteristic zeal, he took advantage of the unique Westinghouse Graduate Study Program to earn his Master's and Doctor's degrees while working at the Research Laboratories.

In addition to his research duties, Dr. Wahl lectures on stress analysis at the Westinghouse Mechanical Design School. For relaxation, he turns to gardening, and to his farm in Iowa where he applies scientific principles to farming.

Now in his 28th year with the Research Laboratories, Dr. Wahl typifies the men at Westinghouse who are working today to create new and improved products for tomorrow. Westinghouse Electric Corporation, Pittsburgh, Pennsylvania. G-10261

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things that we should like to be able to do each time we point the telescope toward a different object: (1) tilt the telescope quickly to it; (2) get the object exactly in the center of the field of view. In this telescope the first is accomplished simply by moving the tube with the hands, the second by turning the slow-motion tangent screw *a*. In most simple telescopes the second is merely a more careful continuation of the first. Doing it with the screw is a pleasing refinement for the upper axis and a more important help for the lower one.

When the assembly, shown exploded, is "imploded" again, the little projection on the ring to the left of *b* fits into the deep groove in the slow-motion screw *a*. This ring is sandwiched between the nonrotating plate *b* (which is permanently fixed by hidden screws to the cheek of bearing block *c*) and the small disk at its left, in a manner concealed in the upper part of the drawing but exactly like the corresponding ring *h* and disk *g* on the other axis. That is, *g* drops into the groove in *h*. The disk cannot rotate because it is screwed to *i*. Similarly the corresponding disk on the other axis is screwed to *c*.

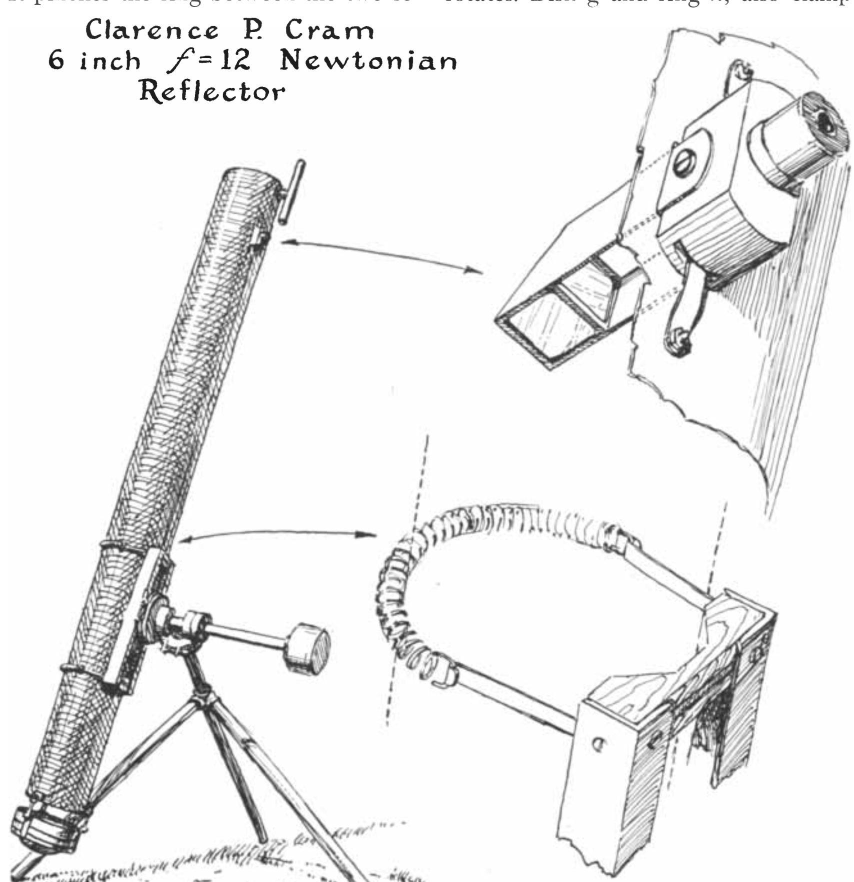
When the telescope is tilted, the ring rotates with it. The slipping occurs between the disk and the groove in the ring.

Now the clamp screw *e* is tightened. It pinches the ring between the two so that it can no longer slip. The rest is done by the slow-motion screw *a*, which now has the immovable little projection to push against in the final centering of the star in the field of view. The sliding occurs now between the end plate to which the screw is fixed and the thicker rim of the ring.

When you shift to another star, you loosen the clamp screw *e*, tilt the tube and repeat the process.

