SCIENTIFIC AMERICAN

SPECTRA OF STARS

FIFTY CENTS

December 1950

Photograph by Barton Murray

Take a look at tomorrow's highway

There's a great new era ahead in highway construction. You can see it in the famous Pennsylvania Turnpike, now being extended eastward to the outskirts of Philadelphia, westward to the Ohio border.

This modern "thru-way", a pioneer triumph of engineering for transportation safety, speed, comfort and convenience, stretches for *260* miles without a single stop light, crossing, sharp turn or noticeable grade. It is the nucleus of a vast super-highway transportation system that one day may link every section of the country.

Cyanamid blasting materials and the cooperation of Cyanamid explosives engineers have helped to telescope the work of years into months in moving "mountains" of earth and rock to make way for this huge project. Supplying explosives and assistance in their use for mining, quarrying and other purposes, as well as construction, is another of many Cyanamid services that are helping America build for the future.

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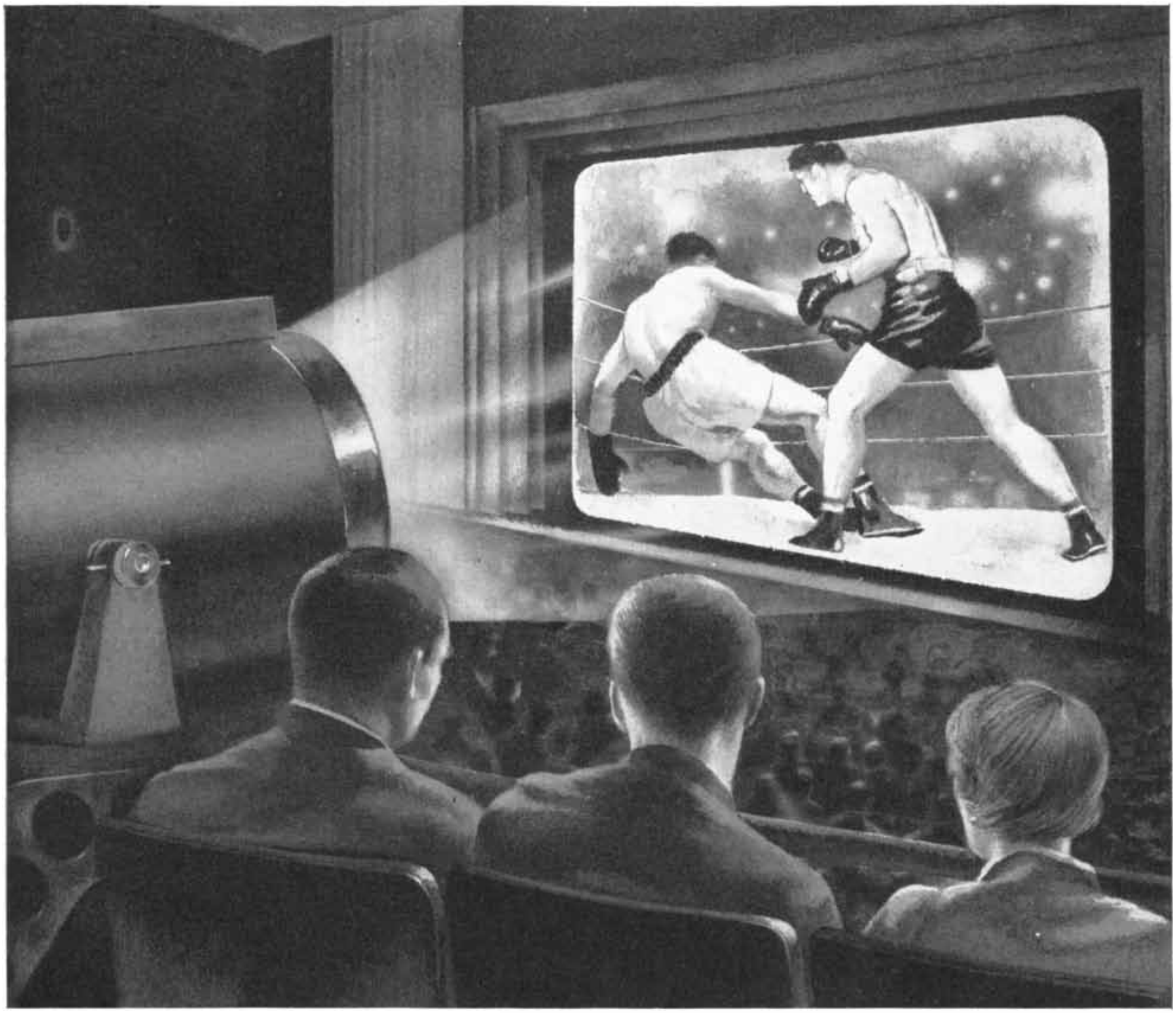
Materials for the explosives-using industries—Another of the services performed by Cyanamid



New RCA Theatre Television System projects 15 x 20 foot pictures of television programs.

Giant size Television—"shot from a Barrel!"

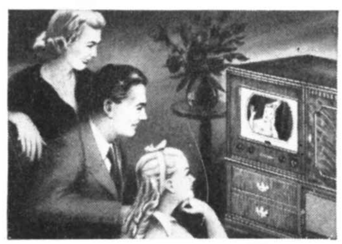
You've seen television. Now you'll see it in its finest form—giant projections of special events, transmitted *only* to theatres on private wires or radio beams to make movie-going *better than ever!*

Success of the system comes from a remarkable RCA kinescope, and something new in projection lenses. The kinescope, developed at RCA Laboratories, is in principle the same as the one on which you see regular telecasts. But it is *small*—only a few inches in diameter—and produces images of high brilliance. These are magnified to 15x20 feet by a "Schmidt-type" lens system like those used in the finest astronomical telescopes.

Because of its size and shape, the new projector is referred to by engineers as the "barrel." It's already going into theatres, where you'll be seeing giant television—shot from a barrel.

* * *

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



The same research laboratories which developed RCA's new theatre television system also give you big, brilliant pictures on 1951 RCA Victor home receivers.

RCA

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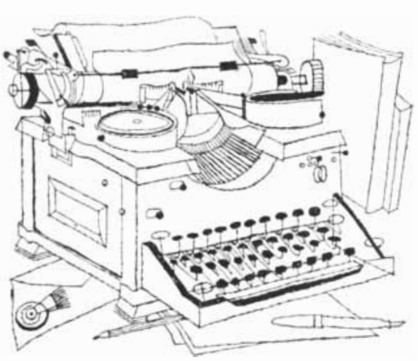

LETTERS

Sirs:

Dr. Weaver has sure demonstrated the "deceptiveness of probability," because if it will throw such a well-educated man as Warren Weaver, Director for the Natural Sciences in the Rockefeller Foundation, it can throw anyone except those who have had to learn to think for themselves. Dr. Weaver has also demonstrated why we gamblers ride in Cadillacs while mathematicians ride in buses.

I am referring to Dr. Weaver's article, "Probability," in your October issue and specifically to his three-card game on page 46. Dr. Weaver is wrong, and I shall be glad to put up against his book of dog-eared tensors my book of syndicated blondes on that proposition.

Dr. Weaver postulates: "The dealer shuffles the cards in a hat, takes one out and places it flat on the table. The side showing is red. The dealer now says: 'Obviously this is not the white-white card. It must be either red-white or red-red. I will bet even money that the other side is red.' . . . the chance that the underside is red is 2 to 1.

Please let me explain the author's mistake.

If the card is red up, as he says, then it is either the red-red card or the red-white one. The author says that the chances that it is the red-red card are 2 to 1. Since he thinks that his betting chances are even if he bets on a 2-to-1 basis, presumably he would be willing to wager 1.5 that the card is red to 1 that it isn't. That bet I would take. Dr. Weaver wouldn't have a chance.

Of course, we experts don't bet this way. The truth is that gamblers copper all bets and never take a chance, even a good one like the above. In other words, gamblers don't gamble.

The statement that Dr. Weaver wouldn't have a chance may not be convincing. The following should be.

With the three cards that the author gives the problem in the beginning, the dealer can pull any one of the three. Case A: If he pulls the first card and it is red up, the chances are even that it is either the red-red card or the red-white card. Case B: If the first card is white up, and the next one he pulls is red up, the chances are that this latter card is red-red or red-white, that is, that the probability that the card is red-red is .5. Case C: The dealer pulls the first card and it is white up and he pulls the second card and it is white up and he pulls the third card and it is red up. I will give you five guesses as to the chances in Case C.

In Cases A and B I would bet 1 that the card is red-white to 1.5 that it is red-red. In Case C the author believes that the chance that the card is red-red is 2 to 1 (as well as in the other cases); he would then likely be happy to take a bet such as this, that I bet 3 that the card is red-red to his 1 that it is the red-white card. Of course, the probability in Case C that it is the red-red card is 1, and that it is the red-white card is 0.

Those are the only three possible cases and the author was wrong no matter which of them he had in mind.

The fallacy of the author lies in the statement: "The other two [cases] are that it is one or the other side of the red-red card." When he specified that the card was red up, he eliminated that side from chance. Only the bottom side was subject to chance. It is either white or red. The chances are even. In other words the author by postulation has eliminated any chance that the red-white card is white up. . . .

Some of the professors of mathematics that I match synapses with get confused as this point, so I have found the following demonstration quite useful.

Take the three cards that the author postulates at the beginning of his demonstration, put them in a hat, shuffle and drop. The white-white card will always come up white. The red-red card will always come up red. The red-white card has an even chance to match either. Say it matches the red, two reds up. Ask a person to choose one. The chances of choosing red-red or red-white are even. The same is true if two whites are up.

Now, should my analysis be not clear or if any of you lace-curtain people there think that an idea is sound just because it has lofty parentage, you can prove the matter in a hurry. There is such a difference between odds of 1 to 1 and odds of 2 to 1 that it doesn't take long to find out the truth by making tests. Now that we are betting, you can bet your life that I did so before taking on the mighty Weaver. (I had to. A gambler can't take a chance.)

HIRAM WILSON SHERIDAN

Glen Ellyn, Ill.

Sirs:

If Mr. Sheridan can shuffle as dexterously as he writes—and I suspect he can—then none of the Weaver money for baby shoes is going to get involved in any card game with him. But if he will just stand still for a minute, I think it ought to be pretty easy to convince him that he is either confused or wrong (or both).

I'm not going to waste time talking about new games that he has invented—games concerning which I said nothing. I'm not going to bother to give the long list of very distinguished mathematicians (Poincaré, Borel, Uspensky, etc., etc.) who have discussed the Problem of the Three Chests (for that is the classical name of the three-card game), and who have pointed out that the inexperienced (!) and the unwary (!!) often get mixed up about the correct answer.

I speak only of what Mr. Sheridan calls Case A. This is the case I discussed, and the only one I mentioned. In his paragraph which begins, "The fallacy of the author . . .," Mr. Sheridan says, about the invisible bottom side of the one exposed card, the top side of which has proved to be red, "It is either white or red. The chances are even." Sorry, but exactly here is where his synapses blew a fuse. The chances are not even. They are two to one in favor of red.

Why? Why is he so wrong in saying that the chances are even?

Maybe if I describe the game in another, less lace-curtain, way it will be easier to see. Take three balls, two marked "Same" and one marked "Different." (I choose balls this time so that we don't need to think about the two separate sides.) Mix the three balls up in a hat and take one at random. "Taking one

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at random" means precisely: take one in such a way that you have just the same chance of taking any specific one ball as of taking any other. What are the odds for getting a ball marked "Same"? Well obviously, the odds are 2 to 1. But if Mr. Sheridan will just warm up the old synapses a bit, he will recognize that the chance of getting a ball marked "Same" is just precisely the same as the chance, in my red-red, white-white, and red-white card game, that the bottom side of the drawn card is the same color as the exposed top side.

He'd better think it over, and in the meantime if I were he I'd stick to craps and draw poker.

WARREN WEAVER

New York, N. Y.

P.S. Too bad that Mr. Sheridan lives in Illinois. Even at his offer to accept 1.5 to 1 (rather than the precisely even bet of 2 to 1) I would not dare play him for high stakes. Both of us have finite resources, and I suspect his are much greater than mine (remember that Cadillac). Chance fluctuations in luck which he could stand might break me. But wouldn't it be fun to play him a nice long sequence at 1.5 to 1, with some modest bus-rider's stake up each time!

P.P.S. If Mr. Sheridan tried this out experimentally, and got something far from 2 to 1, one or both of two things happened: either the procedure wasn't such as to give a truly random choice of the drawn card, and/or he had an unusual but perfectly possible run of luck. But he had better remember that although gamblers escape certain laws, they can't get around the laws of logic.

Sirs:

I should like to correct three errors in my article "The Pituitary," which appeared in your October issue.

In the first paragraph of the article appeared the statement: "This master gland was discovered by Vesalius . . ." The word "discovered" should be "described."

A later paragraph referred to P. Stricker and F. Grueter of the University of Paris. These men should have been identified as P. S. Stricker and F. G. Grueter of the University of Strasbourg.

In the discussion of the gonadotropic pituitary hormones appeared the statement: "Upon maturing, the corpus luteum discharges an ovum and simultaneously produces the hormone progesterone . . ." The words "discharges an ovum and simultaneously" should be omitted.

CHOH HAO LI

University of California
Berkeley, Calif.

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50 AND 100 YEARS AGO

DECEMBER 1900. "The close of the 19th century is marked by no celestial pageant. Indeed, the heavens are more than usually bare, for all the outer planets except Neptune are hidden behind the sun, and the inner ones are all three morning stars. So on the last evening of the century we shall see those silent and eternal stars alone which present the same aspect to us that they did to the sages of the East more than 30 centuries ago."

"The Duke of Abruzzi has chartered the Gothenburg whaler *Capella* to proceed to Franz Josef Land in search of three missing Arctic expeditions."

"The London *Lancet* complains that the ordinary closed cab is a distinct menace to health. It says that they are an undoubted source of infection; microbes infest the cushions and the mats on the floor, and the air might easily contain pathogenic organisms left by a previous user. Hansom cabs are considered to be decidedly more sanitary, but they are considered as a kind of death trap in wet weather, when those riding in them are completely enclosed by windows and aprons, making it impossible to release themselves in an emergency."

"Prof. S. P. Langley had the honorary degree of Doctor of Science conferred upon him by Cambridge University, England, on October 11."

"Important extensions of the Weather Bureau work have been made during the past year. The efforts of the Bureau have been specially directed toward the investigation of methods of electrical communication without wires, with a view to establishing wireless electrical communication between vessels at sea and exposed points on our lake and sea coasts. Already messages have been successfully transmitted and received over 60 miles of land, and the Bureau expresses the hope that in the near future the craft employed in our coastwise commerce and on the Great Lakes will be placed in instantaneous communication with stations located at the principal ports. Special storm forecasts for the North Atlantic will be undertaken shortly through the use of reports received from the West Indies, the Bahamas, the Bermudas, the Azores and Portugal, the new cable system connecting Lisbon with America via the Azores making this possible."

"Count Henry de la Vaulx, a member of the Aero Club of France, has recently returned to Paris, a holder of the world's record for long distance ballooning. The feat accomplished by the aeronaut was a trip of 2,000 kilometers from France to Kiev, Russia, of which 1,300 kilometers was made in exactly 24 hours. The balloon in which Count Henry covered this remarkable distance in record-breaking time is known as the *Centaure*. At 20 minutes past 5 on the 9th of October the *Centaure* rose over the roofs of Vincennes and reached a height of 2,000 meters. The wind forced the *Centaure* along toward the east and the pace was rapid and the temperature agreeably mild. When the sun appeared on the following morning, the aeronauts had lost their bearings. At length a large city loomed up in the distance. The descent was made slowly and safely. The travelers were piloted to the home of a nearby estate owner, who understood French, and from whom Count Henry ascertained that he had sailed straight to the city of Kiev, a distance of 2,000 kilometers."

"A new book by Charles P. Steinmetz, *Theory and Calculation of the Alternating Current Phenomena,* is the first work ever written in any language dealing in a complete and logical manner with all the phenomena of alternating currents in the design of alternating current machinery. The work contains the very latest knowledge relating to alternating current phenomena as applied in engineering, much of which is original with the author."

DECEMBER 1850. "There are many deserted Oriental cities, which have no doubt been depopulated by war, famine and pestilence; these have their counterparts in our suspended factories and silent mills. From Rhode Island, that busy cotton cloth-making hive, we learn that about 70 factories have stopped; from Lowell and other Eastern manufacturing villages we hear the same ominous reports. In the Patapsco Valley of Maryland silence reigns; and even from the sunny South we hear of depression and suspension of manufacturing operations. From East, West, North and South, the times are bad, the cotton manufacturers say, and they say so truly."

"At a sitting of the French Academy of Sciences M. Claude Bernard submitted a communication on the functions of the liver in man and in animals. 'I am about,' he said, 'to demonstrate experimentally that the presence of sugar in animal organisms is a constant and indispensable fact in nutrition, caused in the liver by a special function of that organ. The liver has thus two functions: to wit, on one hand, the secretion of bile and on the other, the production of sugar. This latter function begins to be performed before birth—for I have ascertained the presence of sugary matter in the liver of the fetus of mammals and of birds at different periods of fetal life. The sugar from the liver has all the characteristics of glucose.' "

"The Report of the Secretary of the Navy states that the experiments of Professor Page in testing the application of electro-magnetism as a motive power in mechanics have been continued, and he is now engaged in preparation for a trial trip of a locomotive on a railroad propelled by this power."

"By the arrival in New York of the steamships *Georgia* and *Empire City,* we learn that the cholera has broken out at San Francisco. The steamboat *Sagamore* burst her boiler at San Francisco, by which accident 14 persons were known to have lost their lives. The *Empire City* brought $2,000,000 in gold dust. On October 29 there was a grand rejoicing about the admission of California to the Union."

"At the last meeting of the Royal Institute, Mr. Faraday announced to the members present his discovery that oxygen is magnetic, that this property of the gas is affected by heat, and that he believes the diurnal variation of the magnetic needle to be due to the action of solar heat on this newly discovered character of oxygen."

"Mr. Airy, the Astronomer Royal, expressed his conviction at the late meeting of the British Association that the whole of astronomical work at present done by the eye would at no distant date be accomplished by the daguerreotype."

Testing for sound lost between telephone receiver and ear. Many subjects were used in these tests.

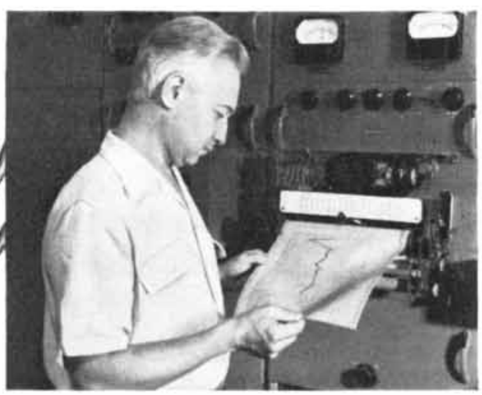
How to compensate for a curl . . . and add to your telephone value

Bell scientists know that the telephone is not used under ideal laboratory conditions. There is never a perfect seal between receiver and user's ear. A curl may get in the way, or the hand relax a trifle. And ears come in many shapes and sizes. So some sound escapes.

Now, sound costs money. To deliver more of it to your ear means bigger wires, more amplifiers. So Bell Laboratories engineers, intent on a thrifty telephone plant, must know how much sound reaches the ear, how much leaks away. They mounted a narrow "sampling tube" on an ordinary handset. The tube extended through the receiver cap into the ear canal. As sounds of many frequencies were sent through the receiver, the tube picked up a portion, and sent it through a condenser microphone to an amplifier. That sampling showed what the ear received.

As a result, Bell scientists can compensate in advance for sound losses—build receivers that give *enough* sound, yet with no waste. That makes telephone listening always easy and pleasant.

It's another example of the way Bell Telephone Laboratories work to keep your telephone service one of today's biggest bargains.



Automatic recorder plots sound pressures developed in the ear canal at different frequencies.

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THE COVER

Because of the narrow field of most telescopes, the spectra of stars are usually made one at a time. The photograph on the cover shows the spectra of a whole cluster of stars: the Hyades. The photograph was made by the Schmidt telescope of the Warner and Swasey Observatory of the Case Institute of Technology. The Schmidt is particularly well suited to making such spectra because of its large field and high photographic speed (*see page 34*). For this purpose the Schmidt is fitted with an objective prism, a wedge-shaped plate of glass that disperses light into its constituent colors. The photograph on the cover was exposed for one hour. The telescope followed the motion of the sky, but it was moved at right angles to the spectra so they would be wider.

THE ILLUSTRATIONS

Cover by J. J. Nassau

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16-17	Adolph Brotman
18-21	Courtesy Charles P. Lyman and Paul O. Chatfield
34	National Geographic Society-Palomar Observatory Sky Survey
36-37	Mount Wilson and Palomar Observatories
38	National Geographic Society-Palomar Observatory Sky Survey
39	Sarah Love
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47	Irving Geis
48	Courtesy Alberto Monroy
50	American Cyanamid Company, courtesy Radio Corporation of America Laboratories
51-53	Radio Corporation of America Laboratories
55	Irving Geis
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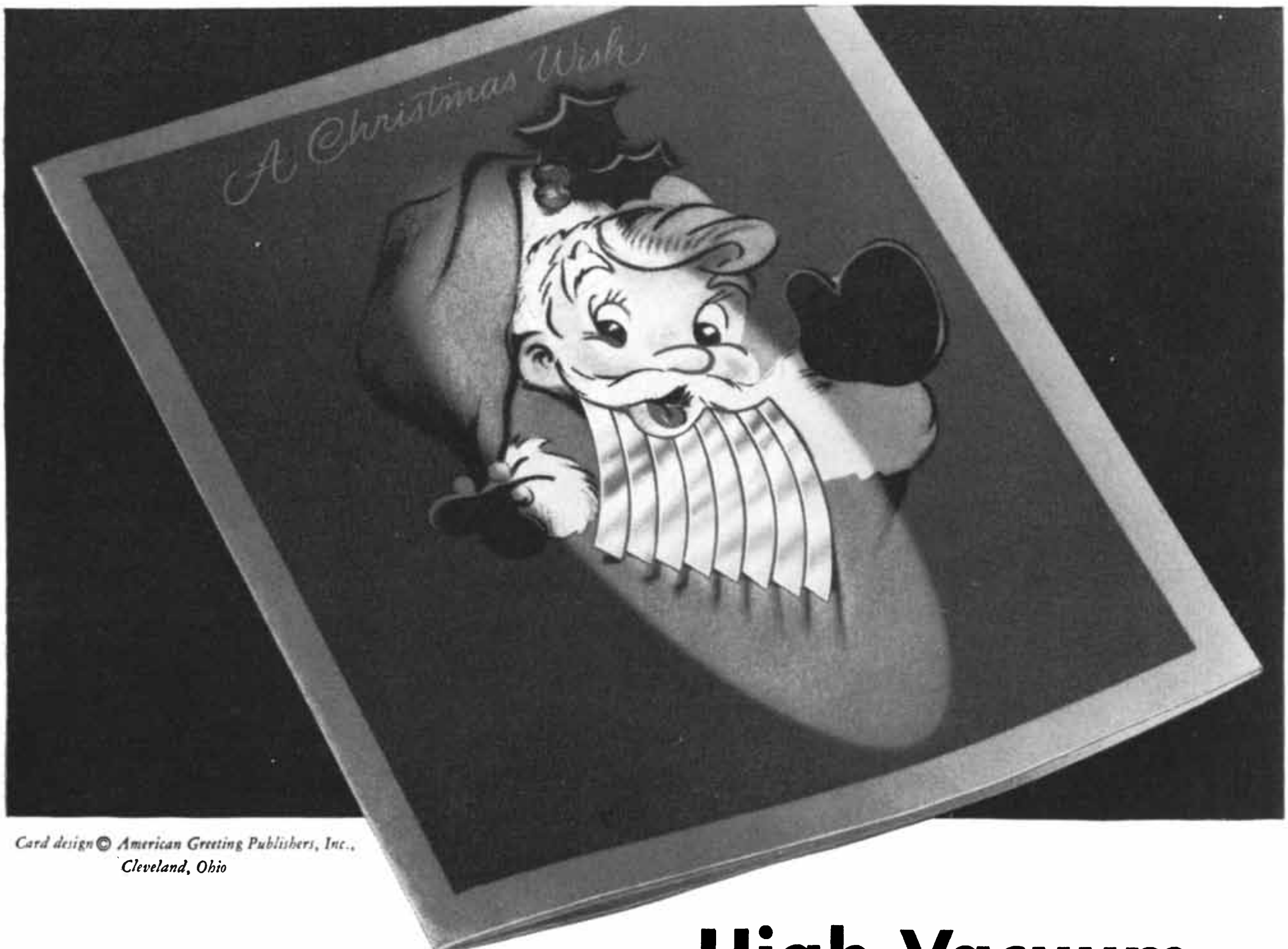

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High Vacuum

is styling Christmas cards this season

• If you see a metallic glint on St. Nick's whiskers this Christmas, the effect probably comes from a wonderful basic new material—cellulose acetate coated with a thin deposit of metal. Variations of it are stimulating both the ingenuity and the sales of fabricators who want an expensive look at low cost.

In this particular case, Santa's whiskers are die-cut from sheeting aluminized in long rolls under high vacuum. The same process, applied to one or both sides, is responsible for the metallic gleam of many materials for packaging, interior decoration, merchandising displays—even sequins to suit the whims of fashion.

The electronics industry deposits metal on tissue in DPi Roll Coaters to make small condensers by the millions. Fighting men wear clothing made from infrared-reflecting cloth to reduce radiation loss from the body. New applications are being developed constantly.

High vacuum serves in many other ways too—in flash distillation of plasticizers, in impregnation of fabrics, in dehydration, in producing new metals, in imparting new properties to familiar metals. As builders of equipment which makes high vacuum a practical, economical production tool, DPi invites your inquiries. Write to Vacuum Equipment Department, ***Distillation Products Industries,*** 751 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company)

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CONTENTS FOR DECEMBER 1950 VOL. 183, NO. 6

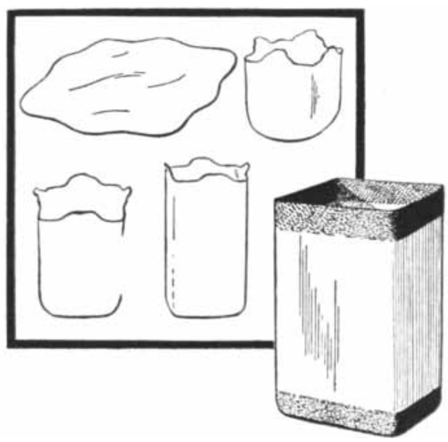
ARTICLES

DEPARTMENTS

BUSINESS IN MOTION

To our Colleagues in American Business . . .

The manufacture of a rectangular brass can or shield for a coil would not seem to be a difficult matter. Brass is noted for its easy workability. It can be stamped, drawn, spun, machined, polished, plated, and so on. However, there are a number of brasses containing varying proportions of copper and zinc and sometimes other metals, and Revere furnishes these alloys in various tempers. To take maximum advantage of the goodness of brass, it is essential to specify the metal with due regard to the fabrication processes to which it is to be subjected.



Take the case of these brass cans. They were being produced in ten steps: blanking from strip; draw; anneal; draw; anneal; draw; anneal; sizing draw; trim; tin both ends. This seems to be a simple, easy and conventional method, yet there was a high percentage of rejection due to cracking or tearing of the metal in drawing. There was also an "orange peel" effect, undesirable in appearance, and which sometimes interferes with plating. The chief trouble, however, was tearing.

The Revere Technical Advisory Service was asked to cooperate and obtained complete data on metal specification, annealing time and temperature (1350° F.) and progressive samples. Information and samples were forwarded to Revere Research, which made a thorough study of them, including photo-micrographs to determine the grain size in each of the samples. It was found that the brass strip had too large and irregular a grain structure, and that the annealing procedure accentuated this condition. It was recommended that strip be specified in 70/30 cartridge brass, with a fairly uniform structure and the proper grain size instead of the size being purchased. Then, two anneals could be dropped, and annealing temperature reduced to 1000° F. for one hour. Conclusion: A better product, increased production at less cost, and lessening of the "earing" seen in the sketch of the original samples.

Two things stand out in this matter. One is the advisability of letting your suppliers know how you intend to fabricate or process the materials you buy, in order that they can work closely with you on specification. The other is that suppliers, no matter what they sell, can and are glad to collaborate with you on fabrication problems. Revere is delighted to give its Research engineers such tasks as described here; so are other good firms, not only in metals, but in other industries such as chemicals, wood, felt, plastics, leather, paper and so on. It will pay you to take advantage of the brains of your suppliers.

Incidentally, the term "grain size" is another way of referring to temper, because annealing and working determine grain size. If you would like to know more about this subject, there is an extended, though non-technical, discussion of it in "Fundamental Characteristics of Revere Metals," which will be sent on request.

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Founded by Paul Revere in 1801

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SCIENTIFIC AMERICAN

DECEMBER 1950 VOL. 183, NO. 6

COLOR TELEVISION

Although the Federal Communications Commission has chosen one of the three competing systems, the debate over their relative merits continues

by Newbern Smith

NOT EVERY rooftop has yet sprouted a television antenna, but almost everyone has an interest in the current controversy about color television. The issue involves not only the fortunes of those engaged in television manufacturing, broadcasting and advertising, not only the investment in an estimated eight million sets now in U. S. homes, but also the many additional millions of families who will someday own a television receiver.

The question at issue, though broad in its ultimate consequences, turns on a comparatively narrow, technical decision: Which one of several alternative and at present mutually exclusive systems shall be adopted for the addition of color to television on a national scale? It is, of course, the mutually exclusive nature of the competing systems that gives this decision its great importance. At the present stage of development transmitters and receivers designed for one system cannot practicably or easily be adapted for another. Thus the decision is one of the knottiest that has ever confronted public officials. The Federal Communications Commission, after prolonged hearings and deliberations, finally adopted the color-television system advanced by the Columbia Broadcasting System.

The FCC decision has not ended the controversy; indeed, the differences between the contending interests have been brought to the stage of action in the law courts and in the court of public opinion. Because the ultimate judgment of the issue will be made by public opinion, it is important that the public have some understanding of the underlying technical problems and issues involved. They will be summarized here as they were analyzed by the Senate Advisory Committee on Color Television, on which the writer served. This Committee, headed by E. U. Condon, Director of the National Bureau of Standards, was set up to survey the technical status of color television for the Senate committee to which FCC reports. The Advisory Committee made no recommendation as to which of the competing systems should be adopted, since such a decision "must include consideration of many social and economic factors not properly the concern of the technical analyst."

The main technical issues among the competing color systems have to do with the fineness of detail of the picture (the number of picture elements), the image continuity (the number of pictures transmitted per second), the fidelity of color reproduction and whether the new system's color broadcasts could be received by present receivers through some relatively easy modification. At the present stage of the art there is no perfect answer to all these requirements; any judgment about them must perforce seek the most satisfactory possible compromise.

THE BASIC principle of television broadcasting by now is well known to most people. The visual picture is scanned by a television camera which impresses the light-and-shade values on a high-frequency radio signal. The receiver transforms this signal into a series of lines with precisely spaced variations in brightness (the picture elements, or "dots") on the picture-tube screen, thereby reproducing the original picture. The fineness of detail in the picture depends on the number of dots in a given area, just as in a halftone engraving of a photograph. A full-page photograph in this magazine, engraved in a screen which has 110 lines to the inch, contains more than a million dots. Such a picture can be examined at ordinary reading distance without the dots themselves becoming separately visible.

In television the necessity for transmitting the picture by radio imposes a practical limit on the number of dots, because the more dots the signal carries, the wider must be the waveband on which it is sent. If the radio spectrum were limitless and the cost could be disregarded, it would be theoretically feasible to transmit a picture containing many millions of dots. A compromise which is accepted as adequate has been adopted for television. Its standard is fairly close to that of motion pictures. In motion-picture viewing, at distances from the screen greater than five to eight times the picture height, pictorial detail corresponding to a few hundred thousand dots, rather than millions, suffices for a satisfactory image. The 35-millimeter film, projected on a standard-size movie screen, actually offers pictorial detail equivalent to one million halftone dots. A 16-millimeter film for smaller screens has the equivalent of 200,000 to 250,000 dots, and the 8-millimeter amateur film presents its image in a mere 50,000 dots on the home movie screen. The standards adopted for television permit pictorial detail equivalent to 200,000 dots. The television image, however, must be classed as somewhat inferior to the 16-millimeter film because its line structure coarsens its definition in the vertical dimension.

Of the 525 lines on a television screen, about 490 make up the effective picture area. Each line has about 420 dots. Thus the picture area has roughly 200,000 dots, divided uniformly between the horizontal and the vertical dimensions. To transmit the entire picture area at once would require hundreds of thousands of separate radio circuits, corresponding to the hundreds of thousands of separate fibres in the optic nerve. Instead, television transmits the picture elements one by one in extremely rapid succession to the receiver, where they are reassembled in a reproduction of the picture. In this manner a sequence of still pictures, or "frames," is sent to the receiver. To blend together into a continuous moving picture they must be presented at a high enough rate to smooth out the illusion of motion and to keep the picture from flickering as a result of the light's being cut off the screen between frames. In movies the standard rate is 24 frames per second. Black-and-white television has been standardized at 30 frames per second. As a measure of further control over flicker, the television frame is assembled as a composite of two "fields." In each field, only the alternate lines are scanned; the lines between are scanned in the next field. The frame thus consists of two interlaced fields, with the fields presented at the rate of 60 per second.

To present 30 frames per second requires the transmission of some eight million picture elements per second. This enormous rate of transmission requires a radio-frequency channel at least four million cycles wide. It is this radio-frequency requirement that sets the ultimate limit on the quality of the picture in television. A doubling of the channel width would bring a perceptible improvement in the television image, but it would reduce greatly the number of channels available to television in the already heavily crowded radio spectrum.

THE addition of pictorial color greatly increases the amount of information that must be sent, for each picture element requires at least three signals, representing three "primary" colors. The primary colors of most use in color television are the so-called "additive" primaries—red, green and blue. These colors, when projected from light sources and mixed in varying strengths, can produce all hues of the spectrum, purples not visible in the spectrum, and all shades of gray, plus mixtures of these. For purposes of color television they may be added either simultaneously or, taking advantage of the eye's persistence of vision, one after the other.

To present a picture using primary colors with the same detail as in a black-and-white picture would require transmission of 600,000 picture elements in a fortieth of a second instead of 200,000. This would call for a radio-frequency channel of more than 12 million cycles. Such a prodigal use of the radio spectrum is, of course, quite impractical, in view of the demands of all the other radio services for the limited number of available frequencies. Designers of color-television systems have accordingly sought acceptable compromises. Some have coarsened the dot structure, thereby reducing the pictorial detail, or lowered the frame repetition rate, raising problems in flicker, image continuity and color mixing. Others have tried to solve the channel problem by reducing the amount of color information and compressing it or interleaving it in some manner. By some such compromise each of the proposed color-television systems has managed to stay within the six-million-cycle radio channel width assigned to black-and-white television.

All three of the demonstrated color systems use sequential rather than simultaneous mixing of the primary colors. The three systems are those of CBS, Color Television, Inc., and the Radio Corporation of America.

THE "field-sequential" system developed by the engineers of the Columbia Broadcasting System is perhaps the simplest of the three. Color filters mounted in a rotating wheel in front of the camera separate the image into its three primary colors. The three images are then projected successively on the same spot on the sensitive plate in the camera. At the receiving end they are reproduced on the screen of a single tube and are translated back into color by another filter wheel synchronized with the camera wheel. By employing a single optical and electrical system for all three colors at both the transmitting and receiving end, the CBS system undertakes to eliminate the major headache of color reproduction, familiar to engravers and printers as "registration." Proper registration requires that the three primary-color images have the same size and shape and be precisely superimposed. Poor registration results in distortion of the color mixtures, obliteration of detail and color-fringing of the outlines of objects in the picture.

As indicated in the table reproduced at the right, the Advisory Committee rated the CBS system as the best of the three in color fidelity and superposition. An inherent difficulty, however, is associated with the fact that it transmits an entire field in one color before it proceeds to the next color. An object that moves very rapidly may change its position considerably between successive scannings in different colors. This may result in the successive images of the object being out of color register. Moreover, the movement of the eye may also record the images out of register on the retina. Fortunately most people soon acquire a substantial tolerance to this effect.

The CBS system requires compromise with other aspects of picture quality. Since it requires six fields to present a single complete picture (*i.e.*, two interlaced fields in each of the three primary colors) the rate of field-scanning must be stepped up by a substantial amount to prevent flicker and discontinuity of motion. This, in turn, requires a proportionate sacrifice in the dot structure and pictorial detail. The compromise is achieved by using a field-scanning rate of 144 fields per second, yielding 24 complete color frames per second. With the resultant reduction in the number of lines per field and in picture elements per line, the dot structure is brought down from the 200,000 standard of black-and-white to 83,000 per color picture.

Because of the step-up in the field-scanning rate, the CBS image cannot be received in black-and-white on existing receivers, geared as they are to 60 fields per second, unless the set is equipped with an "adapter." Once so equipped, however, the set can be converted to receive the CBS image in color by the addition of a rotating color disk in front of the picture tube. In contrast, the two other systems demonstrated to the Commission—CTI and RCA—would permit existing receivers to receive their signals in black-and-white, but present sets could not be converted to receive them in color.

PERFORMANCE CHARACTERISTIC
GEOMETRIC RESOLUTION:
NUMBER OF PICTURE ELEMENTS PER COLOR PICTURE
VERTICAL RESOLUTION
HORIZONTAL RESOLUTION
CONTINUITY OF MOTION:
LARGE OBJECTS
SMALL OBJECTS
FLICKER-BRIGHTNESS RELATIONSHI
LARGE AREAS
SMALL AREAS
INTERDOT FLICKER
INTERLINE FLICKER
COLOR FIDELITY:
LARGE AREAS
SMALL AREAS AND EDGES OF OBJECTS
SUPERPOSITION PERFORMANCE:
REGISTRATION
COLOR BREAKUP
COLOR FRINGING
ADAPTABILITY
(MODIFICATION OF EXISTING SETS TO RECEIVE COLOR TRANSMISSIONS IN BLACK AND WHITE)
COMPATIBILITY
(ABILITY TO PRODUCE BLACK AND WHITE IMAGES ON EXISTING SETS WITHOUT MODIFICATIONS)
CONVERTIBILITY
(MODIFICATION OF EXISTING SETS TO RECEIVE COLOR TRANSMISSIONS IN COLC

THREE SYSTEMS were compared with one another and with black-

SYSTEM				SUPERIOR SYSTEM
BLACK & WHITE	CTI COLOR	CBS COLOR	RCA COLOR	
200,000	200,000	83,000	200,000	CTI; RCA
490 LINES	490 LINES	378 LINES	490 LINES	RCA
320 LINES	320 LINES	185 LINES	320 LINES	CTI; RCA
EXCELLENT	GOOD	GOOD	GOOD	ALL COMPARABLE
GOOD	FAIR	GOOD	GOOD	CBS; RCA
EXCELLENT	EXCELLENT	GOOD	EXCELLENT	CTI; RCA
GOOD	FAIR	GOOD	GOOD	CBS; RCA
ABSENT	ABSENT	ABSENT	FAIR	CTI; CBS
GOOD	POOR	GOOD	GOOD	CBS; RCA
	SATISFACTORY	EXCELLENT	SATISFACTORY	CBS
	FAIR	EXCELLENT	FAIR	CBS
	FAIR	EXCELLENT	FAIR	CBS
	EXCELLENT	SATISFACTORY	EXCELLENT	CTI; RCA
	EXCELLENT	SATISFACTORY	EXCELLENT	CTI; RCA
	NOT NEEDED	ADAPTABLE	NOT NEEDED	CTI; RCA
	FAIR	NOT COMPATIBLE	EXCELLENT	RCA
	NOT EASILY AT PRESENT	CONVERTIBLE UP TO MAXIMUM OF 12½ INCHES TUBE DIAMETER	NOT EASILY AT PRESENT	CBS

and-white television in the Report of the Advisory Committee on Color Television of the Senate Committee on Interstate and Foreign Commerce. The assessment of the Advisory Committee is reproduced in this chart.

The rotating disk is not an inherent feature of color reception in the CBS system. Other types of picture tubes may be used at the receiver. In one type the screen is made up of three areas, each covered by a phosphor which glows in one of the three primary colors when struck by the cathode-ray beam. The three separate primary-color pictures thus formed are then combined and projected on a screen by an optical system. In another type the screen is covered with clusters of tiny dots in which phosphors of each primary are placed in careful geometric arrangement so that the phosphors of only one color are illuminated in the scanning of a given field. This type, called a "tricolor" tube, permits direct viewing of the cathode-ray screen, and has obvious advantages over optical resolution and registration of three separate images.

THE Color Television, Inc., system uses the so-called line-sequential method. In this each primary color is transmitted line by line instead of field by field. Three separate primary-color images are produced side-by-side in one camera tube and are scanned one line at a time by the cathode-ray beam sweeping from side to side. On the receiving end, a single tube with three patches of colored phosphors, as described above, plus an appropriate optical system, reconstruct the image.

Since scanning in the CTI system is done at the standard black-and-white rate, the method approximates the pictorial detail and flicker performance of black-and-white television. The scanning of 60 fields per second, however, nets only 10 fully interlaced and colored pictures per second, or one-third the black-and-white standard. This is the compromise which fits the CTI system into the six-megacycle television waveband. Attendant on the 10-per-second-color-picture rate are serious problems in small-area color mixing and flicker which must be classed as rooted in the line-scanning method.

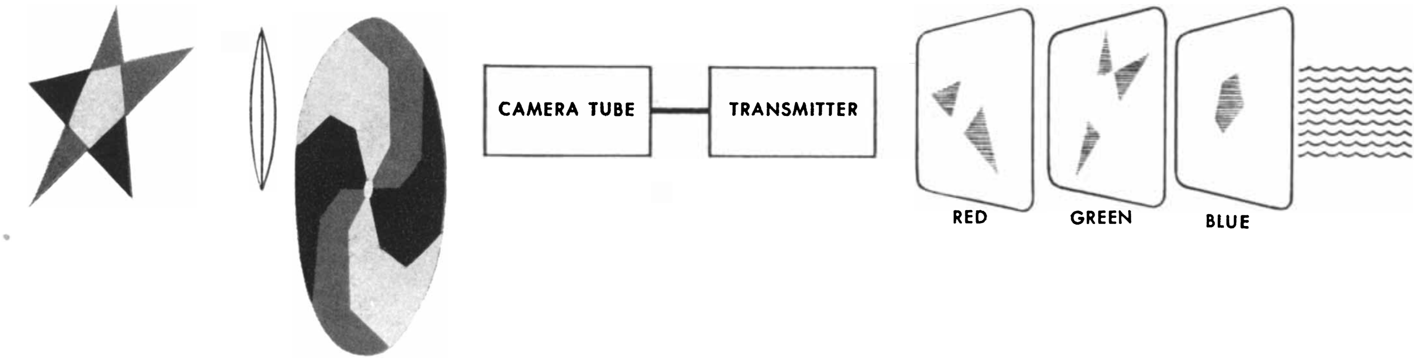
THE Radio Corporation of America system uses the dot-sequential method, transmitting the successive colors not field by field or line by line but dot by dot. Its camera has three separate tubes. A set of color-selective mirrors dissects the scene into its primary colors and projects them separately on the sensitive plates of the three tubes. An electronic switch connects and disconnects each tube in sequence to the transmitter, at the rate of 3,580,000 times a second. Each time a camera tube is connected, it generates a dot of the respective color; when disconnected, a blank space is left for that color. As this process of "sampling" the three images in the three tubes proceeds, the blank spaces between the dots of one color are filled in with dots of the other two colors. At the receiving end, the image is reassembled either by a set of three colored phosphor tubes and the necessary optics or by a single "tricolor" tube which is viewed directly.

By dissecting the color information down to the individual dot, the RCA system achieves an image in color comparable in fineness of detail with a standard black-and-white image. Its color signal can also be received in black-and-white on present television receivers without modification. Moreover, the RCA system employs the so-called "mixed highs" principle to achieve more effective use of the radio channel. This is analogous to the principle of using the black plate in four-color printing, where the fine detail of the picture is rendered in shades of gray, thus reducing the necessity for precise register among the primary color impressions. In the RCA system the fine details of the image are common to all three primary colors and thus are reproduced in shades of gray, while the larger areas are reproduced in color.

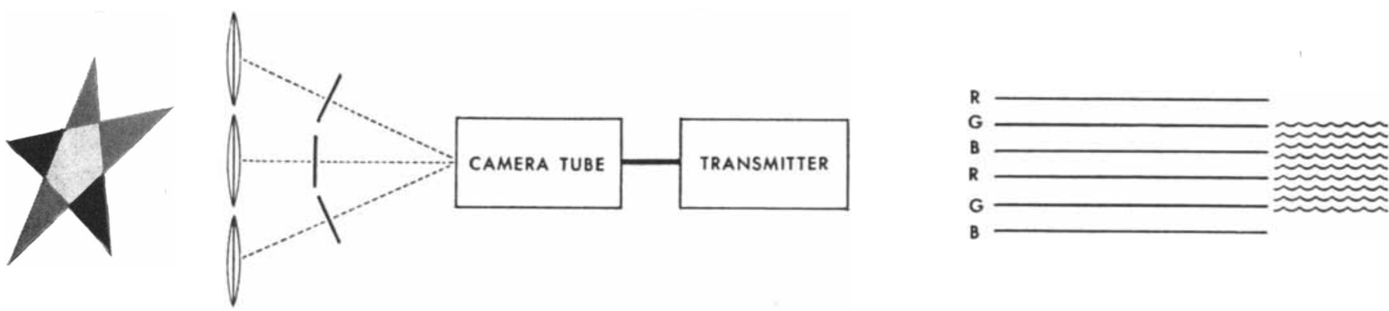
A comparative study by the National Bureau of Standards indicated that in color characteristics the RCA system was theoretically just short of or equivalent to Kodachrome color film and not significantly below the standard of the CBS system. But it was noted that while the CBS system was sufficiently developed to give trouble-free operation at a high level of fidelity, the RCA equipment required constant expert attention. Some of its difficulties come under the heading of registration. They arise from the use of three camera tubes, which introduces the possibility of optical as well as electrical errors in the size, orientation and congruency of the primary images. The three-tube type of receiver raises these same problems at the receiving end, and the receiver's tricolor tube eliminates only the optical errors. From the same sources arise another problem which the engraver knows as "color balance": in the RCA system defects in balance result in a lack of uniformity of the color mixture.

It was the judgment of the Condon committee that, of the three systems, the CBS system had advanced furthest toward full realization of its potentials. The defects still present are inherent in the field-sequential scanning principle upon which it is based. The principal present defects in the CTI and RCA systems are not inherent in their scanning systems and may be mitigated through further research and engineering.

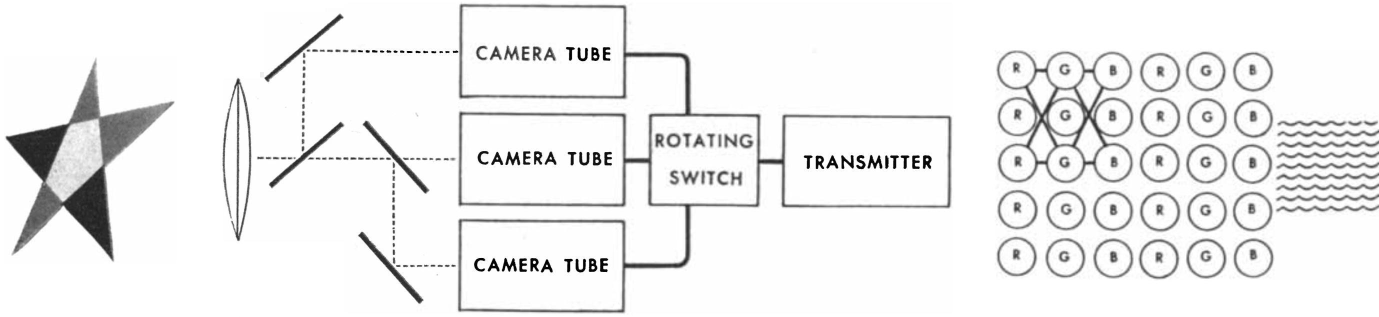
There are promising experiments underway which may eventually make it possible to transmit three color images simultaneously instead of by a sequential method. One such possibility is being explored by the General Electric Com-



CBS or field-sequential system is described in a simplified schematic drawing. At the left is a colored object. In front of the camera tube is a wheel made up of red, green and blue filters. These three primary colors are represented here by black, dark gray and light gray. The rotating wheel dissects the image of the object into three



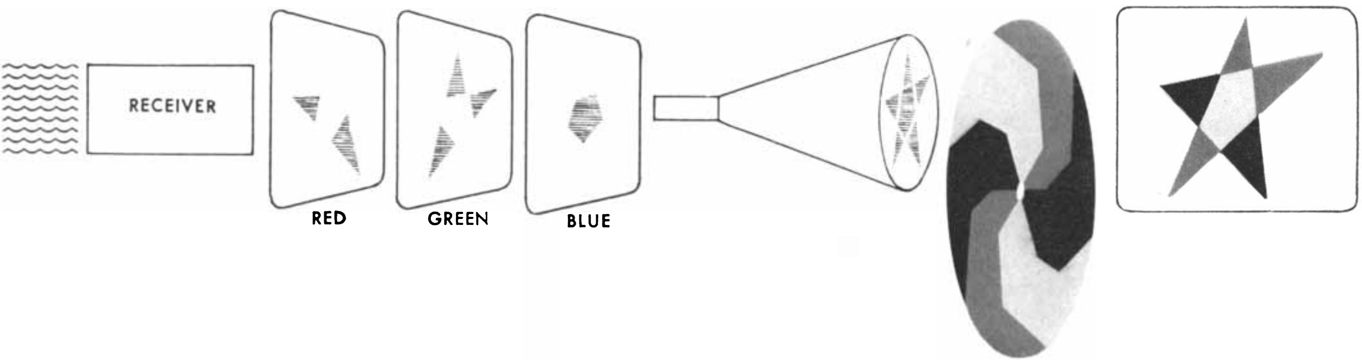
CTI or line-sequential system uses lenses and filters to focus three primary-color images on three separate regions of the light-sensitive element of the camera tube. All three images are then scanned by a single electron beam. A single line of each image is scanned in sequence; thus sequential lines representing red, green



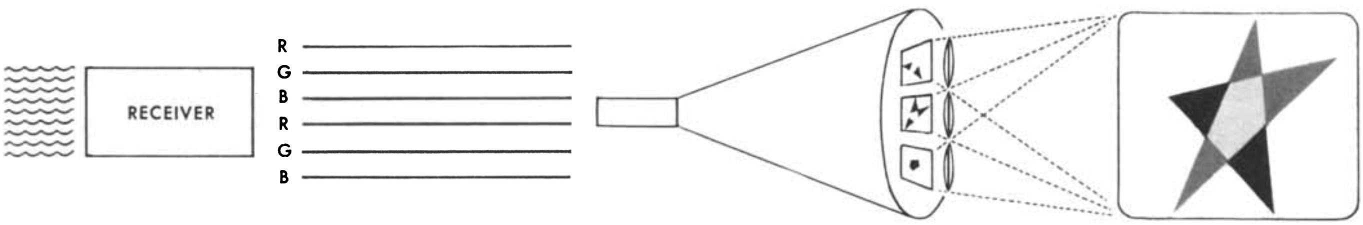
RCA or dot-sequential system uses dichroic mirrors to dissect the image into its three primary colors. Each primary-color image is then scanned in a separate camera tube. By means of a rotating switch small sections of the line scanned in each tube are interleaved in sequence; thus sequential dots representing each color are broadpany radio engineer R. B. Dome. His approach is based on the fact, well known to radio engineers, that the power in a repeating signal is concentrated in the general region of harmonics, or multiples, of the repetition frequency. That is, if a signal repeats itself 15,750 times a second, as does the television-scanning signal, and if the signal is the same or only slightly different each time it repeats, the power in the signal is concentrated in the neighborhood of 15,750 cycles, 31,500 cycles, 47,250 cycles and so forth. Very little power is to be found midway between these "harmonics." It follows that a television signal does not occupy the entire radio-frequency channel uniformly. There are "holes," or at least thin spots, in the video spectrum which could be utilized for transmitting other information, *e.g.*, signals carrying color information. Thus a complete simultaneous color-television picture might be transmitted within the radio-frequency band now assigned to black-and-white. The signal could be received either by an ordinary black-and-white television receiver or by a color-television receiver. This system has not yet, however, been reduced to practice.

Although the basic principle of adding color to present-day black-and-white television is the same, regardless of the system used, the various systems proposed differ among themselves in various degrees. Each system has its advantages and disadvantages. The fact that debate now centers on the relative merits of particular systems is sufficient evidence that color television is now a practical reality. Whatever system comes into common use, it is certain that the use of color will increase the value of television just as much as it has done for printing, photography and motion pictures. There is no doubt that even at the present stage of development color television is a great improvement over black-and-white. Color adds realism and depth to a picture, almost creating the illusion of a third dimension. The picture is not only more pleasing but carries more information.

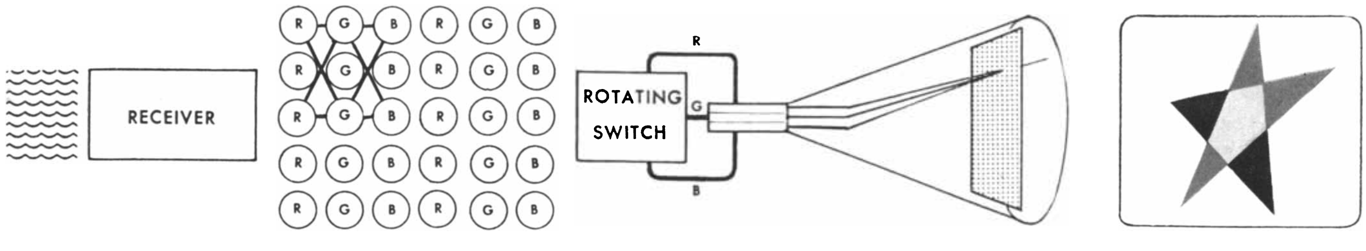
Newbern Smith is Chief of the Central Radio Propagation Laboratory of the National Bureau of Standards.



primary-color images which fall in sequence on the light-sensitive element of the camera tube. The three images are broadcast and received in sequential "fields." They are then reproduced in black-and-white on the face of a cathode-ray tube. The black-and-white image is converted into color by a second filter wheel.



and blue are broadcast and received. On the face of the cathode-ray tube of the receiver a single electron beam recreates the three images from the camera tube. Each image is projected upon a region of the tube coated with a phosphor that glows in one of the three primary colors. These three images are then assembled optically.



cast and received. The triangles on the dot pattern indicate how the lines of dots are interleaved. In the receiver another rotating switch manipulates three electron guns so that they project a color image through a perforated screen on the face of a cathode-ray tube coated with clusters of the three colored phosphors in a dot pattern.