The right-hand bearing block is identical with the left-hand block *c*. Cram made both out of three-inch diameter aluminum shafting, centrally drilled with one-inch holes and sawed off flat on one edge. They are solidly screwed to the headplate below them. At their right is a ring which, when shifted to the left against the cheek of the bearing block and kept from sliding back with a setscrew, prevents the declination axis from shifting endwise. The counterweight on the end of the shaft, shown in the drawing below, is a cylinder of lead cast around three bolts which are bolted to a floor-flange pipe fitting screwed on the end of the axis.

Now for the lower (polar) axis. The upper tip of the polar axis projecting beyond the pipe *k*, into which it fits without turning, is inserted in the bore of a ball bearing that fits snugly into the headplate just behind clamp screw *e*. Disk *i* screws tightly on pipe *k* and never rotates. Disk *g* and ring *h*, also clamp



A long-focus telescope for planetary observation

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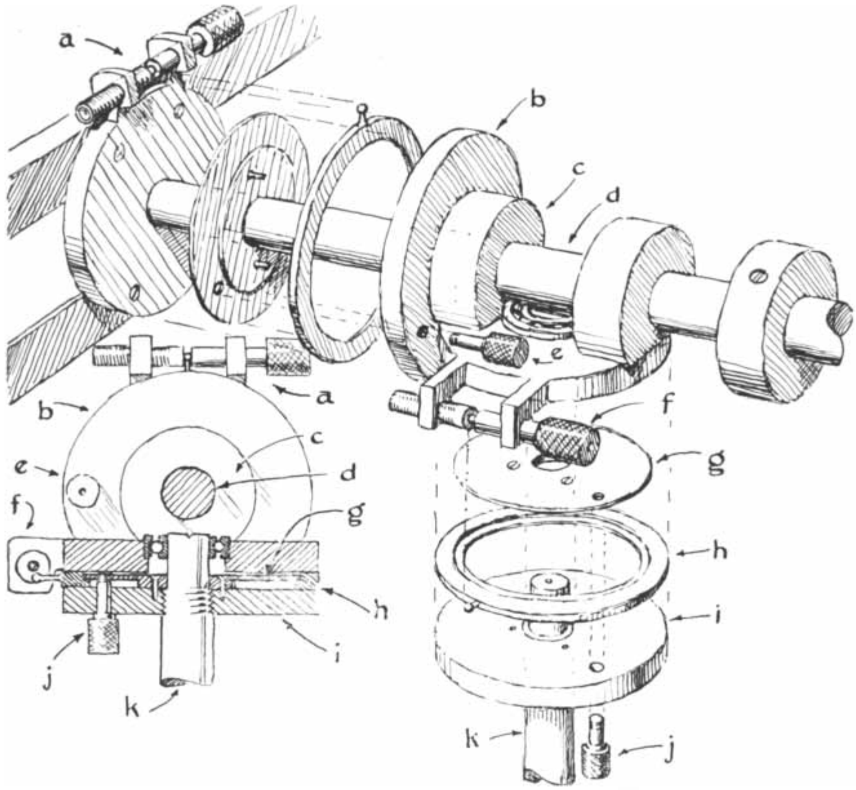

Details of the Porter friction-disk drive

screw *j*, perform exactly like their counterparts on the other axis, but the slow-motion screw *f* is used much more than its counterpart. This is because it must be turned a little every few seconds as the earth rotates. Its threaded part is long enough to permit the observation of one object for half an hour.

This screw will then be run back by hand, and if the knurled thumbnut on its end has been made large with the idea of finer control, instead of small as Cram made his, this job will always be a slow nuisance. Ball bearings are also a nuisance on a telescope, especially on the declination axis, unless there is some kind of friction brake such as the Cram telescope has. On a delicately balanced, frictionless tube even the avoirdupois of a mosquito alighting will swing it out of place. It is better to keep the ball bearing to throw at the mosquito. Numerous telescope makers have written unprintable commentaries on their own early illusion that ball bearings would improve their telescopes.

After making the drawings, Hayward wrote: "My only criticism of the telescope is that the slow motions are so far from the eyepiece that only a long-armed gorilla could operate it without frequently removing his eye from the eyepiece." To this Cram responded: "Mr. Hayward has found the Achilles heel in the arrangement. I had planned to extend a flexible cable from the slow-motion screw, with the other end attached to a four-foot rod that could be stuck in the ground near the observer.

Two considerations led Cram to his arrangement. First, the telescope is uncommonly long, made so for planetary observation, since greater focal length magnifies more. Its focal ratio is $f/12$ instead of the common $f/8$. This adds 24 inches to the length of the tube. Second, it was necessary to pivot the tube at a point far below the middle of its length so that the lower part would clear the legs of the tripod when observing near the zenith; the length of the tube at the top is balanced by lead at the bottom. Combined, these factors put the slow-motion screw out of arm's reach from the eyepiece. A slender two-foot rod, flexibly attached to the slow-motion screw, would enable the observer to rotate the telescope with his hand without leaving the eyepiece.