HIBERNATION

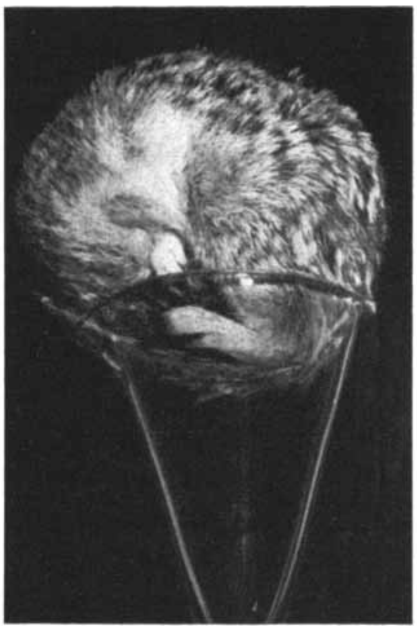
In winter many species of animals curl up and lower their body temperature to conserve their resources. Curiously the bear does not seem to be one of them

by Charles P. Lyman and Paul O. Chatfield

IN ALL the animal world only the mammals and birds are able to maintain a constant body temperature irrespective of the temperature of the environment. Their "warm-blooded" state has great advantages. A mammal or bird can go about its business in a normal manner in a wide range of climates. A cold-blooded animal, on the other hand, is utterly dependent on the environmental temperature. A snake can strike very quickly when it is warmed by the summer sun, but, as snake charmers have found to their profit, it is only necessary to chill the animal in the icebox to render it almost completely incapable of movement. Cold-blooded animals are also vulnerable to too much heat; on a hot day they must find a cool spot to stay alive.

Mammals and birds owe their relative independence of the environmental temperature to a complex thermo-regulatory system controlled largely by a biological thermostat in the hypothalamus, a small section of the brain just above the pituitary gland. It keeps the body temperature so constant that there is usually less than a degree Fahrenheit of fluctuation from day to day; indeed, when a human being runs a temperature one or two degrees above normal, it is automatically inferred that he is sick. The function of the thermostat is to regulate the production of heat by the body to balance the heat it loses to the environment. Except in very hot weather the body temperature is always higher than that of the environment. This means that the body must maintain a high metabolic rate to keep itself warm against the chilling effect of the outside air.

As the temperature of the environment becomes colder, the animal needs more and more food to stoke its internal furnaces and keep its temperature up to normal. The approach of winter's cold weather therefore presents a serious problem to mammals and birds. Most birds avoid the issue by migrating to warmer climates. But for the mammals migration is not so easy, and as a rule they remain in the same area winter and summer. Man, of course, solves the cold problem by wrapping himself in protections against the loss of body heat. Many other animals manage to stay active throughout the winter and eke out a slim existence, usually with the help of a heavier coat of fur. But there are quite a few mammals that surrender to winter's rigors by giving up activity. They have developed physiological adjustments whereby they can abandon the warm-blooded state and let their body temperature fall to that of the environment. In this condition all their chemical processes are slowed and they need much less food to keep alive.



GROUND SQUIRREL hibernates in the laboratory after its temperature has been reduced. Hibernating animals curl up to conserve their heat.

THIS IS the state known as "hibernation." Let us be clear, however, about our use of the word, for it unfortunately is commonly given various meanings. For the purposes of this article "hibernation" is defined as a condition characterized by a marked lowering of body temperature with a concurrent drop in metabolism, heart rate, respiration and other vital functions.

By this definition the most famous "hibernating" animal, the black bear, does not hibernate at all. It is true that the bear spends a great deal of the winter in a drowsy condition, but its body temperature always remains high. Although no one has actually taken a bear's temperature to prove the point (for understandable reasons), there is plenty of indirect evidence. For example, many hunters have reported finding bears curled up on the ground with a new-fallen snow melted from their backs. Moreover, when disturbed the bears make off at once, which would be impossible if the body temperature were near freezing. The most decisive proof is that the she-bear gives birth to her cub in midwinter. How she could give birth and suckle the cub with her body temperature allegedly near freezing has never been explained.

By the same criterion we need not pay serious attention to the occasional tales we hear of the alleged discovery of a state of hibernation in human beings. At various times Eskimos, Siberians and even Vermonters have been reported to have spent the winter in a lethargic state, taking neither food nor water and sometimes exposed to the elements. True hibernation, by our definition, is a manifest impossibility in a human being, for the simple reason that no man can survive a drastic reduction in his body temperature. This was emphasized by the atrociously inhuman "experiments" practiced by the Nazis at the Dachau concentration camp. Nude prisoners were exposed to air temperatures of 21 degrees F., well below freezing, for as long as 14 hours; others were immersed in water at about 36 to 54 degrees. It was found that the hardiest human subject, immersed in cold water, died when his rectal temperature had been lowered to 77 degrees.

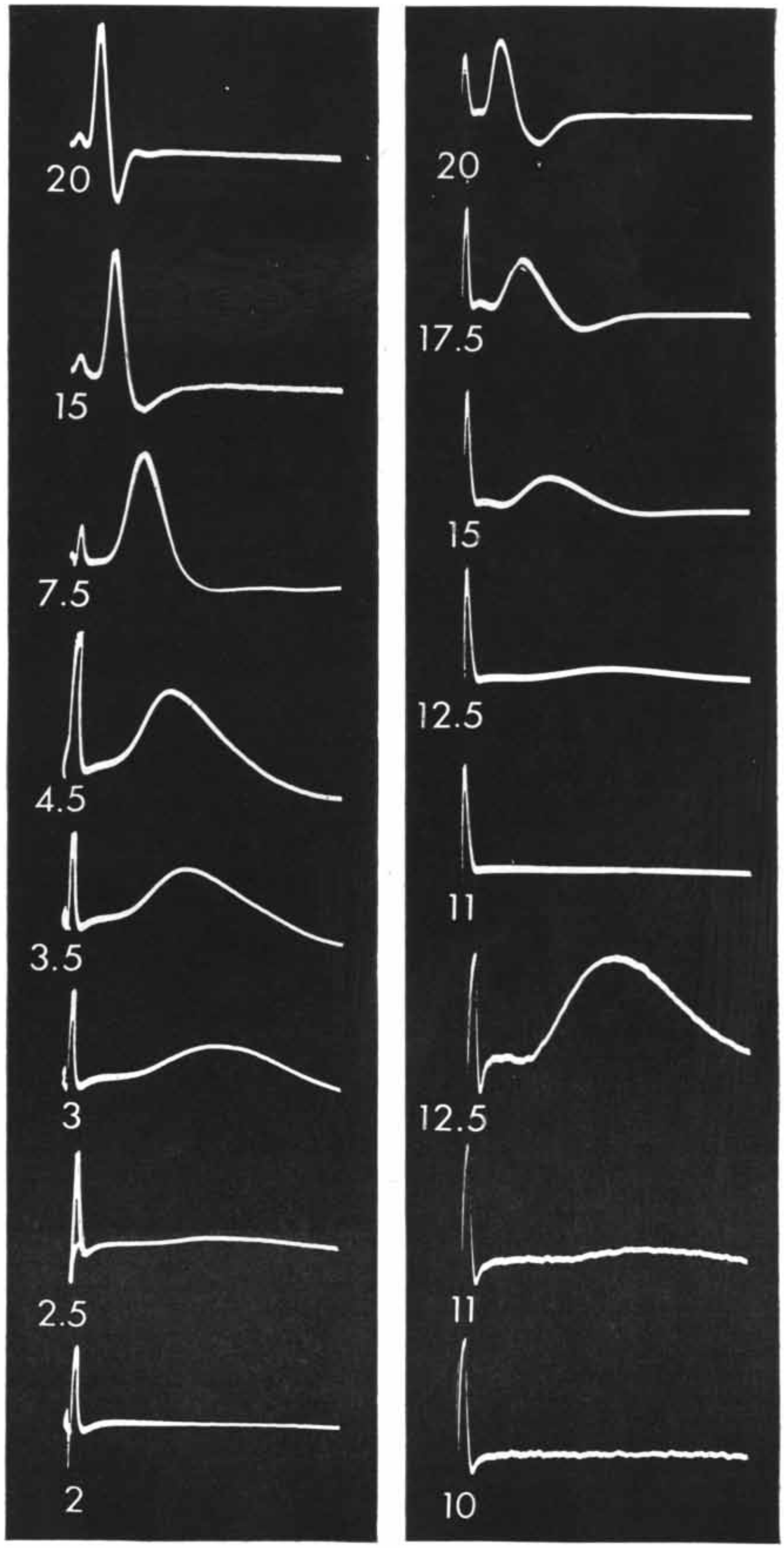
Thus it is clear that a human being cannot tolerate such a lowering of body temperature as occurs during deep hibernation, nor can a dog, cat, rabbit, rat, mouse, guinea pig, monkey or probably any other non-hibernating mammal. Moreover, it must be remembered that the body temperature of a non-hibernating animal does not usually fall to any extent, except under such extreme circumstances as the Dachau treatments, unless the thermo-regulatory mechanisms are first inactivated by an anesthetic. These mechanisms are also partially inactivated during sleep, which is the reason that falling asleep during exposure to cold is liable to be fatal.

LET US proceed, then, to the mammals that do really hibernate. Among them there are probably various degrees of hibernation. Some bats take to hibernation with the greatest ease; in fact, their body temperature and metabolic rate drop markedly every time they go to sleep. In the winter they hang up in caves and hibernate for long periods. As the temperature of the cave drops, the bats awake and move farther and farther from the cold entrance. Other primitive mammals that hibernate are the opossum and the European hedgehog. Hibernation occurs in a great many rodents, probably because they are at a particular disadvantage when the snow covers their food of grains and grasses. The rodent hibernators apparently eke out the winter in two different ways. Members of one group, represented by the woodchuck, become extremely fat and then live off this fat during the whole period of hibernation. Members of the other group, typified by the hamster, do not accumulate as much fat, but store grain for the winter in their burrows. From time to time they awake from hibernation and restore the tissues with some grain.

Naturalists have long believed that birds do not hibernate, notwithstanding Samuel Johnson's assertion that swallows "conglobulate together" and hibernate at the bottom of rivers during the winter. Within the last two years, however, two well-authenticated cases of hibernation in birds have been discovered. One bird, a "poorwill," was found immobile in the crevice of a rock with a body temperature of 64 degrees F. Experiments with the tiny hummingbird show that it, too, may tolerate surprising decreases in body temperature and metabolism.

Mammalian hibernation interested many of the early zoologists, and sporadic research on the subject has been going on for at least 100 years. Yet the fundamental causes of the condition are still a mystery.

Apparently the one essential prerequisite for hibernation is a moderately cold environment. Cold alone, however, will not necessarily cause hibernation, for some animals will live for months in



ACTION POTENTIALS of nerve in hamster, which hibernates, and rat, which does not, are compared at various temperatures. First peak on each trace is artifact; second is action potential. Hamster potential (*left*) persists down to 2 degrees C.; rat potential (*right*), only down to 10 degrees.

the cold before hibernating. When an animal does go into hibernation, it is generally agreed that it passes into this condition from a state of natural sleep. In hibernation there is evidently an effort to conserve heat, for in all mammalian hibernators except bats the animal rolls in a tight ball with its feet tucked beneath it.

Perhaps the most beguiling theory of the physiological cause of hibernation is the one advanced by the French physiologist Raphael Dubois in the 1890s. He noted that hibernators lived deep in a burrow with the mouth of the hole plugged by snow or dirt. Naturally the carbon dioxide of the air in the den increased, and Dubois claimed that this had a narcotic effect on the animal. He was able to show that carbon dioxide in high concentrations did have a narcotic effect, but his "autonarcosis" theory has not stood the test of time.

Since the development of endocrinology many have tried to implicate the endocrine glands in hibernation. Apparently an animal will not hibernate if the glands involved in metabolism are hyperactive. On the other hand, no one has been able to show that the removal of any one endocrine gland can induce hibernation. An animal can be made to go into a state of pseudo-hibernation by injecting various drugs such as insulin and magnesium. The body temperature drops and the animal becomes torpid. Unless the animal is given an injection of some counteracting drug, however, it will die without waking from hibernation, so this can hardly be called a natural hibernating state.

CONSIDERABLE study has been given to metabolism during hibernation. One test of metabolism is the respiratory quotient: the amount of oxygen an animal consumes divided by the amount of carbon dioxide it expires. This quotient is an indication of the type of food the animal is utilizing. When it consumes only carbohydrate, the quotient is 1; when it is living on pure fat, the quotient is low: .7. It has been definitely established that the respiratory quotient of a hibernating woodchuck is very close to .7, which means that it is living on its own store of winter fat. The metabolic rate during hibernation can be as little as 2 or 3 per cent of normal. A better way of reducing food requirements can hardly be imagined, and many woodchucks are still fat when they emerge from hibernation in the spring.

Even in deep hibernation a mammal does not lose all control of its thermoregulatory system. When the environmental temperature drops to near or below the freezing point (32 degrees F.), a hibernating hamster increases its metabolism sufficiently to maintain its body temperature above 37.4 degrees. If the temperature drops too low, the metabolism increases so much that the animal wakes up.

Apparently one of the principal reasons for the increase in a hibernating animal's metabolism when the environmental temperature drops below freezing is to enable its nervous system to continue functioning. Experiments have shown that a peripheral nerve of a hamster or woodchuck will not conduct impulses if the nerve is cooled to below 36.5 degrees F. (In a non-hibernating animal such as the rat the nerve cannot function below about 50 degrees.)

Thus there is an obvious limit to the cold that even a hibernating animal can stand. It cannot maintain itself in any den or burrow where the temperature drops much below freezing. Consequently it is not surprising that there are no hibernators very far north of the Arctic Circle. Apparently the one that lives farthest north is Parry's ground squirrel, which can be found at Point Barrow, the northern tip of Alaska. The mammals that live nearer the North Pole, such as lemmings, arctic hares and foxes, do not hibernate.

WHAT happens to the brain during hibernation? It is rather surprising to find that although the peripheral nerves can function at temperatures fairly close to freezing, the cortex of the brain apparently is incapable of electrical activity until its temperature has reached about 68 degrees F. As a hibernating animal begins to wake up, its muscles tense and it commences to shiver. But this initial activity must be controlled by nervous mechanisms below the level of the cortex. Not until the animal has warmed itself to somewhere around 68 degrees does it begin to make coordinated movements with its body and legs.

Thus during hibernation the animal's brain must be completely dormant, and the only parts of the nervous system that retain any activity are those which are of primary importance in the more basic functions of heat production and metabolic regulation. Further evidence of the inactivity of the higher nervous system comes from tests which show that the auditory nerve of the hamster cannot conduct impulses when the body temperature is below 64 degrees F. Hence it is highly improbable that hibernating animals can be awakened by sound; at low temperatures they must be, to all intents and purposes, quite deaf.

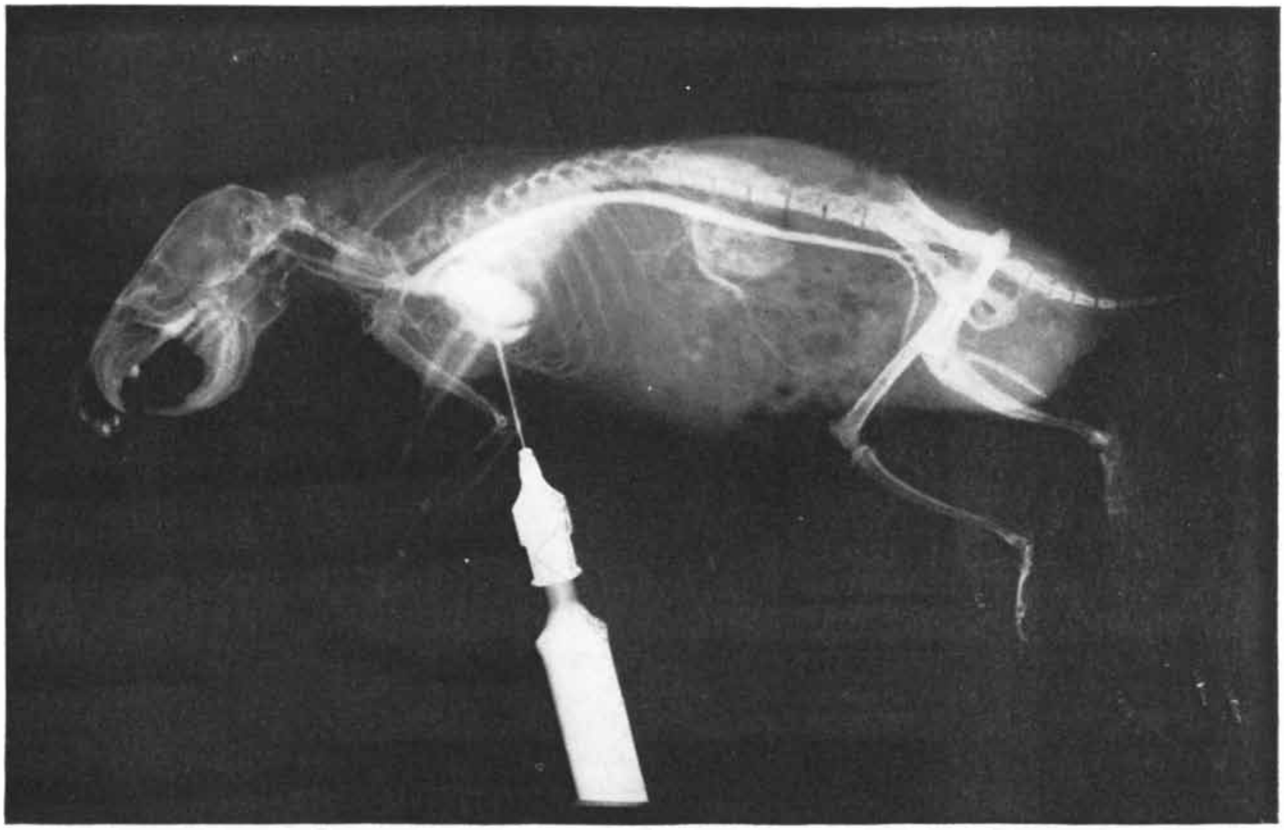
The process by which the hibernator rouses itself from hibernation is the most dramatic phase of the hibernating cycle. To start the process it is usually only necessary to move the animal. Once started, its awakening proceeds irreversibly until the animal reaches its normal body temperature of 98 degrees F. The process is very slow: the hibernating hamster, for instance, takes about three hours to come fully awake. The animal's heart rate, respiration and metabolism gradually speed up at a rising tempo; at the peak of the waking process the heart is racing at almost 600 beats a minute. The metabolism of a woodchuck waking from hibernation is actually much higher than can be obtained even by extraordinary forced exercise of the animal in the normal state.

During a hamster's arousal from artificially induced hibernation in the laboratory, it can be seen that the animal is making a maximum effort to generate heat. Its muscular efforts begin with feeble pawing movements and rise to convulsive struggling and shivering. Apparently the chief source of heat is muscular activity, for if the voluntary muscles are paralyzed by the drug curare the whole waking process is greatly slowed. As the animal awakes, its front part, containing the more vital organs, warms much faster than its posterior; indeed, the blood supply to the posterior is greatly reduced until the fore part reaches the normal body temperature.

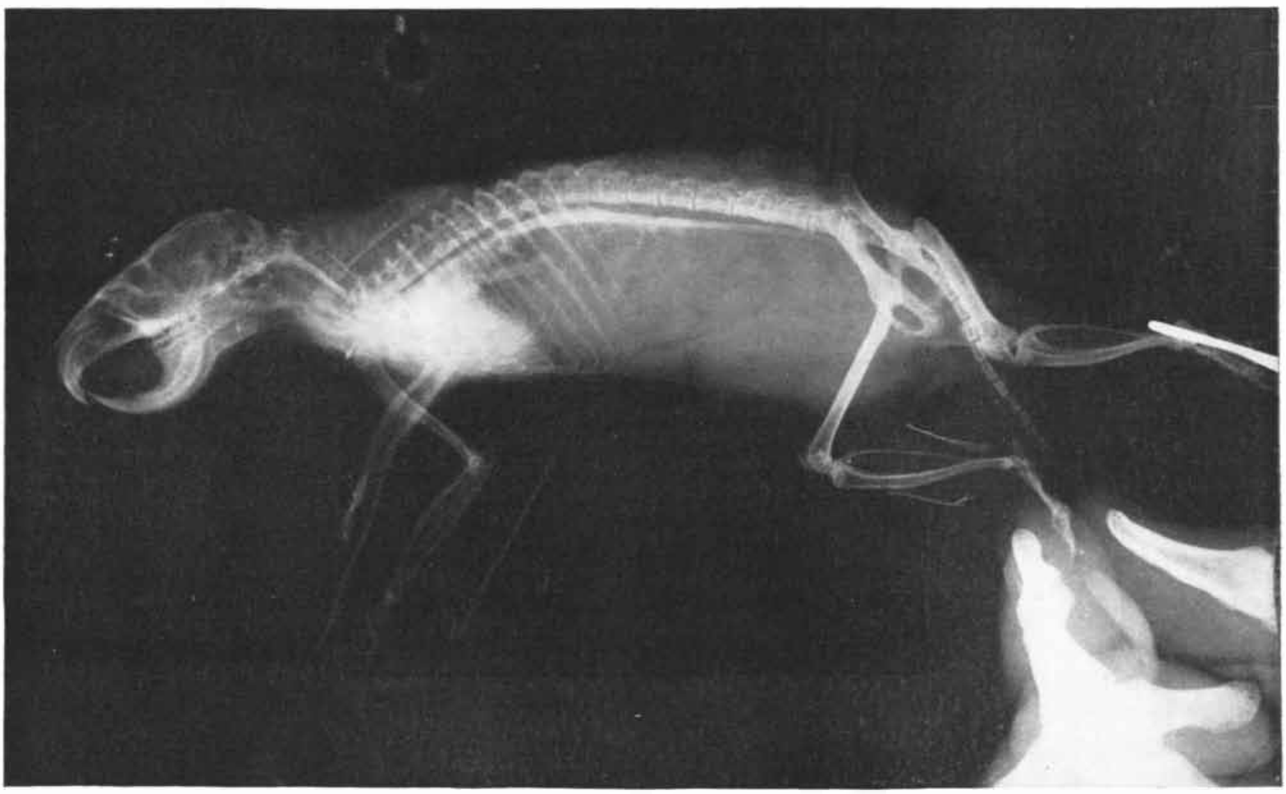
THE ORDERLY precision of events during the waking process, with the whole body attuned to producing heat and regaining the normal body temperature, indicates that the controlling factor must be in the central nervous system. There is every reason to believe that the area chiefly involved is the hypothalamus, the body's central thermostat. It has been shown that the hypothalamus is intimately connected with the sympathetic nervous system, which in turn adjusts blood flow, heart rate and other important functions during times of stress. The hypothalamus is also known to be intimately connected with normal and abnormal sleep.

Presumably when winter's cold comes, signaling the time for the animal to curl up and go to sleep, the hypothalamus undergoes some change so that it no longer tries to maintain the body at normal temperature. The animal then passes quickly into hibernation. The hypothalamus is not, however, completely inactivated; it still keeps the body temperature above freezing, and almost any kind of stimulus can trigger it into starting the waking process. The fundamental question that remains for investigators is: What mechanism causes the inactivation of the hypothalamus? It is possible that the answer to this question would shed some light on the equally puzzling question of what mechanism brings on normal sleep.

Charles P. Lyman is research associate in physiology at the Harvard Medical School and assistant curator of mammals at the Harvard University Museum of Comparative Zoology. Paul O. Chatfield is associate in physiology at the Harvard Medical School.



NON-HIBERNATING HAMSTER was X-rayed only 3 seconds after a fluid opaque to X-rays had been injected into its heart. The X-ray plate shows that the fluid quickly passed into the hamster's circulatory system. It is visible as the outline of the aorta, the mesenteric and femoral arteries and the blood vessels of the kidneys.



HIBERNATING HAMSTER was X-rayed 36 seconds after the same fluid had been injected into its heart. At the same time it was also wakened. Only the outline of the aorta and some small blood vessels about the head are visible, indicating that the fluid is passing very slowly through the circulation of the hibernating animal.

SYMBOLIC LOGIC

It is a language that manipulates ideas as algebra manipulates numbers. It has been applied with notable success to practical problems requiring unusually precise and economical reasoning

by John E. Pfeiffer

WHAT NUMBER added to one fifth of itself equals 21? This problem was too difficult for most of the scholars of ancient Egypt. According to papyrus records, many arithmeticians struggled with it in vain before a patient Egyptian finally arrived at the correct answer about 1600 B.C. Today a ninth-grade algebra student can find the answer in a moment: $x+x/5=21$; therefore $x=17\frac{1}{2}$. What made the problem hard for the Egyptians was that they lacked our handy symbols, *i.e.*, digits for numbers and x for the unknown. Since they had to use words to represent numbers, their operations in arithmetic and algebra were cumbersome and slow.

The substitution of symbols for words is one of the things that has been largely responsible for man's progress in science. Yet in the process of logic—the basic tool with which we must test all ideas and also solve most of our everyday problems—we are still laboring under the Egyptians' handicap. We are at the mercy of the inadequacies and clumsiness of words.

Consider this simple exercise in logic, taken from a textbook on the subject by Lewis Carroll, mathematician and author of *Alice's Adventures in Wonderland*:

No kitten that loves fish is unteachable.

No kitten without a tail will play with a gorilla.

Kittens with whiskers always love fish.

No teachable kitten has green eyes.

No kittens have tails unless they have whiskers.

One, and only one, deduction can be drawn from this set of statements. After considerable trial and error you may find the answer by rewording and rearranging the statements:

Green-eyed kittens cannot be taught.

Kittens that cannot be taught do not love fish.

Kittens that do not love fish have no whiskers.

Kittens that have no whiskers have no tails.

Kittens that have no tails will not play with a gorilla.

The one valid deduction, then, is that green-eyed kittens will not play with a gorilla.

But now take a problem that is somewhat more complicated. The following is adapted from an examination in logic prepared recently by the mathematician Walter Pitts of the Massachusetts Institute of Technology:

If a mathematician does not have to wait 20 minutes for a bus, then he either likes Mozart in the morning or whisky at night, but not both.

If a man likes whisky at night, then he either likes Mozart in the morning and does not have to wait 20 minutes for a bus or he does not like Mozart in the morning and has to wait 20 minutes for a bus or else he is no mathematician.

If a man likes Mozart in the morning and does not have to wait 20 minutes for a bus, then he likes whisky at night.

If a mathematician likes Mozart in the morning, he either likes whisky at night or has to wait 20 minutes for a bus; conversely, if he likes whisky at night and has to wait 20 minutes for a bus, he is a mathematician—if he likes Mozart in the morning.

When must a mathematician wait 20 minutes for a bus?

The reader is not advised to try to work out the solution, for this problem is practically impossible to handle verbally.

ALTHOUGH these particular brainteasers are artificial and trivial, in form they are quite typical of problems that arise every day in modern engineering and business operations. Many of the problems are so complex that they cannot be solved by the conventional processes of verbal logic. The necessary facts may all be known, but their interrelationships are so complex that no expert can organize them logically. In other words, the bigness of modern machines, business and government is creating more and more problems in reasoning which are too intricate for the human brain to analyze with words alone.

As a result a number of corporations and technicians have recently begun to take an active interest in the discipline known as symbolic logic. This invention, devised by mathematicians, is simply an attempt to use symbols to represent ideas and methods of handling them, just as symbols are employed to solve problems in mathematics. With the shorthand of symbolic logic it becomes possible to deal with such complex problems as the Pitts conundrum about the mathematician waiting for the bus.

Formal logic, as every schoolboy knows, began with the syllogisms of Aristotle, the most famous of which is: "All men are mortal; all heroes are men; therefore all heroes are mortal." The Greek philosopher set forth 14 such syllogisms and believed that they summed up most of the operations of reasoning. Medieval theologians added 5 syllogisms to Aristotle's 14. For hundreds of years these 19 syllogisms were the foundation of the teaching of logic.

Not until the 19th century did anyone successfully apply symbols and algebra to logic, in place of the verbalisms of Aristotle and his followers. In 1847 an English schoolteacher and mathematician named George Boole published a pamphlet called *The Mathematical Analysis of Logic—Being an Essay Towards a Calculus of Deductive Reasoning*. In it he stated a set of axioms from which more complex statements could be deduced. The statements were in algebraic terms, with symbols such as x and y representing classes of objects or ideas, and the deductions were arrived at by algebraic operations. Thus Boole became the inventor of symbolic logic. His work was followed up by mathematicians in many countries. Their chief aim was to use symbolic logic to solve logical paradoxes and other fundamental problems of mathematical thinking. By 1913 Alfred North Whitehead and Bertrand Russell, using a system of symbols invented by the Italian mathematician Giuseppe Peano, had developed a formal "mathematical logic," which they presented in their *Principia Mathematica* (see "Mathematics," by Sir Edmund Whittaker; SCIENTIFIC AMERICAN, September, 1950).

Today symbolic logic is an important

branch of mathematics, occupying the full time of about 200 mathematicians in the U. S. alone. But the main subject of this article is its practical applications in engineering and business.

LET US first take a few simple illustrations to indicate some of the basic symbols and operations employed in symbolic logic. Any single proposition, however simple or complex, is represented by a letter of the alphabet. For example, the letter *a* can stand for the statement "The sun is shining," or for something more involved, like "The three-power commission has been directed to look into the question of whether or not a West German federal police force should be created." Then certain special symbols are used to show relations between propositions. A dot, for example, stands for the word "and." Thus the two-proposition statement "The sun is shining and it is Thursday" can be represented by the expression $a \cdot b$.

The symbol $\supset$ stands for the logical relationship "if . . . then." Thus the assertion "If you love cats, then you are a true American" can be written $a \supset b$. Now by the use of other symbols and by operations similar to those in ordinary algebra, this statement can be transformed into a fully equivalent expression in another form. For example, using the symbol *v*, which stands for the word "or," and a superposed bar, representing the negative, the expression becomes $\bar{a}\ v\ b$, meaning "You do not love cats or you are a true American." The statement can also be transformed into one containing the symbol for "and." Thus $\overline{\bar{a} \cdot b}$ means "It is not the case both that you do not love cats and that you are a true American," or in ordinary English: "You cannot be indifferent or hostile to cats and also be a true American."

It is important to bear in mind that the symbols have nothing to do with the truth or falsity of the propositions themselves, just as algebra is not concerned with whether its symbols stand for apples or hours. The operations of symbolic logic can only show that, given certain premises, certain conclusions are valid and others are invalid. In this case, assuming that only cat-lovers are true Americans, if you are not a cat-lover the only logically valid conclusion is that you are not a true American, however debatable the proposition may be as a moral principle. The establishment of factually accurate premises is outside the province of logic; its concern is with the validity of the conclusions drawn from a given set of facts or assumptions.

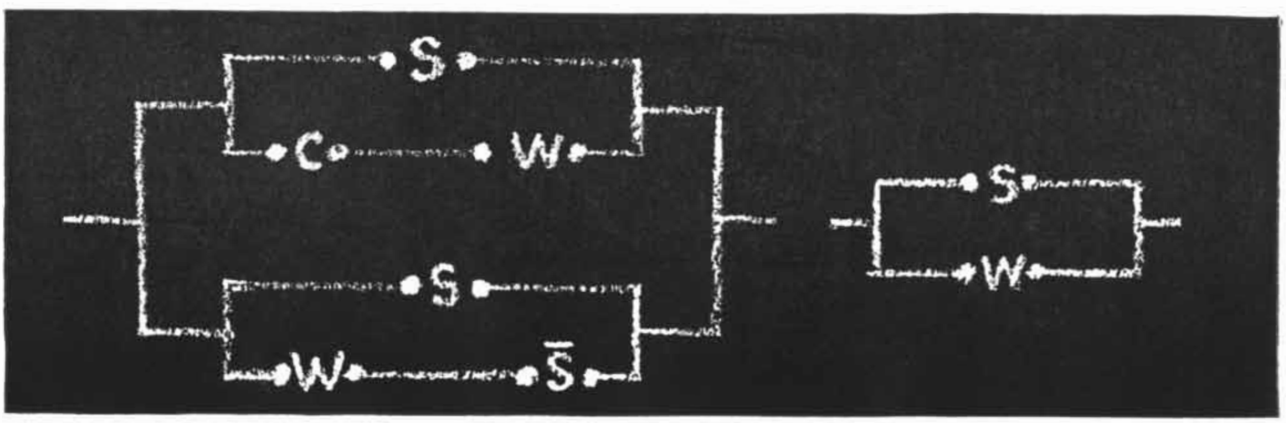
By means of simple signs such as those here illustrated, symbolic logic reduces complex logical problems to manageable proportions. The symbols, like the schoolboy's algebra signs, do much of the logician's thinking for him. Large numbers of propositions can be related to one another in easy algebraic terms; equations can be arranged and rearranged, simplified and expanded, and the results, upon retranslation into English, can reveal new forms of statements that are equivalent to the original or can disclose inconsistencies.

THE FIRST application of symbolic logic to a business problem was made in 1936 by the mathematician Edmund C. Berkeley, who is also the designer of the small mechanical brain known as Simple Simon (SCIENTIFIC AMERICAN, November, 1950). Berkeley, then with the Prudential Life Insurance Company, applied symbolic logic to a difficult problem having to do with the rearrangement of premium payments by policyholders. Every year hundreds of thousands of persons request changes in the schedule of payments on their policies, and there is a bewildering array of factors that must be taken into account in making such changes. The company had devised two sets of rules, intended to take care of all possible cases. Were the two rules equivalent? Berkeley suspected that they were not; that there might be cases in which one rule would call for one method of rearranging the payments and the other for a different method.

His problem was to prove that such cases existed. It was hopeless to try to analyze the possibilities by ordinary verbal logic. One part of one of the rules, for example, stipulated that if a policyholder was making premium payments several times a year, with one of the payments falling due on the policy anniversary, and if he requested that the schedule be changed to one annual payment on the policy anniversary, and if he was paid up to a date which was not an anniversary, and if he made this request more than two months after the issue date, and if his request also came within two months after a policy anniversary—then a certain action should be taken. These five ifs alone can occur in 32 combinations, and there were many other factors involved.

Berkeley decided to reduce the many clauses and possible combinations and actions to the algebraic shorthand of symbolic logic. The stipulation detailed above, for example, could be written $a \cdot b \cdot \bar{c} \cdot d \cdot e \supset C$, meaning that if the conditions *a, b,* $\bar{c}$, *d* and *e* existed, then the action C was called for. By an algebraic analysis Berkeley was able to show that there were four types of cases in which the two rules would indeed conflict, and an examination of the company's files revealed that such cases actually existed. The upshot of Berkeley's work was that the two rules were combined into one simpler and consistent rule.

Symbolic logic has since been used in many other insurance problems. Mathematicians at Equitable, Metropolitan, Aetna and other companies have applied it to the analysis of war clauses and employee eligibility under group contracts. And other corporations have found symbolic logic very helpful in analyzing their contracts. Contracts between large corporations may run into many pages of fine print packed with stipulations, contingencies and a maze of ifs, ands and buts. Are the clauses worded as simply as they might be? Are there loop-



SWITCHING CIRCUITS may be analyzed and simplified by symbolic logic (*see text*). The switches are represented by symbols. Each of these two circuits has the same functions. The one at the left is "redundant."

holes or inconsistencies? A symbolic analysis can readily answer such questions, and lawyers have begun to call on mathematicians to go over their contracts.

Another interesting use of the technique is in checking the accuracy of censuses and of polling reports. If a public opinion poll-taker reports that he has interviewed 100 persons, of whom 70 were white, 10 were women and 5 were Negro men, it is easy enough to see that something is wrong with his figures. But take an actual case such as this: A census of 1,000 cotton-mill employees listed 525 Negroes, 312 males, 470 married persons, 42 Negro males, 147 married Negroes, 86 married males, 25 married Negro males. Are these numbers consistent? Symbolic logic can give the answer quickly.

IN ENGINEERING symbolic logic is particularly useful for the analysis of electric circuits. A circuit can be likened to a contract—it has alternatives, contingencies and possible loopholes, the chief difference being that it uses patterns of switches instead of words and clauses.

More than a dozen years ago Claude E. Shannon, then still a student at the Massachusetts Institute of Technology, began to explore the application of symbolic logic to such problems. At the Bell Telephone Laboratories he has recently completed an elaborate analysis of switching circuits by "engineering logic."

Suppose, to take a simple example, the problem is to simplify the six-switch circuit schematized in the left-hand drawing on the preceding page. The switches are given various symbols. The one labeled C is independent of all the others. The two W switches are connected so that they open and close together. The two S switches also operate together. The sixth switch is designated $\bar{S}$ (not-S, or the opposite of S), because it is open when the S switches are closed and *vice versa*.

There are four possible paths across this circuit from one side to the other. Current will flow across it when the upper S switch is closed, when the C and the upper W switches are closed, when the lower S switch is closed and when the lower W and $\bar{S}$ switches are closed. In the language of symbolic logic this sentence becomes $S\ v\ W \cdot C\ v\ S\ v\ \bar{S}\ W$, with the symbol *v*, as we have seen, meaning "or." It is at once evident that we can drop one S, since S is equivalent to the expression $S\ v\ S$. The statement now becomes $W \cdot C\ v\ S\ v\ \bar{S} \cdot W$. Next, we can simplify further by dropping the $\bar{S}$, for $S\ v\ W$ is the logical equivalent of $S\ v\ \bar{S} \cdot W$—just as the statement "Williams struck out or Williams did not strike out and walked" is the same as "Williams struck out or walked." This reduces the circuit to $S\ v\ W\ v\ W \cdot C$. A further analysis shows that $W\ v\ W \cdot C$ is equivalent to W. Logically speaking, the statement "Williams walked or Williams walked and was left at first base" provides only one unequivocal piece of information, namely that Williams walked. So the entire circuit boils down to $S\ v\ W$. It can be redesigned in a simple form, illustrated in the right-hand drawing on the preceding page, which eliminates four "redundant" switches and is fully equivalent to the original.

To use symbolic logic on a problem as simple as this would be like killing a mouse with an elephant gun. But in designing more complex circuits the method may save considerable time and money. At the Bell Laboratories, for example, a group of engineers some time ago undertook to design a special coding instrument. Applying conventional methods of analysis, they produced a 65-contact circuit for the job after several days of work. Then an engineer trained in symbolic logic, starting from scratch without seeing their design, designed an equally successful circuit, with 18 fewer contacts, in only three hours. Today more than 50 Bell engineers use symbolic logic in their work. The method has been applied successfully to a wide variety of problems, but it is not the final answer to all circuit difficulties. Its use is limited mainly to telephone equipment with about nine two-contact relays, which may be in 512 possible positions. In its present infant state even this powerful method of analysis cannot handle the breath-taking complexity of large central exchange stations where a single telephone call may cause the opening and closing of 10,000 contacts.

Perhaps the chief use of symbolic logic is in the design of large-scale electronic calculating machines. Eniac, the first of these machines, contains about 20,000 tubes and 500,000 soldered connections. One of the most important problems in the attempts to build more efficient and more elaborate computers is to reduce the number of tubes, and symbolic logic has been helpful in simplifying the circuits. For example, in building the Mark III all-electronic computer at the Naval Proving Ground in Dahlgren, Va., the engineers decided that a nine-tube circuit was about the minimum that would serve for its adding units. But Theodore Kalin and William Burkhart of the Harvard Computation Laboratory, applying symbolic logic, reduced it to six tubes.

THESE applications merely suggest the fruitful future that lies ahead for symbolic logic, not only in business and engineering but in science. Wherever complex problems in logical analysis arise, the new shorthand may help to find solutions. One such field is biology, which is beset with a host of complex logical problems. Already Walter Pitts and Warren McCulloch of the University of Illinois Medical School have begun to employ the symbolic logic of the *Principia Mathematica* in an effort to analyze some of the relationships among the 10 billion nerve cells in the human brain. Norbert Wiener of M.I.T. emphasizes that the new study of cybernetics, which analyzes similarities between the brain and computing machines, leans heavily on modern logic.

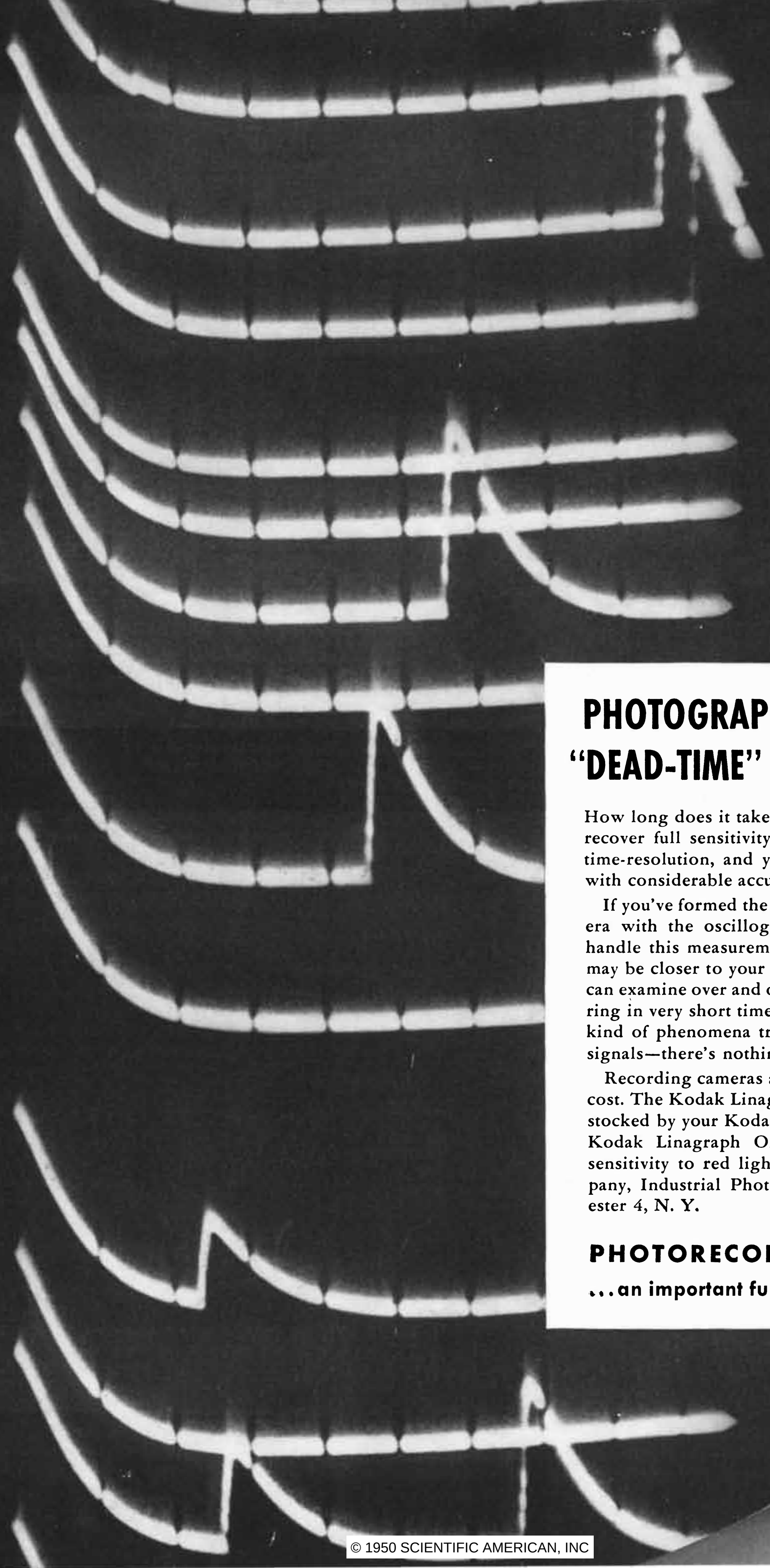
Although its applications are steadily widening, the major part of the work being done in symbolic logic is still in the field of mathematics. In mathematics this new tool has had so powerful an influence during the past four decades that today some consider mathematics to be only a branch of logic. Mathematicians are applying symbolic logic to examine some of the basic assumptions upon which mathematical theories have been built—assumptions that have long been taken for granted as "obvious" but have never been subjected to rigorous analysis. They are using it to try to resolve verbal paradoxes, which have always baffled logicians: *e.g.*, "All rules have exceptions," a rule which denies itself, since by its own assertion this statement must also have exceptions and therefore cannot be true. Many other basic problems in logic and mathematics are being explored by the new analysis.

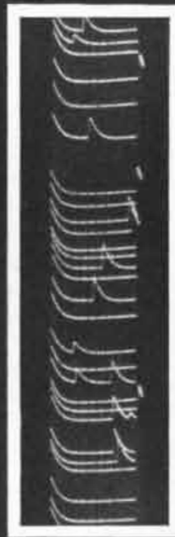
Indeed, modern logicians, assisted by the powerful new technique, have punched the classical Aristotelian system of logic full of holes. Of the 19 syllogisms stated by Aristotle and his medieval followers, four are now rejected, and the rest can be reduced to five theorems. Modern logic has abandoned one of Aristotle's most basic principles: the law of the excluded middle, meaning that a statement must be either true or false. In the new system a statement may have three values: true, false or indeterminate. A close analogy to this system in the legal field is the Scottish trial law, which allows three verdicts—guilty, not guilty or "not proven."

BECAUSE the use of symbols sometimes makes it possible to determine by purely routine operations whether or not a particular statement follows from given assumptions, symbolic logicians have experimented in designing logical machines. Kalin and Burkhart have, for example, built one that can check Aristotelian syllogisms or solve certain insurance problems, and workers at the University of Manchester in England are developing a more elaborate machine.

Not even symbolic logic will ever produce a machine that can do all man's thinking for him. But some logicians believe that symbolic logic may lead to the construction of synthetic languages that will help to free scientific thinking from the murky tyranny of words.

John E. Pfeiffer is the author of Enzymes *and other articles that have appeared in this magazine.*





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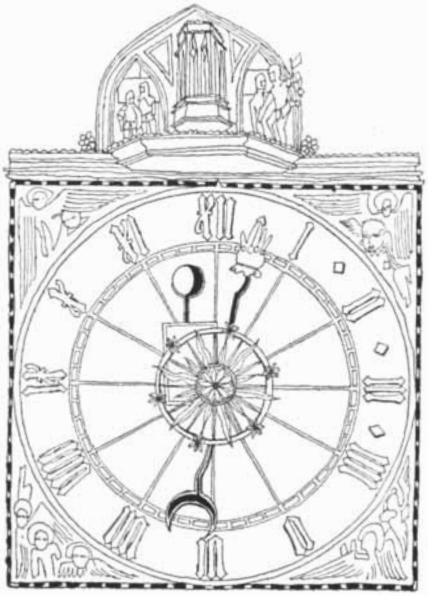


SCIENCE AND

The National Science Board

THE National Science Foundation, which became law last spring and barely received an appropriation this fall, slowly approaches practical reality. On November 2 President Truman announced the appointment of the 24-man National Science Board that will administer the Foundation. The members of the Board, who will elect their own chairman, are:

Sophie B. D. Aberle, special research director of the University of New Mexico.

Chester I. Barnard, president of the Rockefeller Foundation.

Robert Percy Barnes, head of the department of chemistry at Howard University.

Detlev W. Bronk, president of The Johns Hopkins University.

James Bryant Conant, president of Harvard University.

Gerty T. Cori, professor of biological chemistry at Washington University Medical School and co-winner of the 1947 Nobel prize for physiology and medicine.

John W. Davis, president of West Virginia State College.

Charles Dollard, president of the Carnegie Corporation.

Lee A. DuBridge, president of the California Institute of Technology.

Edwin B. Fred, president of the University of Wisconsin.

Paul M. Gross, dean of the Duke University Graduate School.

George D. Humphrey, president of the University of Wyoming.

O. W. Hyman, dean of the medical school and vice president of the University of Tennessee.

Robert F. Loeb, professor at Columbia University's College of Physicians and Surgeons.

Donald H. McLaughlin, president of the Homestake Mining Company of San Francisco and formerly dean of the College of Engineering at the University of California.

Frederick A. Middlebush, president of the University of Missouri.

Edward L. Moreland, partner in the Boston engineering firm of Jackson & Moreland and executive vice president of the Massachusetts Institute of Technology.

Joseph C. Morris, head of the physics department and vice president of Tulane University.

Harold Marston Morse, professor of mathematics at Princeton University.

Andrey A. Potter, dean of engineering at Purdue University.

James A. Reyniers, director of the bacteriology laboratories at Notre Dame University.

Elvin C. Stakman, chief of the division of plant pathology and botany at the University of Minnesota.

Charles E. Wilson, president of the General Electric Company.

Patrick Henry Yancey, head of the department of biology at Spring Hill College.

AEC Appointment

LAST month the Atomic Energy Commission filled the most important job in its domain. To the office of general manager the Commission appointed Marion W. Boyer. Since the resignation of Carroll L. Wilson in August the position had been temporarily held by Carleton Shugg, who now returns to his former post as deputy general manager.

Before his appointment Boyer, a chemical engineer, had been a vice president of the Esso Standard Oil Company. Where Wilson had been appointed by President Truman, Boyer was appointed by the Commission. This was in accordance with new legislation that had been requested by AEC Chairman Gordon E. Dean after Wilson's resignation.

Nobel Prizes

IN recent years the Nobel prizes in science have generally been awarded for work a decade or more old, which in part reflected the wartime hiatus in basic research. In contrast the Nobel awards for 1950, announced last month, began to recognize major postwar discoveries. In physics and medicine the prizes went for important current work. The 1950 winners:

Physiology and Medicine: Philip S. Hench and Edward C. Kendall of the Mayo Clinic, Rochester, Minn., and Tadeus Reichstein of the University of

Basle, Switzerland, "for their discoveries concerning the suprarenal cortex hormones, their structures and biological effects." Kendall and Reichstein are the discoverers of cortisone, and Hench was the first to use it for rheumatic patients.

Physics: Cecil F. Powell of the University of Bristol in Britain, for his work on the medium-size nuclear particles called mesons. Together with G. P. S. Occhialini and C. M. G. Lattes, Powell in 1947 discovered the heavy *pi* mesons of mass 320.

Chemistry: Otto Diels and Kurt Alder of Germany, for discovery in 1927-28 of the Dien synthesis, a method by which odors and complicated chemical compounds can be produced artificially.

The Nobel prize in literature for 1950 was awarded to the British philosopher and mathematician Bertrand Russell, the first scientist to win this award.

The Mathematics of Doom

UNTIL last February few persons seriously thought that atomic weapons might actually annihilate the human race. Then Leo Szilard, a wartime worker on the atomic bomb who is now a biophysicist at the University of Chicago, suggested a means: a 500- to 10,000-ton hydrogen bomb that would produce enough radioactive dust to poison the entire atmosphere.

Szilard's suggestion has now been critically examined by James R. Arnold of the University of Chicago's Institute for Nuclear Studies. Writing in the *Bulletin of the Atomic Scientists,* Arnold breaks Szilard's argument down into six points:

1. *The necessary deuterium can be produced.* True, says Arnold, although making 10,000 tons of this isotope of hydrogen would require $40 billion and a 5- to 10-year all-out effort by a major industrial nation.

2. *If produced, this amount of deuterium can be exploded, either in one package or in many.* Perhaps, says Arnold. He quotes Sumner Pike of the Atomic Energy Commission, who has called the hydrogen bomb "between possible and probable."

3. *In such an explosion, about 50 tons of neutrons will be produced.* Correct, says Arnold.

4. *These neutrons can be absorbed in an element giving rise to a dangerous radioactive isotope.* Maybe, says Arnold. Such an isotope must be sufficiently radioactive, must have a half-life neither too short nor too long and must be made from an element available in sufficient quantity. Arnold finds only two

elements that meet these conditions: zinc and cobalt. Cobalt, which would yield eight times more gamma radiation than zinc, is the poison of choice. The problem is to guarantee that enough of the neutrons are actually absorbed by the cobalt and not dissipated uselessly by the explosion. For this purpose Arnold sees a need for a shell of 100,000 tons of cobalt around the exploding deuterium.

5. *The amount of radioactivity produced, if distributed uniformly as a dust layer over the earth, would irradiate every human being intensely enough to cause death.* True, says Arnold.

6. *The radiation could be effectively distributed in this manner.* Here Arnold disagrees with Szilard. Because dust will be removed from the atmosphere by rain, and from the land by runoff into rivers and oceans, "many areas will be left relatively clean." For this reason Arnold concludes: "It is almost certainly not true that a weapon of the type described can wipe out the human race completely." But he tempers this optimistic note: "It is possible, however, that the vast majority of the race can be killed off in this way. . . . Moreover, it is apparent that advances are to be expected, and a repetition of this discussion 10 years from today may give very different results."

Delinquency Unraveled

EVERYONE knows that children from crowded, low-income neighborhoods are more likely to become delinquent than children from more prosperous neighborhoods. The question remains: Why do some children from slum areas become delinquent while others do not? This is the problem studied for 10 years by Sheldon and Eleanor Glueck of the Harvard Law School, who have published their findings in the book *Unraveling Juvenile Delinquency.*

The Gluecks compared 500 delinquent boys from Boston with 500 nondelinquents nearly identical with them in age, intelligence quotient, national origin, and residence in underprivileged neighborhoods. After exhaustively investigating each boy and his background by several methods of modern psychology and sociology, they found three points of difference between delinquents and nondelinquents: family relations, character traits and personality.

The family relations of the typical delinquent boy were characterized by discipline that was either too lax or too strict, by lack of affection and supervision of the children by their parents, and by lack of family cohesion. The typical delinquent character traits were assertiveness, defiance, suspicion, destructiveness and impulsiveness. The personality of the delinquent was typically adventurous, extroverted, suggestible, stubborn, and emotionally unstable.

Any one of these three measures applied separately was a good indicator of whether a boy would become delinquent. All of them applied together were wrong in only 2.4 per cent of the cases. The Gluecks also identified certain factors as definitely not associated with delinquency: height, weight, bad teeth, home furnishings, culture conflict, domination of the family by the mother, and age at which the boy entered school.

Private Nuclear Research

THE first nuclear reactor to be operated without government supervision has been authorized for North Carolina State College. The reactor will be built, owned and operated by the University of North Carolina, of which the College is a part. Uranium fuel will be lent the College by the Atomic Energy Commission. The project is permissible under the Atomic Energy Act because the amount of plutonium that will be produced, less than a gram a year, would be "insignificant" in the manufacture of atomic weapons. The reactor will consume less than three grams of uranium a year. It will develop a maximum power of only 10 kilowatts, as compared to the 30,000 kilowatts of the new research reactor at Brookhaven National Laboratory. The College expects to use the reactor primarily for non-secret studies of atomic energy.

The announcement of the North Carolina reactor came less than a month after the start of a fund-raising campaign for another non-government atomic research center. The University of Michigan is seeking $6.5 million to do independent, non-secret research in atomic energy. It will investigate such problems as the shielding, materials and design required for a power reactor, the applications of nuclear physics in medicine and biology, and atomic energy's social aspects.