Theoretically it should be possible, by taking utmost pains, to design all the "bugs" out of a telescope in advance, and this should always be attempted. Even then it usually requires the construction of about three telescopes, and their use betweentimes, to inform the builder where to look for bugs. The telescope builder who has not made his share of mistakes has had no fun and is so good that his fellows hate him. In a quarter-century there have been extremely few requests for "tested blueprints" of flawless telescopes designed by perfect human beings. This proves that the amateur telescope maker is jealous of his constitutional right to make his own mistakes.

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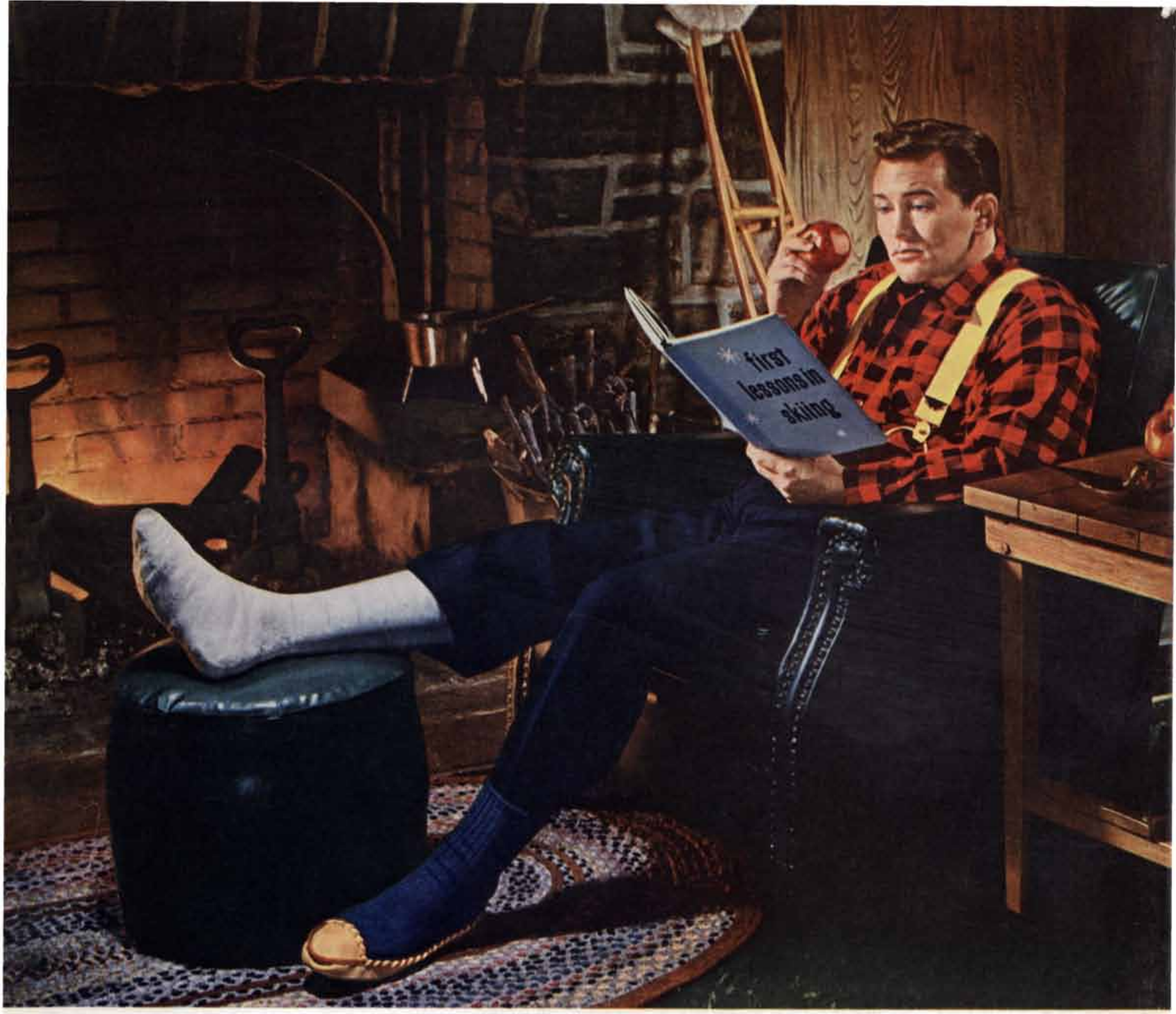

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