Salt Water for Shock

IN the treatment of shock, drinking quarts of salt water is an adequate substitute for injecting blood plasma, the U. S. Public Health Service has announced. The recommended solution is quite palatable: one teaspoonful of table salt and one-half teaspoonful of baking soda for each quart of water. A patient may require as much as 10 quarts a day.

The new treatment was first investigated with mice by Sanford M. Rosenthal of the National Institutes of Health. It was then tested with human patients by Frederick Coller of the University of Michigan and Carl A. Moyer of the University of Texas. Said Moyer: "Personal clinical experience has convinced me that the orally administered salt solutions are valuable in the treatment of shock incident to burns, fractures, peritonitis, and acute anaphylactoid reactions [allergic shock]."

The treatment is expected to be useful

in any large-scale disaster where adequate supplies of plasma are not immediately available. It would have obvious utility in the case of an atomic bombing, where 60 per cent of the surviving population might suffer from burns. Cautioned Surgeon General Leonard A. Scheele of the Public Health Service: "While of enormous benefit in the event of large-scale disaster, [the new treatment] must not be construed as lessening in any way the importance of blood-bank programs. Whole blood and plasma are still essential."

Hazards of the Stratosphere

WHEN intercontinental flight through the stratosphere becomes a reality, the hazard of cosmic radiation must be considered. At sea level the physiological effects of the radiation are negligible, but, as the investigations of physicists have shown, its intensity increases with altitude. Airplanes have already climbed to 60,000 feet, and instrument-bearing rockets have gone many times higher. What would be the consequences of regular flight at more than 60,000 feet? A study of this question has been made by Hermann J. Schaefer of the U. S. Naval School of Aviation Medicine in Pensacola, Fla. He estimates cosmic radiation at 70,000 feet as 15 milliroentgens per day. Because cosmic-ray particles are much more damaging to tissue than gamma- or X-rays, this is equivalent to something between 75 and 150 milliroentgens a day of X-rays—which is in excess of the radiation safety standard set by the Atomic Energy Commission. Such doses will still not cause appreciable physiological damage. "But," says Schaefer, "the prospect that future commercial air traffic will be performed at those altitudes and an increasing percentage of the population will be exposed to those dosages is bad from a genetic viewpoint."

Beyond 70,000 feet the situation becomes more serious. Says Schaefer: "At 90,000 feet, you find that about 15 times more cells are hit by heavy nuclei than by alpha particles from the natural concentration in the tissue. That means the toxic limit of bombardment is clearly surpassed." The fliers would not necessarily be killed. Schaefer says: "We can expect that the harmful effects are slowly accumulating. It might take 20 or 50 or 100 hours of exposure to produce the first symptoms." Recalling the altitudes attained by the pioneer balloonists, Schaefer concludes that "the idea of the Montgolfier brothers to send up some test animals on the very first flight was very good. We should do the same."

Plague in the U. S.

THERE were five cases of bubonic plague in New Mexico between July, 1949, and July, 1950, and eight more suspected cases from California to Texas. Although plague is still a rare disease in the U. S., it is known to be latent in 132 Western counties. A plea for vigilance has been made by Vernon B. Link in *The Journal of the American Medical Association*. He urges that physicians in all 15 Western states where plague has appeared should suspect the disease in any case where there is swelling of the lymph nodes in the groin or the armpit.

In the U. S. plague is carried by fleas on prairie dogs, gophers, squirrels and cottontail rabbits. Physicians who do not suspect the disease often waste penicillin injections on it. "Without exception," writes Link, "all five of the New Mexico cases received penicillin as the first therapeutic measure. In the two fatal cases, penicillin was the only drug employed. . . . Penicillin is a valuable addition to the physician's armamentarium but has no value whatsoever in the treatment of human plague. Streptomycin and sulfadiazine should be given immediately." Link adds that unless bubonic plague is suspected, diagnosed and treated early, sooner or later a case will develop into pneumonic plague. This form of disease spreads from person to person and could result in "a far more serious loss of life than generally occurs from the sporadic occurrence of single bubonic cases."

"Cancer Cure"

MANY readers of *Picture Post*, which describes itself as "Britain's National Weekly," were startled when a recent issue of the magazine carried in bold letters on its cover: PICTURE POST INVESTIGATES A TREATMENT FOR CANCER. There followed an article about a secret cancer cure written by Derek Wragge Morley, a biologist employed by *Picture Post*. The treatment was the property of David Rees Evans, a man who had had no medical training but whose father and uncle had treated cancer with herbs. Despite Evans' refusal to disclose the nature of his treatment, *Picture Post* maintained that his achievements called for an official investigation.

British physicians were quick to reply. Said the *British Medical Journal*: "*Picture Post* has done a grave disservice to science and to the British public. . . . We can but repeat what was written in these columns in 1908 [in regard to a patient treated by Evans' father and uncle]: " 'Cancer curing' is to our mind the most execrable of all forms of quackery, for, in addition to the bitterness of disappointed hope, it inflicts an incalculable amount of unnecessary suffering."

Less than three weeks after the first article appeared in *Picture Post*, British Minister of Health Aneurin Bevan appointed a committee of four of the most distinguished names in British medicine, including Sir Alexander Fleming, discoverer of penicillin, to examine Evans' claims. Commented the *Journal*: "We think it is a pity that on behalf of the public the Minister of Health did not see fit to condemn outright the use of a *secret* remedy for the treatment of such a serious condition as cancer. Mr. Evans now says: 'I am perfectly willing to submit to the committee . . . whatever they may ask concerning my materials and methods.' Could he not have made this offer years ago to a properly accredited research organization, and shared then with mankind the benefit, if any, of a remedy he has hitherto kept secret?"

Neurotic Rats

A NUMBER of experimental psychologists have deliberately made rats neurotic by subjecting them to conflicting situations. The rats generally have responded by eccentric behavior such as squealing or biting the psychologist's hand. This behavior is not sufficiently neurotic for J. M. Hunt of the Institute of Welfare Research and H. Schlosberg of Brown University. In *The Journal of Comparative and Physiological Psychology* they note that such experimentally neurotic rats later have shown very little abnormality. Hunt and Schlosberg conclude that the effects of conflict were too brief to accumulate from one session to another. "Hence," they write, "it seemed desirable to set up a situation in which the rat would be subjected to continual conflict; like the neurotic human being, he would never be able to get away from his conflict."

The two psychologists subjected six rats to continual conflict by conducting an electric current through a water dish so that the rats would receive a mild electric shock when they attempted to drink. The rats suffered this treatment for 144 days. They showed no increase in total activity, but Hunt and Schlosberg note that "the portion of their activity which occurred during the normally quiet light half of the day became larger." In addition, the psychologists observed "certain types of maladaptive behavior." For example, even when the electricity had been temporarily turned off a rat would "drink for a few seconds, and then jump away from the tube, wiggle its nose and withdraw as if shocked. In such cases the animal did not return to the bottle for the period of observation." Hunt and Schlosberg find this behavior "difficult to understand without invoking some intervening variable such as anxiety or hallucination, which would be strong enough to reinforce the avoidance tendencies in the absence of actual shock." Three of the rats also developed tantrums. These consisted in "climbing the side of the cage, falling, throwing food pellets around, and gnawing the bars of the cage. This sort of thing was repeated until the animal lay, apparently exhausted, with wheezy breathing."

NORTH AMERICAN NEBULA, an area of light and dark nebulosity in Cygnus, is shown in unprecedented detail by a photograph from the 48-inch Schmidt. This represents a quarter of one Schmidt plate, which covers 44 square degrees. Photograph copyright National Geographic Society-Palomar Observatory Sky Survey.

THE BIG SCHMIDT

The wide, sharp field of the 48-inch telescope, now engaged in a survey of the entire sky visible from Palomar Mountain, complements the deep but narrow view of the great 200-inch

by Albert G. Wilson

THERE was a time when the only instruments an astronomer needed in the practice of his profession were a conventional telescope and a good clock. Today the problems astronomy is tackling are so intricate and diverse that an astronomer who set out to investigate them armed only with a traditional telescope would be a little like a naturalist setting out to collect whales and microbes with a butterfly net. The modern astronomer, concerned with such matters as the method of energy generation in stars, the relative abundances of the chemical elements in the universe and the distribution in space of fantastically far-off galaxies, requires a large array of special instruments, each designed for a particular purpose. His equipment nowadays includes such devices as photoelectric photometers, radio "telescopes," high-altitude rockets and devices for producing artificial eclipses of the sun. And the evolution of the optical telescope itself has produced a number of highly specialized forms.

Public attention has focused mainly on Palomar Mountain's giant 200-inch telescope. Not many people realize that the 200-inch is a specialist of a kind. It looks a billion light-years into space, but it gives us only a gimlet-eyed view; what it gains in penetration it loses in breadth of vision. Looking through such a telescope is like looking into a ball park through a nail hole in the fence.

The 200-inch is the culmination of the main line of development in classical telescopes. We have been building ever larger and more powerful instruments, reaching farther and farther into space but steadily narrowing our view. As a result we have in a sense been seeing less and less of the sky as a whole. At the farthest range of our more powerful telescopes less than two per cent of the sky has been photographed so far. Our present picture of the universe is based on a few long thin views of these remote regions and on what we know about the regions near us.

Obviously to get a comprehensive view of the universe we need a new type of telescope that can look both far and wide at the same time. The best answer to this need has been found in the large Schmidt-type photographic telescope. By an ingenious combination of mirror and lens it can photograph the sky at once to great depths and over a wide field. This article will describe the largest instrument of this type now in existence—the 48-inch Schmidt on Palomar Mountain.

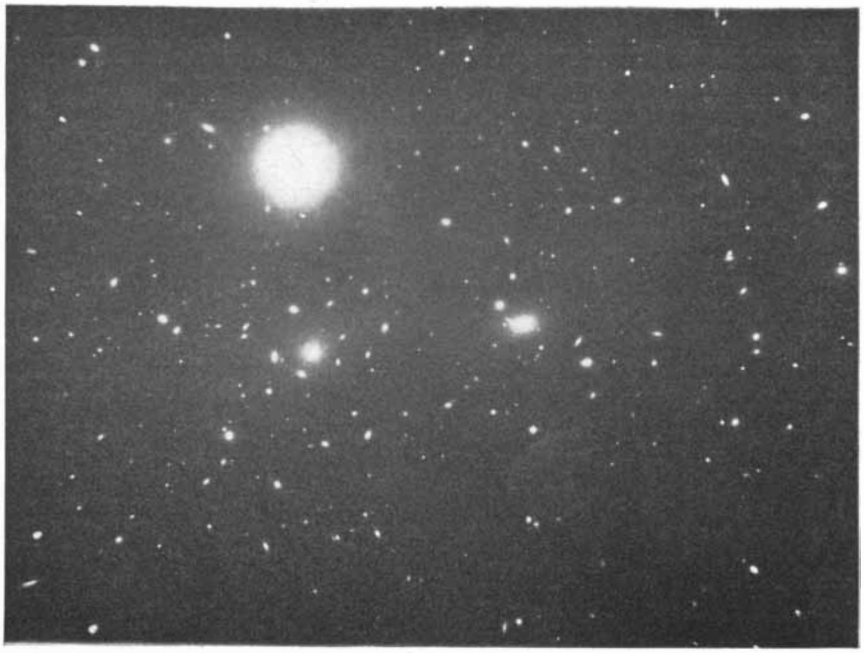
Aberrations

The main problem in designing a telescope to provide a wide field of view is to get rid of the optical aberrations or interferences with the quality of the image that are inherent in reflectors and refractors. One of these aberrations goes by the name of chromatism. It occurs in all lenses, and it is caused by the fact that the refracting lens splits the transmitted light slightly into its spectrum of wavelengths, thereby producing a colored fringe that makes the image fuzzy. Another fault, common to both lenses and mirrors, is spherical aberration, arising from the fact that the different zones of even a perfect spherical lens or mirror focus the light falling on them at different points; the result again is a hazy image. Other serious aberrations are astigmatism and coma. These defects, which affect only off-axis rays, are caused by unequal magnification of the different zones and become more serious as the angle of the ray with the axis increases, *i.e.*, toward the edges of the picture.

The history of telescopes is largely a history of the various devices used to remove aberrations. In the early telescopes, which were mainly refractors, chromatism was mitigated by using lenses with a very large focal length; this reduces the effects of differences in refraction of the various wavelengths. A telescope with a large focal length is, however, unwieldy. Later it was discovered that two or more lenses with different refractive indices could be used in combination to correct the color defects.

The largest modern telescopes are all reflectors, so chromatism is not a problem. But the large reflectors must still contend with the other aberrations. Spherical aberration is usually overcome by making the curve of the primary mirror a parabola rather than truly spherical. A parabolic reflector, however, possesses the off-axis aberrations, and it is these, principally the coma, which cause the trouble today. They are the principal reason why the modern large reflecting telescopes, though mighty in light-gathering power and ability to penetrate to great depths of space, have so narrow a field.

Several solutions have been proposed for the removal of the off-axis defects.



CLUSTER OF GALAXIES in Coma Berenices is photographed by both the 48-inch Schmidt (*left*) and the 200-inch (*above*). The three bright objects in the 200-inch plate, which shows the heart of the cluster, appear in the center of the Schmidt plate. On this one Schmidt plate some 8,000 galaxies have been counted, of which about a tenth belong to the cluster itself. The cluster is about 45 million light-years away; the large galaxy at the lower left on the Schmidt plate is three or four million light-years away. Note the sharpness of the images that are near the edge of the Schmidt plate and the distortion of the images that are near the edge of the 200-inch plate.

Small gains in the size of the field can be obtained by introducing a correcting lens near the focus; in the 200-inch such a lense increases the usable field from 2 minutes of arc to about 15 minutes (a quarter of a degree) of arc. Other systems, using two mirrors to free images of spherical aberration and coma, have made possible still larger fields. But the most radical and also the most successful design is that of the late Bernhard Schmidt of the Hamburg-Bergedorf Observatory in Germany.

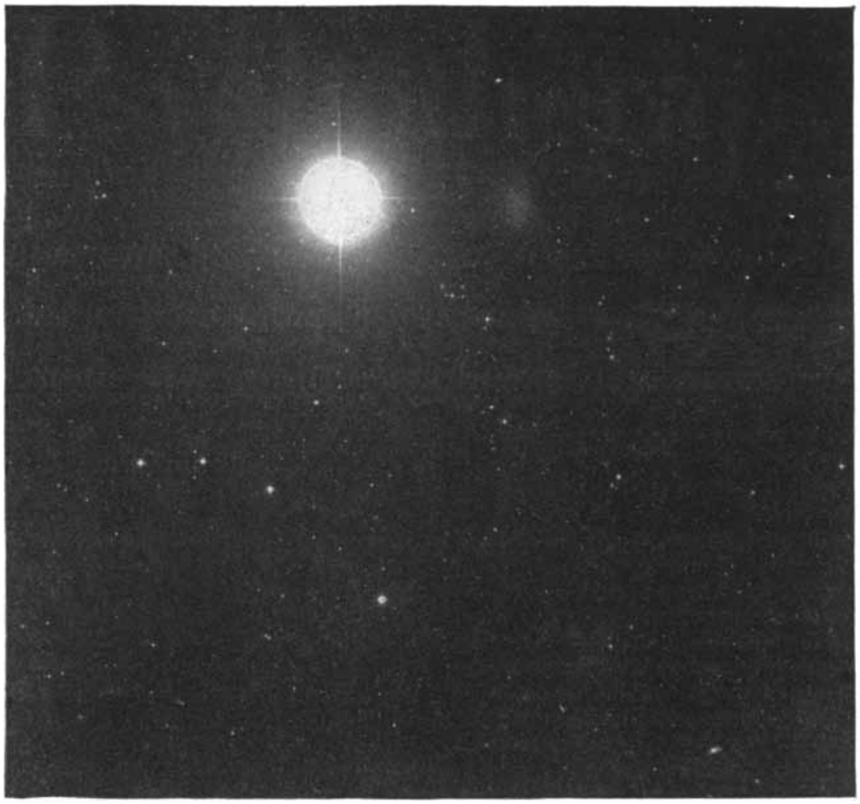
Schmidt's Idea

To rid the optical system of off-axis aberrations, Schmidt resorted to a revolutionary remedy: he did away with the axis. He decided to use a spherical mirror, because a sphere has no axis and no off-axis aberrations, and to try to solve the problem of spherical aberrations in a new way. He conceived the idea of altering the direction of the incident rays *before* they reached the spherical mirror in such a manner that after reflection they would be brought to the same focus by all zones. To effect this Schmidt designed a lens, properly called a correcting plate, which he placed out in front at the center of curvature of the mirror. This combination lens-mirror design removes both spherical aberration and coma and provides images of excellent definition over fields several degrees in diameter. Schmidt's system has the further advantage that it can be built with photographic speeds faster than $f/1$.

On the other hand, there are some disadvantages to the Schmidt system. One is that the picture is not focused on a flat plane but on a spherical surface. This means that the photographic plate must be bent to a spherical surface or that a third optical element must be introduced into the system to flatten the field. Further, the focal surface, where the photographic plate must be placed, is located about halfway between the mirror and the correcting plate—a not readily accessible position. In large Schmidts the problem of loading and unloading the plates can become a serious one. But all of these disadvantages are of little weight when compared with the great advantages of excellent definition, wide field and high speed.

It was the amateur astronomers who did much of the pioneering work with Schmidt cameras. Partly because of their valuable experiments on a small scale, it was soon realized that a Schmidt camera of large dimensions would be the ideal answer to the need for a wide-angle camera capable of photographing faint objects.

How large a camera of this type was it feasible to build? Schmidt's first camera, built in 1930, was an $f/1.74$ system with a 14-inch correcting plate and a



DWARF GALAXY near our own was discovered by the Schmidt. The galaxy is a very faint patch to the right of the bright star Regulus. Photograph copyright National Geographic Society-Palomar Observatory Sky Survey.

FAINT NEBULOSITY left by a supernova also was found by the Schmidt. The nebulosity is too large to be appreciated by the 200-inch. Photograph copyright National Geographic Society-Palomar Observatory Sky Survey.

17-inch mirror. North American observatories began to construct larger and larger models: the Palomar Observatory had one built with an 18-inch correcting plate and 26-inch mirror (18/26), the Warner and Swasey Observatory in Cleveland a 24/36, the Harvard College Observatory a 24/33, the Mexican National Astrophysical Observatory a 26/30. But it seemed that Schmidts much beyond this size might not be feasible.

There was no problem about getting a large mirror; successful mirrors with diameters up to 100 inches had been built. The trouble lay in increasing the size of the correcting plate. The Schmidt correcting plate, unlike a conventional lens, is very thin; on the average it has a thickness of the order of only one fiftieth of its diameter. Consequently as it is increased in size the elastic bending of the thin plate may become appreciable. Fortunately, however, the optical system is relatively insensitive to such deflections, and it is even possible to support the correcting plate at its center, so this factor is not a serious limitation on the plate's size. More serious is the fact that the correcting plate, like all lenses, is subject to chromatic aberration. It is possible, of course, to achromatize the system by employing two plates of different indices of refraction. But in large sizes this might be very difficult.

The Building of the 48-Inch

In 1938 the Observatory Council of the California Institute of Technology, the group responsible for the design and construction of the 200-inch telescope and its auxiliaries, decided that a large Schmidt-type camera would make an excellent auxiliary for the 200-inch. It was decided to build as large a Schmidt as could feasibly be constructed without the necessity of revolutionary modifications to overcome chromatism. Calculations showed that an *f*/2.5 camera with a 48-inch conventional correcting plate and 72-inch mirror would not introduce objectionable chromatism. In 1939 construction was begun on such a Schmidt for the Palomar Observatory.

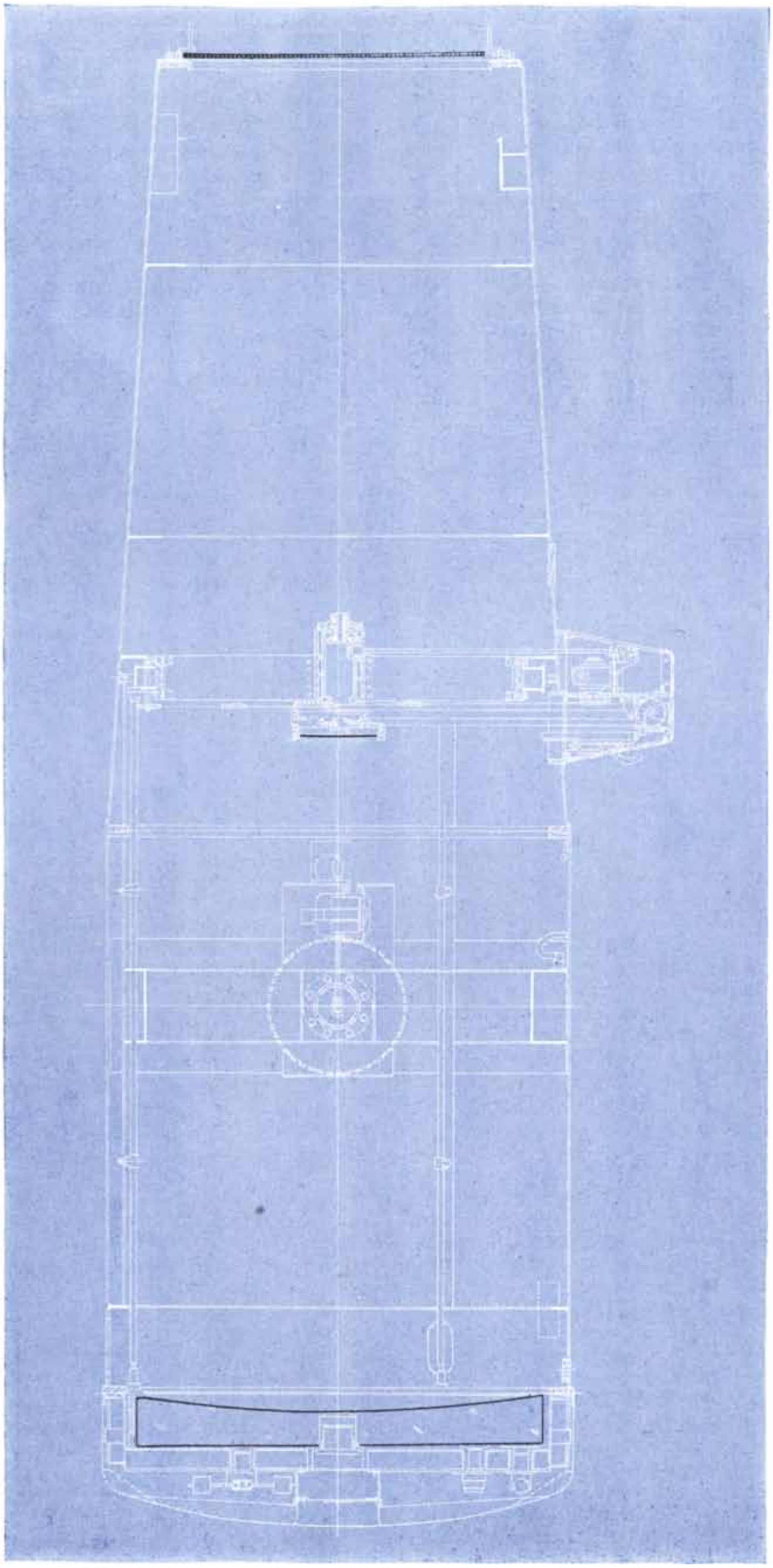
Overshadowed by its giant colleague, the 48-inch Schmidt attracted little attention. But its engineering and optics required the same sort of highly skilled techniques that were demanded for the 200-inch. The most exacting single item was the shaping of the large correcting plate. This pioneering piece of work was taken over by Don Hendrix of the Mount Wilson Observatory optical staff. Hendrix inspected a whole carload of plate glass before he found a piece sufficiently free of defects to make a useful blank for the correcting plate. He then devised tools and methods for grinding, polishing and testing the large plate and in only three months' working time succeeded in producing a correcting plate of excellent quality. Hendrix also shaped the spherical surface for the 72-inch Pyrex mirror. The remaining optical parts, including two 10-inch refractors used for guide telescopes, were made in the optical shops of the California Institute of Technology.

The telescope itself was manufactured in the Caltech machine shops and set up on Palomar in a dome about a quarter of a mile east of the 200-inch. The Big Schmidt, as it is called, consists of a tube 20 feet long in a fork-type mounting which allows the telescope to sweep all parts of the sky from the pole to as far south as declination minus 45 degrees. The combined weight of the fork and tube is over 12 tons. This whole assembly moves on two-inch ball bearings in the polar axis. The tube, partly cylindrical and partly conical and made of 5/16-inch welded steel plate, looks like a large mortar. The telescope shutter consists of two rotating shells located inside the tube behind the correcting plate. This construction allows the correcting plate to be removed or auxiliaries to be mounted without removing the shutters. The mirror and its cell are mounted at the lower end of the tube and are kept at a constant distance from the focal surface, regardless of temperature fluctuations, by means of three floating metal-alloy rods.

The telescope does not have positioning circles but instead employs Selsyn indicators which take their signals from declination and right-ascension gears and transmit the position electrically to the control desk. Other electrical features include automatic limit switches which stop the telescope four degrees from the horizon, automatic control of the dome's rotation and automatic regulation of the wind-screen height. The telescope is driven by a 1/25th-horsepower synchronous motor.

Two sizes of photographic plates are used in the camera: 10 inches square and 14 inches square. Since the plates must be bent to a spherical surface with a radius of 120 inches, to conform to the curved focal surface, they have to be very thin—less than one millimeter in thickness. The delicate glass plates are tested by bending beforehand to make sure they will not break in the telescope.

Construction of the telescope was finally completed in the autumn of 1948. The first tests showed that the telescope was much better than its specifications called for: the usable aperture of the correcting plate was actually 49.5 inches instead of 48. On 14-inch photographic plates the images were found to possess excellent definition over the entire field of 44 square degrees. The telescope is so fast that with 103a-O emulsion it reaches its limiting magnitude of 20.3 in about 12 minutes. This limit corresponds to the brightness of an average



BLUEPRINT OF THE SCHMIDT shows its three principal elements in black. At the top of the tube is the correcting plate. At the bottom is the mirror. At the center are the photographic plate and its loading assembly.

galaxy at a distance of 300 million light-years; in other words, the 48-inch Schmidt can "see" about one third as far as the 200-inch itself. So finally here was available a telescope of excellent quality that could photograph to great depths over a wide field.

The Schmidt's Big Project

The question now arose: What assignment should this great new instrument tackle first? There are three general types of job it is especially well qualified to do. One is to photograph wide, extended objects that an ordinary telescope can only sample piecemeal—such objects, for example, as the large galactic clouds of dark or luminescent gas called nebulosities. It was known that a few nebulosities covered several square degrees in the sky. Preliminary surveys with the new Schmidt revealed that some of them were much more extensive than had been realized. Moreover, the new telescope disclosed new nebulosities so large that their identity would never have been suspected from the knothole views obtained with conventional telescopes. The Schmidt makes it possible to study the turbulence in these gas clouds as no other instrument could. Another type of large object that only the Schmidt can see anywhere nearly whole is a cluster of galaxies relatively close to us, such as the clusters in the constellations of Coma, Hydra and Virgo. It would take scores of plates with a reflector telescope to give the same coverage of these objects that four or five Schmidt plates afford.

The second kind of program for which the Schmidt is particularly suited is the statistical study of large numbers of objects. Statistical information about the distribution of stars in position, motion, brightness, color and so on is basic in the study of the structure of our galaxy. The Schmidt, used with various filter and emulsion combinations, can single out particular types of objects such as planetary nebulae and emission stars and chart their distribution. Similarly, for clues as to the structure of the universe the astronomer is interested in the distribution of systems outside our galaxy. This information will be made much more complete through the Schmidt.

The third appropriate big job for the Schmidt is a simple voyage of exploration. Its high speed combined with its wide field make this telescope ideal for patrolling the skies. Indeed, for this it is as superior to the conventional telescope as an airplane is to an automobile. The primary purpose of a patrol is discovery. The Big Schmidt can be used for two kinds of patrol. It can explore new regions out to fainter magnitudes than have been surveyed before; there it will undoubtedly discover many new faint objects. And it can rapidly resurvey parts of the sky already covered to detect changes there, *e.g.*, to discover new supernovae. The veteran 18-inch Schmidt on Palomar revealed 18 of these giant exploding stars in five years of patrolling certain galaxies.

When the Big Schmidt had proved its excellence in its preliminary tests, the Observatory's research committee, headed by Edwin P. Hubble, met to discuss the question of priority. It was decided that the best way to begin was to take the bull by the horns; namely, to undertake one extremely ambitious program—a systematic survey of the *entire sky* visible from Palomar. Such a project would at once cover many of the research programs awaiting the Schmidt. Not only would it provide an exploratory patrol of the skies but it would collect the observational material needed for the study of extended celestial objects and of distributions of stars and galaxies.

The National Geographic Society, which for over 60 years has sponsored expeditions to far corners of the earth in quest of geographic and scientific knowledge, became interested in this proposed exploration of the heavens. It therefore undertook the financial sponsorship of the survey, and the ambitious program was made possible as a cooperative undertaking of the Society and the Mount Wilson and Palomar Observatories. It was decided that photographic prints of each field should be distributed at cost to interested institutions and individuals. The whole set of prints will be known as the National Geographic Society Palomar Sky Atlas.

Hubble, the scientific director of the project, has pointed out that the Atlas will serve as a record of the heavens at one epoch, will provide an invaluable reference library for a great number of astronomical research projects, and, most important, will give us the first good look at the universe around us out to the distance to which the largest telescopes are working. Only one photographic atlas of the entire sky has ever been made. This was the Franklin Adams Survey conducted over 40 years ago with a small camera that reached only to the magnitude of 17.5. The Big Schmidt reaches out to stars 15 times fainter. In addition there is a tremendous gain in the improved definition and image quality of the Schmidt plates.

The survey with the Big Schmidt was formally inaugurated in July, 1949. The present objective is to photograph the sky to declination minus 24 degrees. It is hoped that in time funds can be obtained to construct a duplicate Schmidt in the Southern Hemisphere and complete the map for the entire sky.

The entire sky contains 41,259 square degrees. Of this, three-fourths is visible from Palomar. One 14-inch photographic plate used in the 48-inch Schmidt covers over 40 square degrees. This means that the Schmidt, even with fields overlapping, can cover the whole visible sky with less than 1,000 plates. Assuming that each field can be photographed in approximately one hour, it should take only about four years to map the sky.

The Sky in Two Colors

Each field is photographed twice—once with a blue-sensitive emulsion and once with a red-sensitive emulsion. The two exposures are made in rapid sucession in order to obtain an accurate comparison of the sky in two colors. The two-color photography is in effect equivalent to a rough spectral analysis. Comparisons of starlight in the two colors provide what is known as the color index of the star. The color index provides a great deal of information about a star, since it indicates the star's spectral type and temperature. Colors of nebulosities are an aid in identifying the sources and mechanisms of their luminescence. Colors of extragalactic systems are helpful in identifying what kinds of stellar populations are present and aid in checking the remoteness of galaxies, for distant galaxies show considerable reddening because of the red shift. Colors also give a clue to the presence of obscuring material in interstellar space, because such material is more transparent to red light than to blue light. So in addition to the ordinary positional data available from a single photographic plate, the two color plates give appreciable physical data.

In its first few months the survey has already produced many interesting discoveries and accumulated much significant material. As expected, it has discovered new clusters of galaxies, new faint galaxies, new planetary nebulae, nebulosities, comets and asteroids. Some oddities and phenomena not yet explained have appeared. New information of possible cosmological significance has turned up, both on the distribution of extragalactic nebulae and on the density of matter in the universe. This material will be made available to astronomers everywhere in the near future. The process of systematic evaluation can then begin. It has been estimated that the Atlas as a whole will furnish so much information that astronomers will be kept busy for 50 years tabulating and interpreting it.

Great advances in scientific knowledge have been made either by the discovery of new objects or by looking at familiar objects in a new manner. The survey with the 48-inch Schmidt embodies both of these aspects. It may well prove to be one of the most significant astronomical endeavors of all time.

Albert G. Wilson is a member of the staff of the Mount Wilson and Palomar Observatories.

A RICH VARIETY OF OBJECTS is shown by the Schmidt's view of Scorpio. At lower right is the bright star Antares, embedded in a diffuse nebula that shines by reflected light. At left center is a nebula that shines by emitted light. At lower right and upper left are three globular clusters. At upper right are dark nebulae that blot out the stars in the background. Also on the plate are 30 asteroids too faint to show in this reproduction.

Group Psychotherapy

Man is a social animal, and his neuroses can often be treated in a social context. One psychotherapist can work with several patients, who at the same time greatly influence one another

by S. R. Slavson

SCIENCE and scientific practice usually develop from the general to the particular. The inductive method yields general principles, and these are then modified and refined by being applied to specific situations. This has been the history of psychotherapy as well as of other sciences. Before Freud's epochal formulations as to the nature of mental and emotional disorders, psychiatry was concerned mainly with description and classification, and its therapy was applied in a blanket fashion, through such measures as hypnotism and suggestion. As psychiatry has become more and more centered on therapy, emphasis has increasingly been laid upon skills and methods of treatment rather than upon classification.

From the parent trunk of psychoanalysis have come a number of different methods of treatment. One of them is group psychotherapy. As its name implies, it is a method in which patients are treated in groups, with the group itself constituting an important element in the therapeutic process.

Group psychotherapy is by no means suitable for all kinds of mental or emotional disorders; patients with deep neuroses generally need individual psychoanalysis. But a large proportion of neuroses and even some types of psychoses can be treated successfully in groups or by a combination of group and individual therapy.

The rationale of group therapy is briefly as follows: One of the chief aims of psychotherapy is to release from repression the early resentments and hostility which are unavoidably attached to one's parents and to bring to consciousness the conflict between one's destructive impulses and the restraints of the conscious and unconscious super-ego. The psychotherapist's method of achieving this aim is to permit the patient to regress to the early stages in his development in which these conflicts originated. The patient is then encouraged to act out or talk out those early feelings, that is, to experience a "catharsis." Now it is no simple matter to obtain regression. The patient will allow himself to regress only if he feels sure that he will not be disapproved or punished. The great value of group therapy is that it facilitates the regression and release of the patient. The members of the group have a catalytic effect upon one another. Their mutual support reduces each patient's defenses and fear of self-revelation. As a result the patients act out and reveal their problems more easily and therapy is speeded up. Transference, too, is greatly facilitated, because the group is a protection against the therapist and the parental and environmental authority of which he is the symbol.

An important aspect of the method is that the group is not composed of ordinary persons, nor is it held to ordinary standards of conduct. In normal society an emotionally disturbed person feels so constrained by the fixed pattern of expected behavior that he is likely to withdraw from the group or to act aggressively or antisocially. But in a therapy group each individual is able to fit because he is permitted by the therapist and the other members to act out freely, to discharge his feelings and to display his attitudes; he is not expected, at least at the start, to curb his actions or his language. This pattern we designate as "group mobility," as distinguished from the "group fixity" characteristic of ordinary groups in our society.

Naturally the method of treatment is not the same for all groups. Different age groups and different mental problems require different types of treatment. Before a patient is assigned to a group, a thorough diagnostic study of his problems and behavior is made. Great care is given to the formation of each group: the members must be so selected that they will have a beneficial rather than harmful effect upon one another and that the group as a whole will have the maximum therapeutic "balance."

Four general types of group treatment have been evolved: 1) "activity group therapy," for children aged 7 to 13; 2) "analytic group therapy," for psychoneurotic adolescents or adults; 3) "activity-interview group therapy," for school-age children with unusually serious problems, and 4) "play-group therapy," for preschool children. These four methods will be described and illustrated by a few cases.

AN ACTIVITY group is made up of seven or eight children of the same sex and nearly the same age, with a specially trained therapist as leader. The common pattern of these patients is that they have been rejected by parents, school or play companions. Cruelty, neglect, overstrict discipline or too little understanding and love have usually been their lot, but in some instances their emotional problems arise from indirect rejection of their powers and personalities in the shape of pampering and coddling by their parents, who treat them in this way to satisfy their own emotional needs. Some of these children are actively hostile and destructive; others reject the world by withdrawing from it. Obsessed with great fears or guilt, they overcompensate by nonsocial or antisocial behavior.

For these children the therapy group provides a haven. They come together in their "club" once a week for two hours. There are no discussions, no explanations, no efforts to direct the children toward insight or understanding of their problems. They are simply given an opportunity to release their drives within a group. Arts and crafts materials are supplied to them, and they are free to use these as they wish. They can make things, or throw the tools, material and furniture around and destroy them. They can work or play or quarrel or fight. They can deface walls and damage the room. Refreshments are served at each session, and the children may fight over the food, gobble it or retire to a corner to eat by themselves. In all these ways they displace or sublimate primary and acquired impulses and energies that have been unacceptable in their normal environment. The adult therapist allows the children to act out their infantile aggressive impulses and their hostilities without fear of punishment, criticism or disapproval. They are never criticized or told what to do. The therapist truly accepts each child by giving him unconditional love and support.

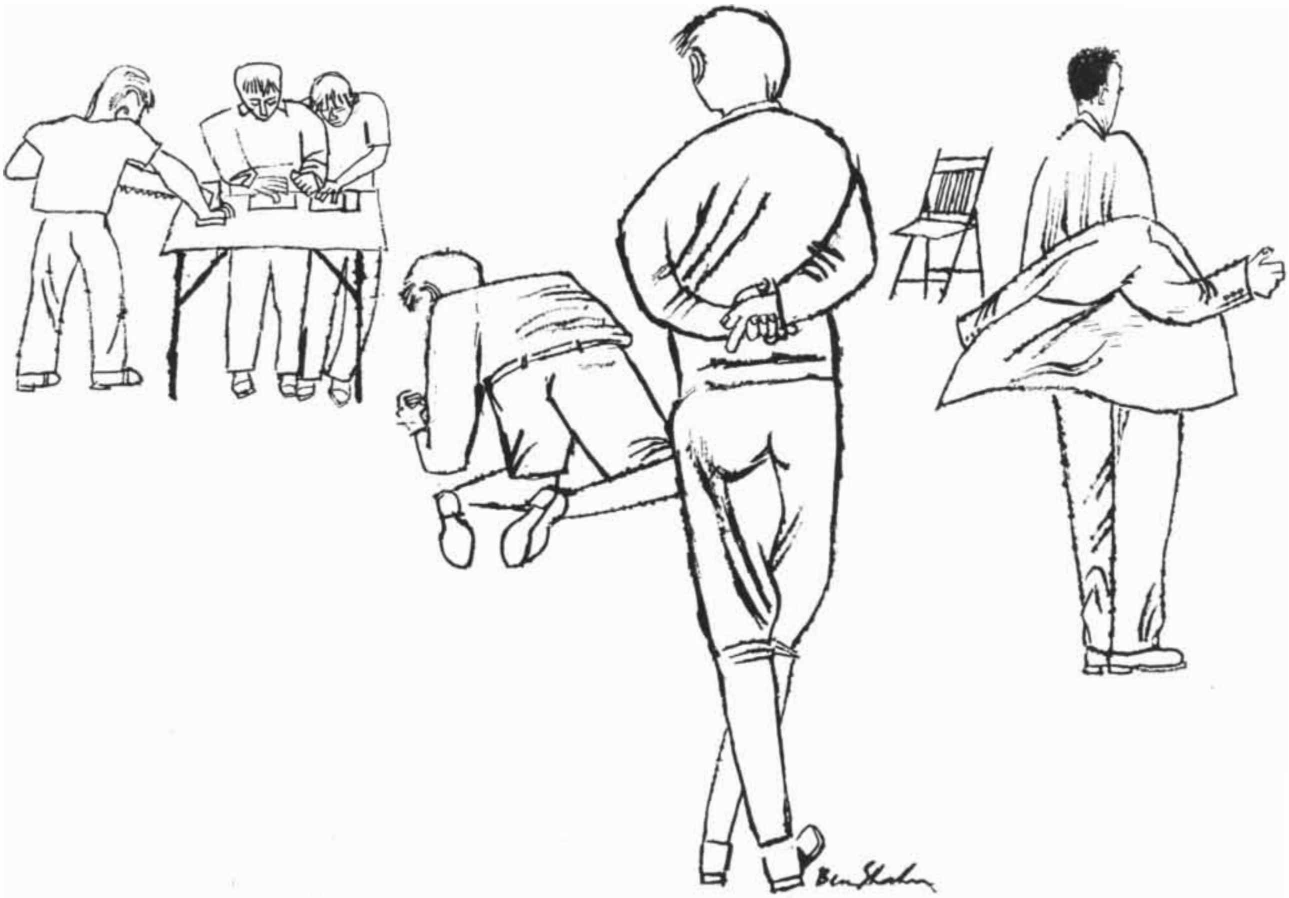
This method seems simple; actually it involves thorough and careful planning and a great deal of advance study, as well as great understanding and skill in the therapist. The choice of suitable patients and their proper grouping is of paramount importance. Some children, especially those with deep psychoneuroses, serious schizoid personalities or active schizophrenia, are unable to withstand the boisterous and frequently violent activity of the children in the group. But the great majority of problem children are accessible to activity group therapy.

In time definite order and group adaptations emerge. As the sense of self-worth is established, as fear and conflicts about their impulses are diminished and their ego-formations are strengthened, each member of the group changes. The diffident and frightened become more outgoing; the hyperactive and overaggressive level off to more controlled behavior. Neurotic fears are sloughed off in nearly all the children as their ego grows strong enough to deal with their inner and outer conflicts. They are now able to take their place in their culture and society and feel themselves adequate and capable. The new feeling of security they have found in the special group is applied to other life situations, and as they fit in there more and more, their egos are further strengthened and their feelings about themselves become more positive and wholesome.

A TYPICAL case was that of Richard, a 12-year-old boy referred for treatment by his parents because of severe temper tantrums during which he called them vile names and threw things at them. Richard was nervous and afraid of the dark; he bit his nails, grated his teeth during sleep, was dirty and sloppy, was finicky about food and refused to wash himself. He had a history of behavior difficulties at school, was in marked rivalry with his younger siblings, could not get along well with other children and had a "bad name" in his neighborhood. His mother was a tense, anxious, oversolicitous, weak woman who frequently lost her temper, screamed, cried and beat her children. She had sought in her husband a combination of father and mother, and having been frustrated in this respect, had unconsciously turned to Richard for substitute gratifications. As a child the boy had slept in her bed, and she had continued to bathe him until he was 10 years old. Because of this the boy had a strong Oedipal drive toward his mother and therefore was in serious conflict.

Treated in activity group therapy, Richard made progress from the start. He reached out for friendships, enjoyed the acceptance of the other children and the therapist, tested himself by tackling more and more difficult craft projects and soon began to assume a leading role in the group. This was paralleled by a marked improvement in his relationships at school and in his school work. At home his temper tantrums gradually disappeared, as did his fears and fads. He became neat and tidy, gradually acquired many friends and acted like a reasonably secure, happy youngster. Meanwhile, the mother was treated in individual therapy. She began to see Richard more objectively. As a result the mother and son now have a more normal and mutually satisfactory, if not exactly ideal, relationship.

Barbara, aged 10, was referred to us because of fears of the dark, of noise and of being alone, a marked concern



ACTIVITY GROUP THERAPY is designed for children of 7 to 13. Once a week the children and the therapist come together. There is no overt therapy; the children are allowed to release their drives, even violently.

ANALYTIC GROUP THERAPY is designed for adolescents and adults. Each group consists of patients with the same general psychological problems. Their revelations are much like those in an individual psychoanalysis.

over illness and difficulty in making friends with other girls. She was first given individual treatment. It was soon discovered that she hated her preferred younger sister and felt rejected by her father, whose special favor she had once enjoyed. She had slept in the parental bedroom for many years, and it appeared that her problem stemmed in part from an intense, unresolved Oedipal situation. Her condition was diagnosed as anxiety hysteria.

Individual treatment helped remove her fears. But her hatred of her sister, her feeling of rejection and her inability to play with other girls remained. When she was 11, Barbara was placed in a group. Gradually she was able to join the other girls in work, play and discussion. As she applied her new ego-strength and self-confidence in outside groups and experienced satisfactions in them, her hatred of her younger sister diminished, her personality became more attractive and she was able to regain her father's affection. After about a year and a half of group treatment Barbara's case was closed with an excellent prognosis for normal development.

IN THE second form of group treatment, analytic group therapy, the emphasis is on interviews and discussion. No materials of any kind are provided; instead the patients discuss their problems with the guidance of the therapist. Each group consists of patients having the same general psychological syndromes. The presence of other people with similar problems gives each patient support to reveal his feelings and attitudes. The group members develop friendships which they sometimes continue outside the group. The therapist helps each to break through resistances, allay anxieties, gain understanding of his or her difficulties and develop more wholesome attitudes toward self, parents, brothers and sisters, husband or wife and the world generally. The dynamics are the same as in individual psychotherapy: transference, catharsis, ego-strengthening and the gaining of insight into one's own behavior, testing of one's ideas against reality and sublimation of destructive drives.

Because all the members of the group have common problems and a natural need for one another, they soon establish comparatively easy relations. Adolescents especially make ready contact with one another. Once the patients' ego and super-ego defenses are lowered they readily reveal their most intimate problems and seem to be almost entirely free of what is commonly referred to as "self-consciousness." They talk in an uninhibited way about prohibited subjects; they expose their hidden feelings about themselves and repressed hostilities toward persons in their environment. The less repressed members act as catalysts for the more inhibited and anxious.

A TYPICAL case was that of a mother who was treated in an analytic group while her son was treated in an activity group. A domineering woman, she was demanding, rigid and perfectionist, dominated her family and was unable to show affection. During the group interviews it became clear that she unconsciously identified her son with her husband and transferred her hostile feelings for her mate to the boy. As treatment proceeded it also became evident that unconsciously she confused her original feelings toward her father and an older brother with those she now had for her husband. It was essential both for her son's improvement and the solution of her own problem that these feelings be brought to consciousness and that she come to understand and emotionally accept the different roles that her husband, father, brother and son really played in her life.

The patient, Mrs. A, was assigned to a group with five other women. They were encouraged to speak freely. First they talked about their children and in-laws, but they soon got around to discussing their husbands. Though they all found fault with their mates, as the conversations developed they began to show a growing awareness of their own inadequacies. The talk then shifted to narrations of their problems in relationships with their own parents, brothers and sisters.

After several sessions Mrs. A admitted that she was less affectionate toward the boy who had become our patient than toward a younger son. She also admitted that she did not "know the right thing to do about it; I have tried to use my will power, but it's not working." In short, she had come to realize that the problem lay within herself and that she must change basic attitudes which did not respond to her conscious control. Eventually she realized that her aggressions against her husband and son sprang from her need for support, formerly supplied by her father and brother but not forthcoming from her husband. At one point she said: "I guess I can't expect the same babying from my husband. Maybe he wants me to mother him." The other women agreed that all men are children at heart and one cannot expect too much emotional support from them. They all found themselves in the same boat, and the "dynamics of universalization" served to diminish their anxiety. Mrs. A became freer; her tension gradually diminished and she was less strict with her children. She was even able to show some affection.

Another dramatic case was that of an adolescent girl named Ruth. She had presented problems for years: was frequently absent from school, had no friends, clung to her mother and suffered from repeated facial tics, head jerks and other involuntary losses of motor control. Ruth was in strong rivalry with her older sister, whom her mother preferred. Her father was immature, demanding and irresponsible, frequently moody and depressed; her mother domineering, anxious, harassed. Ruth expressed her hostility against her parents and sister through her tics and also gained a measure of attention for herself thereby.

Individual treatment over a period of nearly two years succeeded in reducing the severity of some of her symptoms, but they would reappear whenever family strains increased. Ruth was prone to sexual fantasies and harbored many sex fears. At 15 she was placed in an analytic therapy group with six other girls. During the first 12 sessions she said nothing; when she did speak she pretended that her parents were "wonderful." But eventually she began to admit the truth about her unhappy home life and finally to discuss her "sex life" and her emotional involvement with her father. Gradually she came to realize that this involvement was the core of her problems. She was able to accept the fact that her father was not the ideally "wonderful" man she had imagined as a child. She began to feel free to think of her unconscious incestuous wishes with less guilt. Ultimately she transferred her interest to "outside" men and developed a healthy attitude toward her parents, no longer hating them for their insufficiencies. Her tics disappeared.

THE THIRD and fourth types of group treatment—activity-interview and play-group therapy—are really variations of the first two: a combination of activity and interpretation. Deeply disturbed children of school age frequently need to talk about their anxieties and internal conflicts as well as act out their feelings, which are often expressed in sexual fantasies. The therapist therefore helps them to interpret the meaning of their play and verbalizations.

Play-group therapy, as already mentioned, is used with children of preschool age. These children present a special problem. They have not yet matured enough to gain much from mere acting out. To permit such children to follow their aggressive impulses freely would be inadvisable, even harmful. The therapist must apply limitations and controls of some sort, supplying the ego-strength the child himself does not have. In a play group the young children are supplied with dolls, blocks, clay, water, water-color paints, doll houses and other toys. Through the play the children convey hidden resentments, feelings of frustration, fears and confusions. A youngster of five may be viciously tearing at a doll. The therapist helps him to see that he is expressing his feelings toward a younger brother or sister who took his place in the affections of his parents. Another attacks the therapist. The therapist asks a question that will lead the child to perceive that he is expressing toward the therapist hostile feelings which he bears his mother. The children do not always gain these insights at once, but repeated incidents and explanations soon lead to understanding. Because these attacks are both permitted and accepted, guilt and fears associated with the prohibited feelings they reflect are diminished; the child grows freer and happier.

Robert, a hyperactive, aggressive youngster of five, was a typical case. He was subject to severe temper tantrums, played with fire, masturbated excessively, picked his nose, stuttered, cried instead of asking for things and suffered from various fears. His well-educated mother was somewhat immature and domineering; his father was friendly and affectionate but weak, and had little time to spend with the boy.

In the group Robert readily, but belligerently, joined in the games and play projects. He soon found an "ideal" in another boy. Robert emulated and eventually competed with his "ideal" on a friendly basis; moreover, he became able to accept criticism gracefully. The female therapist in charge of the group served, at different stages in Robert's development, variously as a target for hostility, a subject of secondary identification, a sexual attraction and an object for dependence. But he steadily gained success and independence in the group and this was reflected outside. He was enrolled in school and had no difficulty adjusting. Now his hyperactivity and temper tantrums are gone; his stuttering has ceased and he has largely lost his other symptoms.

THE development of group therapy has been a slow, steady process. The method is now being used in many parts of this country and abroad. Its principles have spread beyond psychiatry itself. They have found their way into the treatment of prisoners and into "reform" schools and convalescent homes. But the most important area where these ideas can be put to use is in the educational system. Although the actual techniques of group therapy cannot and should not be employed in schools, its findings concerning the basic needs of children and the attitudes teachers should take toward their job and pupils can be of great help. Good schools—good for the total personality of the child—can reduce the need for clinics.

S. R. Slavson, founder of the American Group Therapy Association, directs group therapy for the Jewish Board of Guardians.

Fertilization of the Egg

What happens when the germ cells of animals unite? The answer has partly been given by the useful eggs of sea urchins, which are visibly fertilized in water

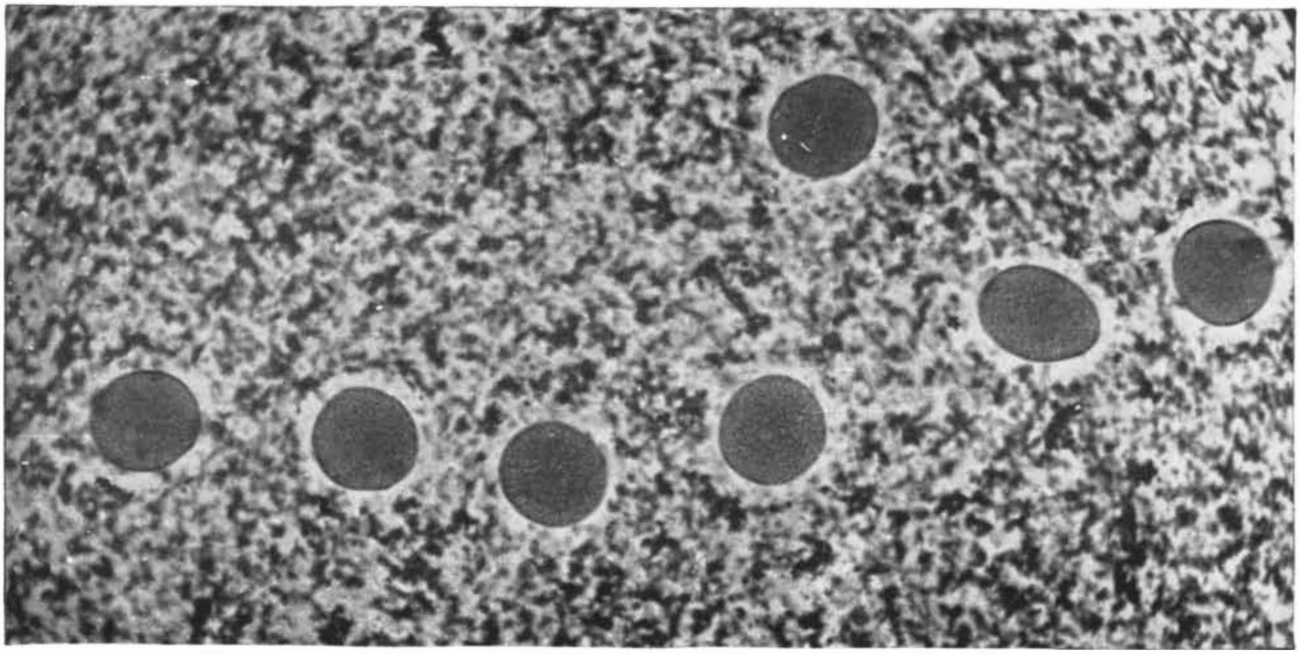
by Alberto Monroy

IT IS one of the ironies of modern science that the most elementary questions are still the hardest to answer. How, for instance, is a new animal created? We know that an egg and a spermatozoon unite to form a single cell, and this union somehow sets in motion a chain of events that gives rise to a new being. But what trigger, what spark, starts the process? What, in short, is the secret of fertilization? We do not yet know, although many eminent biologists have searched many long years for the answer.

The investigation has nevertheless been fascinating, and there is some progress to report. Most of what we know about fertilization has been learned from studies of sea-urchin eggs. Why sea-urchin eggs? Well, plainly it is rather impractical to study fertilization in a mammal; nobody has yet succeeded in following the penetration of the sperm into the egg in a mammalian mother's body. The eggs of fishes and amphibians are fertilized outside the animal's body, but these eggs are too large and opaque for convenient examination of what is going on inside them. The best material is the egg of a marine invertebrate such as the sea urchin; its eggs are small and transparent, and the major changes that take place in them after fertilization can be followed step by step under the microscope. Large numbers of eggs can be fertilized at the same time in a laboratory dish and their simultaneous development studied; the eggs can also be frozen, dried in a high vacuum and stored for later chemical analysis.

A sea urchin's egg is a small sphere barely visible to the naked eye. The fertilizing sperm is many times smaller than the egg. Under a high-powered microscope one can see that the sperm has a "head" and a very thin, fast-moving tail that propels it. When a drop of water containing sperm is added to a suspension of sea-urchin eggs in sea water, within a few seconds the sperm start rushing toward the eggs at an incredible speed. They are evidently stimulated by a substance that comes from the surface of the egg. This substance, a gelatinous material that coats the egg and is therefore called "jelly coat," slowly dissolves in the sea water. Besides stimulating the sperm, it makes them sticky. Hence when they collide with the jelly coat surrounding the egg, they are easily trapped there. Because of the important role this jelly coat plays in fertilization, the late U. S. zoologist Frank R. Lillie gave it the name "fertilizin."

Soon each egg is surrounded by a halo of sperm sticking to the jelly coat. The sperm's tails move so fast that they are invisible. It seems as if the sperm are trying to force their way through the jelly coat. In a few minutes they succeed in this objective, probably with the aid of an enzymatic process whereby



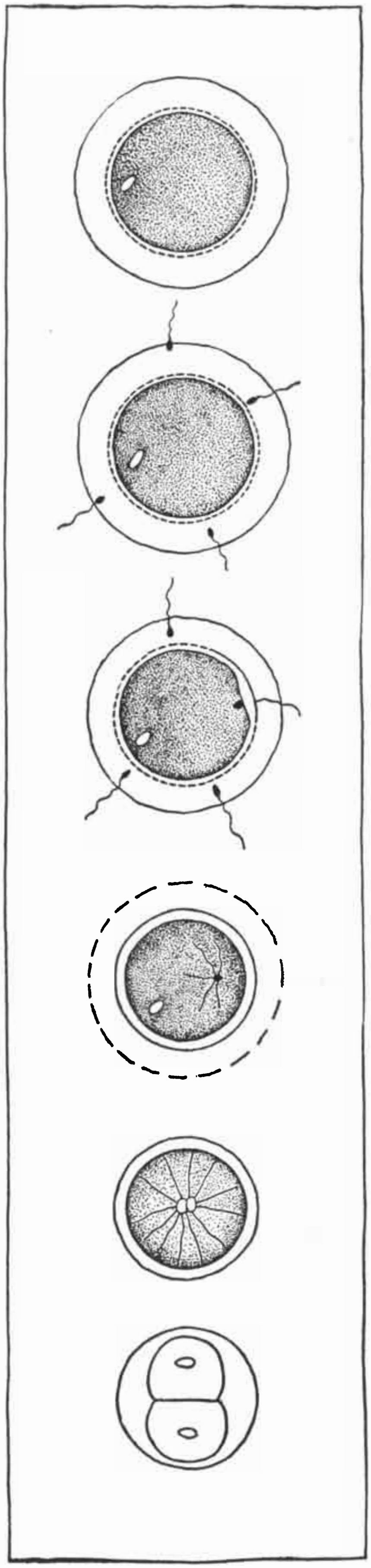
SEA-URCHIN EGGS float in water containing particles of India ink. The particles do not adhere to the eggs because each egg is covered with "jelly coat." This substance dissolves in the water and attracts the sperm.

they digest the jelly coat substance. When they reach the surface of the egg itself, one—and only one—of the sperm succeeds in reacting with the surface in some unknown way that permits it to penetrate into the egg. Only the head of the sperm (*i.e.*, the nucleus of the cell) enters the egg; the tail is somehow cut off. As soon as the successful sperm gets in, the egg contracts slightly, and at the same time the thin, tight skin around the outside of the egg, called the vitelline membrane, expands and undergoes some peculiar transformations which convert it into the so-called fertilization membrane. It used to be thought that this transformed membrane was what prevented other sperm from entering the egg after one sperm had succeeded in getting in, but it has been found that even if the fertilization membrane is shaken off, by a gentle shaking of the eggs, it is still impossible for other sperm to enter. So the defense mechanism that keeps out all but one sperm must reside inside the egg.

Once the sperm nucleus penetrates the egg, it starts moving toward the egg nucleus. A little later the egg nucleus starts moving too. Eventually the two nuclei meet and merge. About half an hour later the fertilized egg cleaves and gives rise to the first two cells of the new organism.

THIS IS the plot of the fertilization drama—the visible events in the play. What is the character of the actors, and what are the underlying forces and interactions that determine the final outcome? The egg or the sperm alone has no role to play, or even any viability. Left to itself, the unfertilized egg would succumb in a short time. Fertilization saves the egg, wakes it from its lethargy, "activates" it, as the embryologist says. To understand the play (*i.e.*, how fertilization works) we need answers to two questions: 1) what is the cause of the unfertilized egg's lethargy, and 2) what stimulus awakens it?

We have a few clues to the answers. Let us begin with the first question. We know that before the egg (or the sperm) becomes ready for fertilization, it must undergo a process of maturation; for example, the number of its chromosomes must be reduced to one-half, so that when it mates with the sperm both will contribute chromosomes equally to restore the full number in the new cell. Now it is an interesting and significant fact that in most species of animals the egg does not complete the process of maturation before fertilization. At some more or less advanced stage maturation stops, and it can continue to completion only after the egg is fertilized. It looks as if the egg develops some kind of "block" which prevents maturation from proceeding beyond a certain stage, and fertilization removes this block.



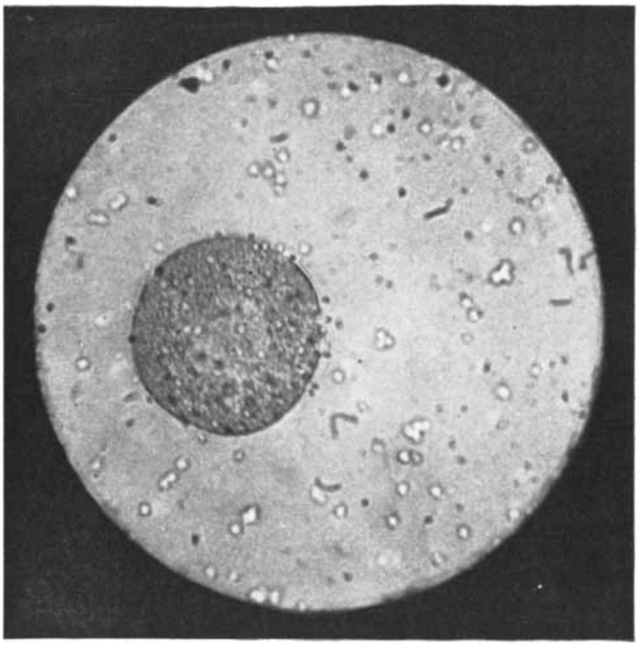
STAGES OF FERTILIZATION are shown in drawings. In first drawing is unfertilized egg. Outer line is jelly coat; dotted line, vitelline membrane. In second drawing four sperm have penetrated jelly coat. In third drawing one sperm has penetrated vitelline membrane. The tail of the sperm is cut off and vitelline membrane begins to form fertilization membrane. In fourth drawing fertilization membrane is complete and jelly coat begins to dissolve. In fifth drawing sperm, egg nuclei unite. In last drawing fertilized egg divides.

Moreover, there seems to be a block of a similar kind even in those few species of animal eggs that mature fully before fertilization. The sea-urchin egg is in this class. In it the block is manifested, among other ways, in reduced respiration of the egg. Recent studies have shown that as sea-urchin eggs mature, their rate of respiration slows down greatly. But as soon as the eggs are fertilized, there is a striking increase in respiration—a fact which was discovered as early as 1908 by the German biochemist Otto Warburg. In other words, the egg seems to develop a block in its respiratory system during maturation and fertilization removes the block.

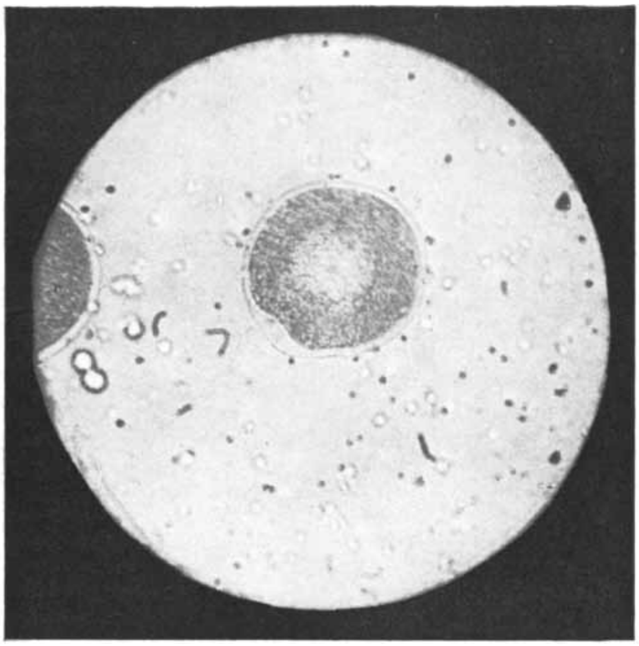
THIS BRINGS us to the second question: What factor in the sperm is responsible for removing the block? So far all attempts to find such a factor in the sperm itself have been quite unsuccessful. But we have learned something about what types of stimuli can activate the egg. This has been accomplished by means of experiments in artificial parthenogenesis, *i.e.*, the artificial development of organisms from unfertilized eggs.

It had long been known, of course, that the eggs of some insects develop in nature without fertilization: the bee is a good case in point. As early as 1886 it had been found that if unfertilized eggs of the silkworm were immersed in concentrated sulfuric acid, they would undergo development. Then in 1899 the great U. S. biologist Jacques Loeb discovered a systematic method for artificial parthenogenesis in certain historic experiments at Woods Hole. He treated unfertilized sea-urchin eggs with a dilute solution of butyric acid and followed up with a second treatment of concentrated salt solution. The treated eggs, on being returned to sea water, went through a series of processes very similar to those occurring in normally fertilized eggs, and in a number of cases they developed in an apparently normal manner.

Since then it has been discovered that various other chemical and even physical treatments can make eggs develop parthenogenetically: the frog egg, for



EGG of the annelid worm Pomatoceros was photomicrographed immediately after sperm were added to the water about it. Several sperm already adhere to the egg.



SAME EGG was photomicrographed a few minutes later. One sperm has penetrated the egg. Behind it is the fertilization cone, beginning of the fertilization membrane.

example, can be activated by puncturing it with a needle; sea urchin and starfish eggs can be made to develop by heating them to a certain temperature. To be effective the activating treatment must act on the egg for a certain length of time which is critical for each treatment. It need not be continuous, however; the treatment can be interrupted and completed after an interval. And in some cases the method of treatment can be changed in midstream; for example, one can expose the eggs to butyric acid and then complete the treatment by heating the eggs for a certain length of time.

These results indicate two important facts: 1) the effect of the activating stimulus on the egg is irreversible, and 2) the removal of the hypothetical "blocking" factor in the egg is a rather unspecific matter, that is, it does not require one particular stimulus but may be accomplished in various ways.

The discovery of artificial parthenogenesis naturally led biologists to hope that a solution could soon be found to the problem of the nature of the stimuli involved in fertilization. The results, however, have been far inferior to what was expected. The study of artificial parthenogenesis has certainly made possible an experimental approach to many questions, but on the whole it has opened more problems than it has solved. Moreover, we must bear in mind that the agent which normally activates the egg, namely, the sperm, is not merely a stimulus like heat or a chemical; for one thing, it is the bearer of a set of hereditary characters. In addition, many of its reactions with the egg are very specific indeed; one of the best examples of this is the fact that ordinarily sperm of one species of animal will not penetrate the egg of a different species.

ON THE basis of his experiments in parthenogenesis, Loeb came to the conclusion that the first step in the activation of an egg, by whatever agent, is the infliction of some kind of damage to the egg surface. As a matter of fact all the artificial agents that are capable of activating an egg will kill the egg, mainly by disintegrating it, if applied in too high concentration or for too long. It follows from Loeb's reasoning that the sperm must possess some factor that damages the surface of the egg, and that this damage in turn releases an activating factor.

Recently the Swedish biologist John Runnström and his associates at the Wenner-Grens Institute in Stockholm made a most interesting discovery: they isolated from the sperm of sea urchins and salmon a substance which, when applied to unfertilized sea-urchin eggs in concentrated form, makes the eggs impermeable to sperm. The effect proved to be due mainly to the substance's action on the egg surface. Curiously this substance turned out to be similar to butyric acid, which, as we have seen, can activate the egg. The new substance does not, however, seem to have any activating power. The Swedish investigators suggest that perhaps this is the agent responsible for marshaling the defenses of the egg so as to keep out other sperm after one has gained entrance.

That the surface layer of the egg plays an important role in fertilization seems rather probable. It is the scene of some very interesting phenomena during fertilization. One of the best known is the formation of the "fertilization cone"—a spectacle that is particularly impressive in the eggs of the starfish and of some annelid worms. While the sperm is making its way through the egg's surrounding envelope (jelly coat in the case of the starfish, a thick membrane in the case of annelids), a cone of protoplasm emerges from the egg surface and grows toward the sperm. Eventually the sperm is engulfed in the cone and so passes into the interior of the egg. A few minutes later the cone disappears. The formation of the cone seems to be due to the diffusion of some substance from the spermatozoon which induces this peculiar reaction in the egg surface. In the sea-urchin egg there is a curious variation of the process: the cone appears only after the sperm enters the egg. The cone emerges from the egg surface exactly at the point of entrance.

Runnström learned some further facts about the reaction of the egg surface by studying it under dark-field illumination. He found that as soon as a sperm has entered the egg, a sudden change occurs in the egg's cortical (outer) layer. This change is brought about by a change in the physico-chemical condition of the fatty substances—lipids—which are the major components of the cortical layer. Our own studies of sea-urchin eggs in polarized light suggest that fertilization causes a disarrangement of the molecular organization of the cortical layer. Other investigations have shown that at the same time the layer expels tiny granules, still unidentified, which are then incorporated in the newly formed fertilization membrane. Moreover, it has been found that newly fertilized eggs are more susceptible than unfertilized eggs to surface damage by chemical parthenogenetic agents.

We cannot be at all sure, however, that the processes responsible for activating the egg occur solely in the cortical layer. Actually chemical investigations have shown that upon fertilization profound rearrangements occur in the egg interior also. Particular attention has been directed toward the proteins, which are among the most important components of all living organisms. Immediately after fertilization a rearrangement of the protein pattern of the egg occurs. These changes are most probably brought about by the activity of some specific enzyme. Apparently the enzyme is inactive until it is activated by fertilization. As a matter of fact, the Swedish biochemist G. Lundblad has recently found in sea-urchin eggs just such an enzyme—one that acts on proteins and is activated by fertilization. Runnström considers the activation of this enzyme to be the most important factor in the activation of the egg. He further suggests that in the unfertilized egg the inactive enzyme resides in the cortical layer, and that the activation of the enzyme is the result of a reaction with some factor in the sperm. The sperm factor might well be an enzyme also, for it is known that one protein-dissolving enzyme can be activated by another. This theory is supported by the fact that a protein-dissolving enzyme has actually been found in sperm.

The main effect of the activated protein-dissolving enzyme in the egg on the egg's proteins would be to "unmask" some important reactive groups. In this way the quiescent protein system that existed in the unfertilized egg would be transformed by fertilization into a highly reactive system. Moreover, there are other enzymes in the egg which have also been shown to undergo activation on fertilization, and these, too, may set metabolic processes in motion. One of the best examples of the latter is the increase in respiration of the sea-urchin egg that follows fertilization.

Although the results of these investigations still leave us considerably short of a full understanding of fertilization, they do at least show clearly that the word "activation" is not merely a mystical concept. As matters stand now, we can say that the launching of a new organism, the most dynamic process in all nature, is traceable to a series of biochemical changes in the egg, involving every aspect of its metabolism.

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FINE PARTICLES

The fertility of the soil, the color of the sky and a multitude of other things depend on bits of matter either barely visible or smaller than the eye can see

by Clyde Orr, Jr.

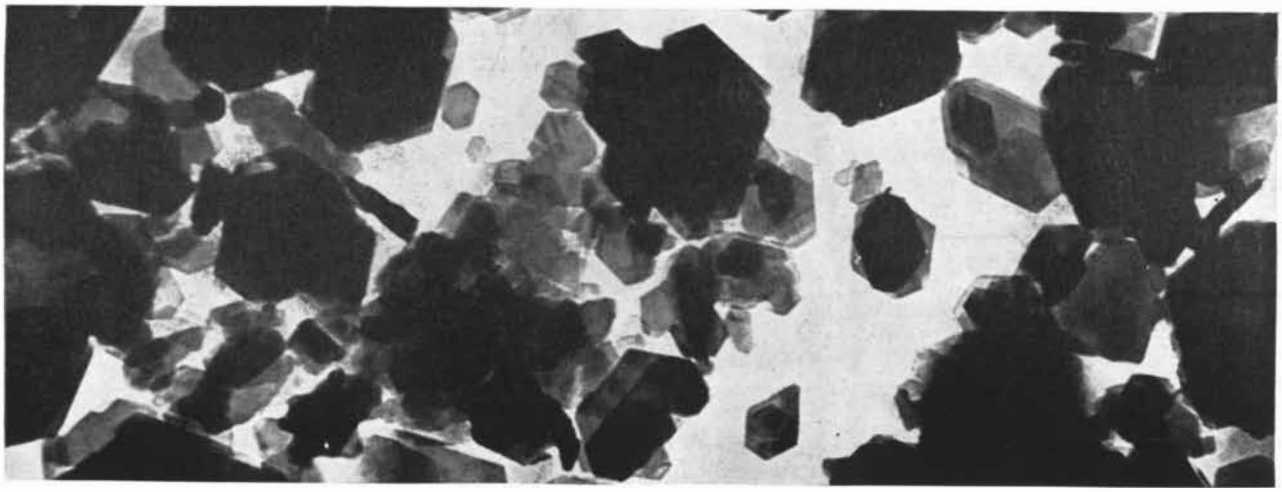
WHEN A PHYSICIST hears the word particle, he usually thinks of electrons, protons, neutrons and the like. But to most people the word is more likely to suggest a speck of dust in the eye. This is the kind of particle to be considered here: in other words, matter in a pulverized state. The study of dust and powder may seem rather special, but actually fine particles affect our lives in an astonishing variety of ways. Particles in the atmosphere are responsible for our sunsets, our rainfall and some of our diseases; the taste of coffee, chocolate, peanut butter and chewing gum is influenced by the fineness of the ground particles in them; the particle structure of soils is a matter of great importance to agriculture; fine particles play a big part in industry, both as catalysts and as end products. In fact, the physical behavior of particles influences so many phases of our existence that the real mystery is why it has taken man so long to get around to investigating the basic facts of this phenomenon.

The first to become interested in the subject were the soil scientists. They discovered several decades ago that the size and character of the particles making up a soil were mainly responsible for its capacity to hold moisture, heat and air. In recent years attention has been concentrated on the physical properties of individual particles. The development of the electron microscope has made it possible for the first time to make a really detailed examination of them. The study of fine particles has become a new branch of science called "micromeritics," from the Greek words meaning small and part. Special laboratories for work in this specialty have been established at the Georgia Institute of Technology, Stanford University, the University of Illinois and stations of the U. S. Army's Signal Corps and the biological division of its Chemical Corps. Most of what has been learned about fine particles thus far is summed up in a classic work, *Micromeritics,* by Joseph M. Dalla Valle of the Georgia Institute of Technology, a leader in the investigation.

The particles that a micromeritician studies are really small; most of them are invisible to the naked eye. They range from a fifth of a micron to 250 microns in diameter, that is, from about eight millionths to a hundredth of an inch. It is the size and surface area of a particle that largely determine its interesting physical properties. But the particles are so irregular in shape that measuring them is no small problem; the best that can be done is to measure the length of a large number of particles in one given direction and so arrive at an average diameter for the type of particle under examination. No satisfactory formula for calculating the surface area of a particle from its diameter has yet been devised, but the area can be estimated by indirect methods.

AS EVERY physics student knows, even a small mass of powdered material has an enormous aggregate surface area. A solid cube one centimeter long on each side has a surface area of six square centimeters; if you were to divide this cube into smaller ones one micron on a side, the total surface area of all the cubes would become 60,000 square centimeters. If you broke it into irregularly shaped pieces, the increase in area would be even greater. Some finely divided materials have truly stupendous surface areas; for example, a single gram of pulverized charcoal may have a surface area of 10 million square centimeters.

One of the reasons the great surface area of fine particles is so important is that the surface of a solid fairly bristles



KAOLINITE particles are enlarged 20,000 times in an electron micrograph made by the American Cyanamid Company. Kaolinite is crystalline kaolin, a white silicate of aluminum that is mainly used to make porcelain.

with energy. Even a comparatively incombustible substance, when divided into fine particles to expose more surface, will burn with explosive violence in contact with air. Powdered aluminum, for example, burns with a brilliant flame and the release of great quantities of heat, and in the late war powdered magnesium and other metals were mixed with petroleum jelly in fire bombs. Coal, wheat, sugar and many other materials must be handled with extreme caution when in finely divided form. Large charges of static electricity may be generated in them by the friction of moving air and collisions between the particles; the discharge of this electricity can ignite an explosion. This has been the cause of some disastrous explosions in flour mills and grain elevators in the Middle West. Another property of fine particles that facilitates the release of energy is their increased solubility. Solid aluminum hydroxide, for example, is insoluble in hydrochloric acid, but it becomes soluble when divided into particles two microns in diameter.

THE MOST useful property of fine particles is their ability to adsorb a material, *i.e.*, make it stick to their surfaces. Fine particles always tend to coat their surfaces with a layer of the substance to which they are exposed, be it gas, liquid or a finer solid. The surface holds an adsorbed substance with tremendous force: equivalent to a pressure of 10,000 atmospheres in the case of an adsorbed gas, according to some estimates. The volcanic clay called bentonite adsorbs water voraciously and in so doing swells to several times its original volume. During the building of Grand Coulee Dam a serious leak developed; bentonite was forced into the voids in the sand and in a short time reduced the leak from 30,000 gallons per minute to a trickle.

The adsorbing ability of powders is also put to use in gas masks. Activated (*i.e.*, powdered) charcoal can take up poison gases from the air and at the same time let oxygen through. Some of the activated carbons used in these masks are capable of reducing a deadly gas to a harmless concentration even when the gas is in contact with the carbon only three tenths of a second. Some types of particles show a marked preference for a particular gas, liquid or solid, and they are used for recovery of such a material by adsorption. One example is the utilization of charcoal to recover gasoline vapor from natural gas.

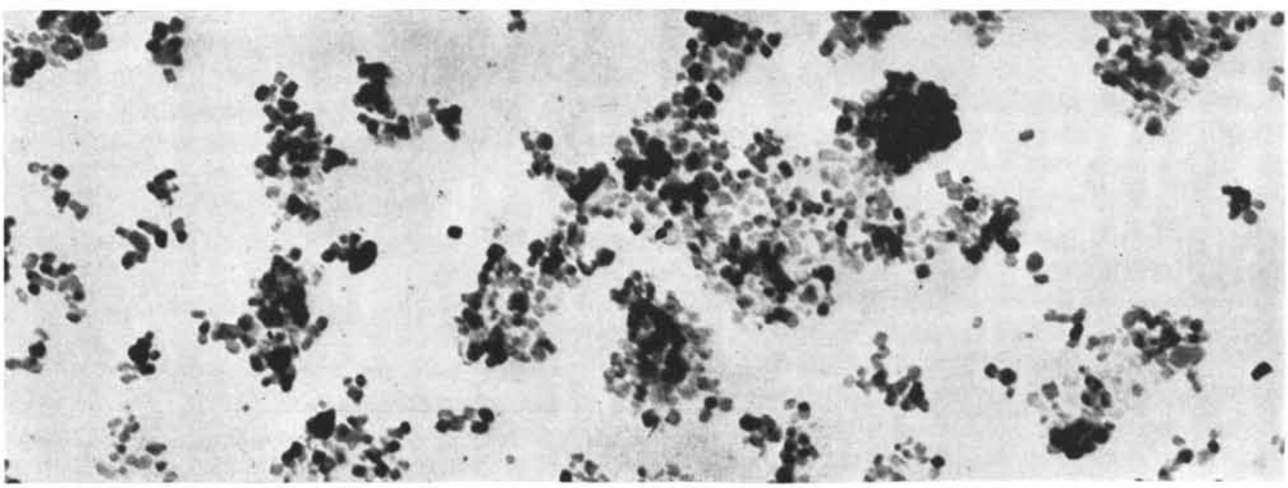
Small particles readily adhere to a large surface, as anyone who has ever washed a car has noticed. When you write on paper with a pencil or on a blackboard with chalk, you are making use of the phenomenon of adsorption of particles. The particles adhere mainly because of electrical charges between the surfaces.

Powder metallurgy, flotation processes for separating minerals, powdered catalysts, powdered fuels, paper and paint manufacture, abrasives, aerosol insecticides, drugs, powdered foods—all these are examples of the large-scale utilization of fine particles. The greatest example of all, of course, is the soil, which supports life on our planet. Soil scientists now know that the surface area and activity of the fine clay particles in the soil are as important to its fertility as humus and nutrients. The fine particles concentrate the minerals and other nutrients in the soil for assimilation by plants. They do this by attracting the ions of these compounds which are formed when water dissolves them. The ions then are able to diffuse from the particles into the root cells of the plants.

PROBABLY the most fascinating phase of the whole subject is the many-sided role that fine particles play in our atmosphere. They have at times put on a highly dramatic and spectacular show. One such performance was the volcanic eruption of Krakatoa on August 27, 1883. This awesome explosion threw into the air a huge volume of dust which was carried into the Northern Hemisphere by the antitrade winds and eventually spread westward around the world. For more than two years the great layer of fine particles hung 5 to 15 miles above the earth's surface; every day at sunset the western sky glowed a lurid red, as if lighted by a great and distant fire. For several years the haze, intercepting part of the sun's heat, made the whole Northern Hemisphere a few degrees cooler than normal. Eventually the dust was dissipated by falling rain and settled to the earth. In our own time we have seen large areas of the U. S. darkened by immense clouds of dust from the Dust Bowl—an estimated 10 million tons of fine particles drifting across the country at one time.

That the dust normally in the atmosphere has a great influence on the weather has been known for some time; recently this knowledge has been applied to artificial rain-making. For many years fruit farmers have made use of it in protecting their groves with smudgepots, whose effectiveness depends mainly not on the heat they produce but on the dense clouds of smoke particles, which prevent the earth's heat from escaping.

We know also that the fine particles in the atmosphere profoundly affect the appearance of the sky. Were it not for them the sky would be black, not blue. It was the physicist Lord Rayleigh who first suspected that this was the explanation of the sky's blueness and in 1871 formulated a theory about it which is now fully confirmed. Particles suspended in a transparent medium scatter blue light more than they do red light. Such a system appears reddish by transmitted light and bluish by reflected light. At sunrise and sunset the sky in the direction of the sun is a vivid red, while the other portions of the sky are a



TITANIA particles are enlarged 92,000 times in an electron micrograph made by the Radio Corporation of America. Titania is titanium dioxide, a white powder that is commonly used in white pigments for paint.

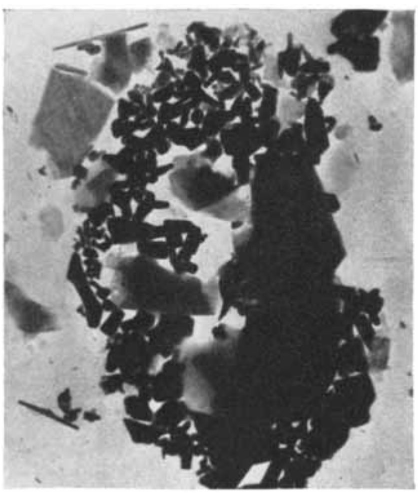
deep blue. The colors are enhanced at these times by the fact that the rays of sunlight enter the atmosphere obliquely and therefore pass through a greater depth of atmosphere. At midday the entire sky is a paler blue, practically all the light having been scattered by the particles in the atmosphere overhead. Twilight comes when light rays from the sun fall upon the upper air too obliquely to be bent down to the earth's surface by refraction. The rays are scattered and sent down from particle to particle as a soft shimmering light.

IN INDUSTRIAL nations the fine particles in the air are a matter of no small consequence to man's health. The pollution of our lower atmosphere by dust and smoke is becoming a critical problem in the U. S. The exhaust from our chimneys and smokestacks is composed of tremendous quantities of fine particles of carbon, metallic dusts and other materials. In addition there are soil particles from the fields and roads, rubber and carbon particles from truck and automobile tires, carbon particles from engine exhausts, particles of plant or animal origin, including pollen, and volcanic and cosmic particles. The particles that hang in the air—too light to fall to earth and too heavy to be driven there by thermal diffusion—have an average diameter of about half a micron. In New York City as many as 80,000 such particles are found in one average cubic centimeter of air. Since a normal human being's intake of air is about five million cubic centimeters per day, the number of particles taken into the respiratory system daily is truly prodigious. The air in the country, on the other hand, is relatively free of suspended particles. As a result the lungs of a rural dweller are comparatively pink and devoid of foreign solid matter, while those of a city dweller often appear black and are sometimes caked with large quantities of solid matter. Pollution of the city air is believed to be responsible for the high incidence of colds and sinus infections among city residents.

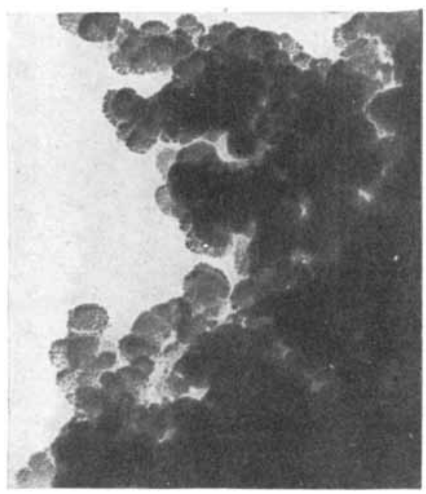
Siliceous dust particles are known to cause the incurable disease called silicosis, and they are suspected to produce a tendency to tuberculosis. Curiously, the damage to lung tissue caused by breathing siliceous particles can be greatly reduced by adding very fine particles of aluminum or aluminum oxide to the air to be breathed; just why the latter particles should act as an antidote is not understood.

When particles from the air enter the upper respiratory tract, they are selectively sifted out. Particles larger than five microns are absorbed and eventually discharged from the system. Some of the finer particles are expelled in breathing. The ones that do the damage are those deposited in the alveoli (air sacs) of the lungs. Once deposited, they have three possible courses to follow: they can go into chemical solution and be spread throughout the body; they can pass into the bloodstream without dissolving, or they can remain in the lungs. Particles that dissolve produce reactions that may be harmless or injurious, depending on their toxicity. Those in the bloodstream are efficiently removed by the kidneys and liver, but can often prove fatal in high concentration. Those retained in the lungs produce a permanent tissue change called fibrosis, and they are probably the most dangerous. The degree of toxicity shows rapid increase as the particle size decreases, as might be expected, since the finer the particle, the greater its physical and chemical activity. Much of the nature of fine-particle toxicity is at present unknown. Size seems to be at least as important as chemical composition; particles about two tenths of a micron in diameter, whatever their composition, appear to be the ones that cause fibrosis.

The ancient Greeks discovered that fine particles, properly used, had healing properties. Dioscorides observed that kaolin clay particles used as a dressing



FACE POWDER with several ingredients is enlarged 15,000 times.

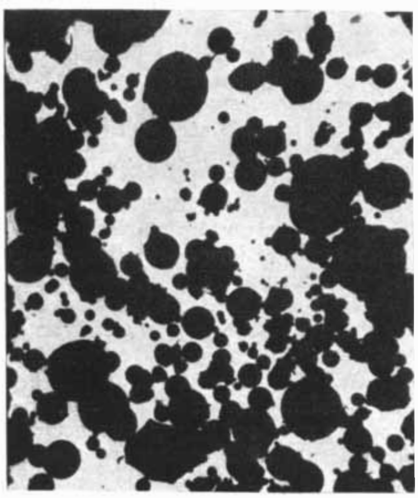


CARBON PARTICLES are shadowed and enlarged 200,000 times.

could heal such skin diseases as erysipelas. Today finely divided kaolin medicaments promote healing in external gastrointestinal fistulas, and given internally they relieve diarrhea, dysentery and colitis. Activated charcoal is an efficacious remedy for hyperchlorhydria, an abnormal stomach condition. Powdered aluminum hydroxide is effective in the treatment of peptic ulcer. The medicinal value of some of these materials stems from their power to adsorb preferentially certain toxins or acids. Aluminum hydroxide, for example, reduces excess acidity by adsorbing the acid. Cosmetic powder, as every woman knows, helps to evaporate sweat from the skin. A very recent development utilizes fine particles in the treatment of coronary occlusion: talcum powder injected into the pericardial sac encasing the heart apparently stimulates weakened heart muscles.

NOT LONG ago a doctor's knowledge of fine-particle behavior decided a case in a law court. He was called upon to help identify the heir of a man who had died while his son was still an infant and whose apparently worthless stock had become valuable when his son was nearly grown. Two claimants, each asserting he was the dead man's son, appeared. It was known that the true heir had suffered a severe attack of smallpox in infancy. With a wisdom reminiscent of Solomon, the doctor ordered the two boys into a cellar to move a large pile of fine coal. When the blackened pair emerged, one youth had white spots on his skin, the other was completely covered with dust. The doctor thereupon proclaimed the boy with the spots the rightful heir. Coal dust will not readily stick to smallpox scars.

Clyde Orr, Jr., is a research assistant at the State Engineering Experiment Station of the Georgia Institute of Technology.



FLY ASH PARTICLES are enlarged some 2,600 times after precipitation.

The Earth's Heat

Like the fever of a sick man, the temperature of rocks in the crust of our planet is a clue to the processes of its inaccessible interior

by A. E. Benfield

WHEN a doctor examines a patient, one of the things that is apt to interest him is his patient's temperature. The temperature, together with other tests, helps the doctor to understand what is going on inside the patient's body. A geophysicist similarly hopes to get some clues as to what is going on inside the earth by taking its temperature. The earth of course makes things a good deal more difficult for us, because, unlike the human body, it does not have a self-regulating thermostat to keep its temperature uniform, and we cannot insert a thermometer any deeper than the outer part of its skin. The best we can do is to take the temperature in deep oil wells, mines, railroad tunnels, hydroelectric shafts and so on, sampling at most the top few thousand feet of the earth's crust. The deepest well man has drilled is only about four miles down. It seems safe to say that we will be able to fly through the vast spaces of the solar system and reach some of our neighbor planets long before we find a way to penetrate to the center of our own planet, 4,000 miles away.

Nevertheless our information about the heat of the earth, meager as it is, is helpful. The subject of course has its utilitarian aspects. Prehistoric man learned thousands of years ago not to go too near an erupting volcano, and to use earth-warmed hot springs for bathing and medical purposes. In Reykjavik, the capital of volcanic Iceland, offices and homes are heated today by natural hot water piped from the ground. Elsewhere, engineers are giving considerable attention to the possibility of heating houses in winter and cooling them in summer by means of the heat pump, a device for transferring heat from the earth to the house and *vice versa*. In oil wells studies of temperature conditions at depth provide helpful information for drilling and for getting oil production. In very deep mines, such as the gold mines of South Africa, the heat of the earth becomes a serious problem; ways must be found to cool the mines sufficiently so men can exist and work in them.

Primarily, however, our interest in the heat of the earth is the same as the doctor's in his patient; we want to find out what it can tell us about the inaccessible interior—from which we may eventually be able to determine how mountains are made, what causes volcanic eruptions, how the earth's magnetic field is created, why the great ocean deeps are where they are, and various other intriguing matters that have long concerned geophysicists.

IT HAS been known for many years that as we go deeper and deeper into the earth the temperature steadily rises. This is not true, of course, of the top few tens of feet near the surface—as we notice on descending into the cellar on a warm spring day when the cold of the preceding winter is still in the ground. But the effect of seasonal changes in temperature is seldom appreciable more than 50 feet below the surface. Below that the temperature of the earth always increases with depth; at the bottom of some of the deep oil wells in California and elsewhere it exceeds the boiling point of water at atmospheric pressure.

Why does the temperature always increase with increasing depth? There are various answers, depending on various theories as to how the earth was created. The classical view is that the earth originated as a hot body and still retains much of the original heat in its interior. It is easy to understand how this might be so if the earth was formed from a piece of the sun, or from a stellar fragment released by the close approach of two or more stars. There is another theory, variously known as the "dust-cloud hypothesis" and by other names, that the earth was formed by the gradual coalescence of cool dust, gas or small particles in interstellar space. A planet growing in this way might have ended up with a hot surface, due to the melting and vaporization of the fast-falling particles as they collided with the planet toward the end of its growth. At the same time the planet's interior would become hot, though possibly not hot enough to melt, due to its compression by the increasing weight of the accreting material accumulating on the surface, and for other reasons.

Yet we cannot be at all sure that the earth actually was very hot when it was formed. In fact, on the basis of the observed abundance of the elements in the earth's crust the University of Chicago chemist Harold C. Urey has recently advanced the theory that the earth may have formed at a relatively low temperature. It is too early to say what lasting effect this theory will have on our ideas, but it is possible that discussions of it may clarify some of our notions about the temperature, early history and structure of the earth. In any case, we must seriously consider the possibility that the earth's crust is not cooling, as was once supposed, but on the contrary is steadily becoming warmer.

The chief difficulty in knowing the temperature deep in the earth is that we cannot get there to measure it. If we could, we might find information that could help us to decide what is the correct theory of the earth's origin. We can, of course, study the temperature of the molten lava arising in volcanoes, but we do not know how much the temperature of this has changed on its upward journey, nor from what depth it comes. It used to be thought that lava came from a shallow depth, but recently it has been suggested that it may originate quite deep in the mantle.

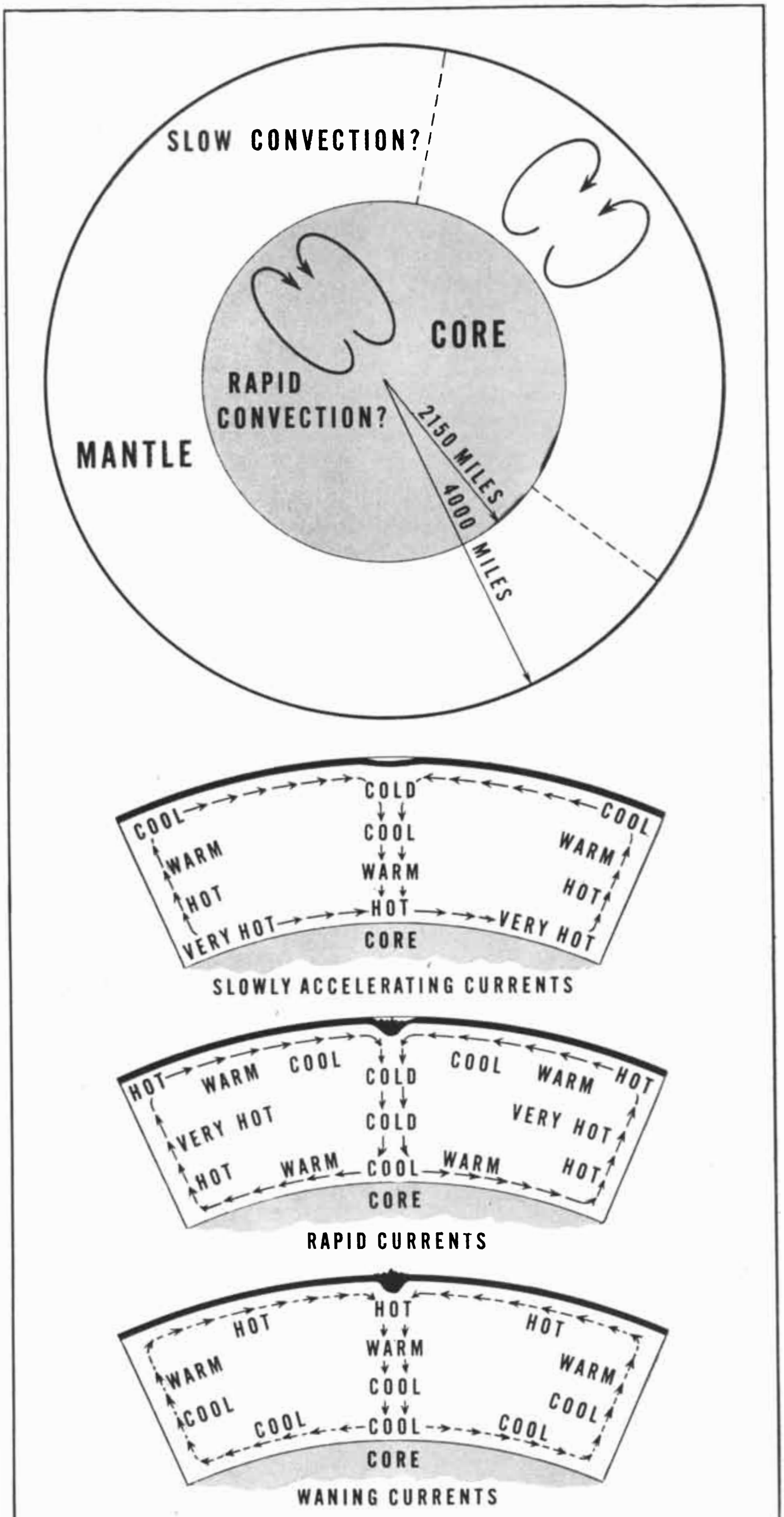
We know that in the accessible outermost crust the rate of increase of temperature with depth, called the temperature gradient, differs widely from one place to another. This is true not only for volcanic or hot-spring areas, where we would expect to find wide departures from the "normal," but even in quiet areas far from volcanic activity. Temperature gradients in ordinary quiet areas range anywhere from less than 10 to as much as 50 degrees Celsius (Centigrade) per kilometer. Furthermore, even in a single location the temperature gradient is not always smooth but may change abruptly at some particular depth; for example, in some wells in Cheshire, England, the rate of temperature increase suddenly doubles at a certain level.

WHAT IS the reason for these differences in temperature gradients from place to place? One explanation might be that there are differences in the amount of heat flowing from the depths of the earth at the various places. This is certainly partly true. We now know, however, that the observed variations in quiet areas are due largely to differences in the thermal conductivity of the particular rock strata at each place. This would also account for the variations in temperature gradients from one depth to the next; one layer of rock is a better conductor of heat than the other. The heat flowing in a solid depends on the product obtained by multiplying the temperature gradient in the solid by its thermal conductivity.

Measurements on rock samples from wells, mines and tunnels, made during the last 12 years in quiet areas of South Africa, England, Iran and the U. S., have shown that temperature gradients tend to be low where the thermal conductivities of the rocks are high, and *vice versa*, so that the product of these two quantities is fairly constant. It is beginning to be clear, in fact, that apart from special areas like Yellowstone National Park, where some local disturbance causes high temperatures near the surface, the amount of heat flowing out of the earth from below is probably pretty much the same almost everywhere on the continents. However, very little of the earth's surface has yet been investigated, and interesting regional anomalies may well be found in the future.

We do not know how much heat is flowing up from below into the oceans, but Hans Pettersson of Sweden and E. C. Bullard of England have recently begun to make some of the necessary measurements and we should have some information about it before long. Since almost three quarters of the earth's surface is covered by water, we clearly need such information before we can begin to estimate how much heat is coming from the interior of the earth as a whole.

One thing we do know, of course, is that per unit of area the amount of heat emerging from the earth is very small. On the continents where we have measured it (disregarding such special local phenomena as volcanoes and hot springs), the heat flow amounts to only about one millionth of a calorie per square centimeter of surface area per second. This is several thousand times



CONVECTION CURRENTS which possibly exist in the mantle of the earth might be detected from measurements of the earth's heat in the vicinity of a young mountain range. Such currents have been proposed as the cause of mountain building. The possible stages in the process are shown in the three cross sections of the mantle at the bottom of this drawing.

less than the average heat per square centimeter reaching the earth from the sun; obviously it is the sun, not the heat of the earth, that decides our atmospheric temperature and climate.

IT IS likely that most of the heat we detect flowing to the surface does not come from the hot core at all but originates in the crust. This is an idea that came with the discovery of radioactivity, and it has not only heavily revised old notions about the age of the earth (which the late Lord Kelvin as recently as 1899 estimated to be only 20 million years, on the basis of the rate of the earth's supposed cooling from an original molten state) but has raised the possibility that the earth may be warming up rather than cooling off.

We know now that heat is continually being produced in small quantities in all common rocks by the disintegration of radium, uranium, thorium, potassium and other radioactive atoms in them. Radioactivity is particularly pronounced in the granitic type of rocks, of which the continents are largely made. The thickness of the continents' granitic layer is thought to average something of the order of six miles. The amount of heat produced by natural radioactivity in this thickness of granite would account for about half the heat we observe flowing to the earth's surface. (Mountain ranges, where the granitic layer is probably compressed and thickened, should generate more heat than low-lying plains, and the Harvard geophysicist Francis Birch added support to this supposition last year by measurements which showed that the heat flow in the mountains of Colorado is some 60 per cent higher than normal.) Then, to the radioactive heat from granite, we must add that from the basaltic rocks which probably underlie the continents and the oceans. Volume for volume basaltic rocks produce radioactive heat only about half or a third as rapidly as granite, but the basaltic layer is thought to be about twice as thick as the normal continental granitic layer that overlies it. To be sure, we are not absolutely certain about the existence of these postulated layers of granite and basalt, or about the amount of their radioactivity. Nor do we know how radioactive the earth's interior may be, though we have reason to believe from the evidence of meteorites, which are considered by some to be fragments of a broken planet, that it has some radioactivity. (Our ignorance of the amount of radioactivity in the earth's interior is, by the way, another major reason why we cannot estimate its temperature.) At all events, it seems quite possible that the earth is generating radioactive heat faster than it is losing heat to space. Consequently the earth may be gradually warming, though at so slow a rate that we need not be anxious about it.

It has been suggested that radioactivity may be the explanation of volcanic heat, but this is unlikely because lavas usually exhibit rather little radioactivity. However, the possible radioactive content of the earth's liquid core has recently been suggested by Bullard as the possible cause of convection in the core, and perhaps of the mechanism that creates the earth's magnetic field ("The Earth's Magnetism," by A. E. Benfield; SCIENTIFIC AMERICAN, June, 1950).

ANOTHER kind of convection current, of a very slow and intermittent nature, may occur outside the core in the earth's mantle. The mantle of the earth, as a geophysicist uses the term, means not the crust but the 2,000-mile-thick section that lies between the crust and the earth's core. The mantle behaves like a solid for earthquake waves, but it probably resembles a thick viscous liquid more than a real crystalline solid. D. T. Griggs of the University of California and others have suggested that thermal convection currents in the mantle might account for the building of mountain ranges and for certain gravity anomalies associated with some of the ocean deeps.

The theory is that material at the base of the mantle, near the core, may be expanded by heat so that it becomes light enough to rise. On rising it forces adjacent cooler material to sink and take its place, thus starting a "convection cell" in the mantle (*see diagram on page 55*). At the base of the crust, the convection current may tend to drag down a section of the crust, thereby forming a hollow which fills with light sediments. This may explain the curious gravity deficiencies found over some parts of the oceans. Eventually the convection current may bring up enough hot material from below so that the cell stabilizes and the current itself ceases. This would end the downward-pulling force on the crust. Released from the downward pull, the submerged crustal material would rebound upward, like a piece of ice pushed down into a pond and then released. The rising buoyant material, according to the theory, might create a mountain range.

Now there is a way by which this theory of the existence of convection currents in the mantle might be tested. If such currents exist, and if they bring up relatively hot material to the top of the mantle close to the surface, the heat flow to the surface there should be greater than normal. The place to make such a test is near a young mountain range, where the convection current would have ceased only recently, geologically speaking. One such measurement has been made in California, and the heat flow was indeed found to be about 20 per cent greater than normal. But many more measurements are needed, and even then a high heat flow would not be definite proof of the theory, for other interpretations of the flow might easily be found.

ONE of the most remarkable facts about the earth's heat is the extreme slowness with which it travels through the soil and rocks by conduction and the great length of time that temperatures linger. Just a foot or two below the surface of the ground the daily variations of temperature in the air are hardly felt; the heat or cold of the day seldom produces a change of more than one degree Celsius in the ground at that depth. And the effect arrives there from half a day to a day late, depending on the thermal properties of the particular soil. A few feet farther below the surface only the longer-term seasonal changes in temperature can be detected, and these arrive months late, so that the rock at this depth is warmest at midwinter and coldest at midsummer. At 50 feet below the surface the effect of the seasonal change is something like a year late, and the fluctuation of temperature is tiny. Those familiar with the behavior of electricity at high frequencies will recognize this to be a thermal "skin effect" of rather fantastic dimensions.

As for the lingering of temperatures: the effect of the cold of the last Ice Age, some 20,000 years ago, is still appreciable at a depth of a few thousand feet. Recently Birch has shown that in measuring the flow of heat in a deep well it is even advisable to take account of a prolonged spell of cold weather that is thought to have lasted for about 100,000 years at the beginning of the Pleistocene Period, a million years ago.

In fact, the earth's conduction of heat is so slow that the whole three billion years of its age has not been long enough for the possible radioactive heat from much below a depth of about 200 miles to arrive at the surface in appreciable amounts by conduction alone. L. B. Slichter of the University of California has shown that radioactive heat generated below this depth is still largely accumulating and has not had time to reach us, so that we cannot yet detect it at the surface. A few billion years from now we should, of course, have a better idea of the situation.

In the meantime, for those not endowed with supernatural patience, heat-flow measurements in the earth can aid in our diagnosis of the earth's condition. These measurements do not tell us the whole story nor answer all our questions, but they do bear on a good many of the interesting geophysical problems of the past, present and future history of the earth.

A. E. Benfield, assistant professor of applied physics at Harvard University, was the author of The Earth's Magnetism, *which appeared in the June issue of this magazine.*

by L. C. Dunn

Genetics and the Races of Man, by William C. Boyd. Little, Brown and Company ($6.00).

ANTHROPOLOGY stands potentially at the center of what might be called the humane sciences. A humane science is, or should be, one that deals with man and unites the social and natural sciences. On the one hand anthropology deals with man's culture; thus it tends to include the history of civilizations and the social sciences of economics, government, sociology and social psychology. The origins of art, language and literature belong to anthropology; it reaches out from the primitive cultures that were its first workshop to the sophisticated industrial societies that now present the same kind of problems. On the other hand anthropology is concerned with the biology of man and his immediate relatives in the animal kingdom, with their structure, function, behavior, ecology, evolution, in the same way that zoology is concerned with these features of animals in general.

The unifying problem that underlies the whole science is human variety. The origin of man's many cultures is the question that animates cultural anthropology. The primary problem of biological anthropology, which its practitioners call physical anthropology, is to understand the immense variety, both in time and space, that marks all human beings.

The nature of the differences among individuals and among the populations called races is a problem of transcendent practical importance. Somehow the polyglot inhabitants of this world must learn how to live together. "Know thyself" is more than a wise recommendation; it is about to become a condition of survival. We have begun to realize that knowing oneself means knowing everyone else—all those other animals in the one species that became human. How did our individual and group differences originate, and how are they perpetuated? Are they absolute and permanent, or relative and transitory?

Answering such questions has turned out to be much more difficult than one might have expected. The biological characteristics of man appear to be as tangible and accessible as the information that a physician must gather in a

BOOKS

An important work on the application of genetics to the problems of race

physical examination of his patient, but the answers to questions about man's biology and especially about the nature of racial variation have been slower in taking form than those relating to man's culture. In a sense cultural anthropology has outstripped biological anthropology because, strange as it may seem, its problems are better defined. Now illuminated by a new point of view and new methods, biological anthropology bids fair to assume its rightful place among the humane sciences.

One sign of the renaissance is *Genetics and the Races of Man.* This new book by William C. Boyd, professor of immunochemistry at the Boston University School of Medicine, has for the first time comprehensively brought together both the data and the methods by which the theory of heredity can be applied to the problem of racial variation in man. Mendel's proof that the hereditary substance is not something continuous like a fluid but consists of elementary particles, or genes, which maintain their integrity generation after generation, was a revolutionary discovery destined to change the traditional views of evolutionary processes, of species and races of animals, plants and men. Professor Boyd has attempted to explain the resulting "revolution in anthropological thinking" in a book which is certainly a landmark in biological anthropology.

The revolution described by Boyd is the consequence of thinking in terms of constellations of genes, or genotypes. Of course the genotype of an individual or group is partly inferred from its appearance, or phenotype. It is also inferred from the phenotypes of relatives, particularly parents, siblings and offspring. There is no doubt that the phenotypic description is indispensable. But when the phenotype has been described as, say, "brown-eyed," its usefulness is ended. The description may be greatly extended by specifying the genotype. A brown-eyed man may be one of two distinct genotypes, transmitting genes for brown eyes to either half or all of his children. In dealing with populations this consideration is obviously of great importance.

The criterion of race or "racial type" has generally been taken to be similarity in appearance. This has never described the underlying reality. All human groups consist of individuals of whom no two are alike, and no one represents an "ideal" type. But when a given group can be described by the frequency of certain genes found in it, and when this group can be distinguished from other groups having different frequencies of the same genes, the way is open for supplementing the present methods of race classification with new techniques. What is more important, the application of this "gene-frequency" method provides a means for understanding race formation as a part of the process by which the human species continuously changes and evolves.

It is no coincidence that the most reliable indicators of human genes are the blood groups and that Boyd has been for many years one of the chief students of these hereditary properties of the blood. What is more natural than that he should use the tool that he helped to perfect for the analysis of one of the chief problems of anthropology? Anthropologists trained in the use of body measurements are probably going to regret having their criteria passed over in the setting up of race classifications. But there is no reason why biological anthropology should not employ chemical or immunological or any other methods.

The racial classification derived from the new method is sensible and consistent. At many points it agrees with results reached by a combination of the older phenotypic methods. The six races that emerge are, except for a hypothetical type ancestral to the present peoples of Europe, those which the great race-making factors of isolation have stamped with the familiar imprints of white, black, yellow, red and Australian dark. But something distinctly new has been added. The same pairs of blood genes exist in all groups, indicating their fundamental kinship. The nature of the differences among the groups is indicated by Boyd's definition of a race as "a population which differs significantly from other human populations in regard to the frequency of one or more of the genes it possesses."

We have thus come a long way from the absolute kind of difference promulgated by the older anthropology. That position has now been made untenable by the demonstration of a continuous circulation of the same genes through large segments of the earth's population. Needless to say, ideas of racial superiority and inferiority and of fixed divisions among peoples get no support from this new view of race.

Genetics and the Races of Man will be many things to many people. The author has put between one set of covers an outline of the principles of genetics for both the anthropologist and the general reader. He has brought together the most complete study of racial variations in blood groups and newly compiled data on the recently discovered groups (A_1, A_2 and Rh). He has even provided appendices showing how the several kinds of calculus needed for the application of the gene-frequency method can be used in the study of general problems in anthropology and genetics.

Leslie Dunn is professor of zoology at Columbia University.

THE HUMAN USE OF HUMAN BEINGS, by Norbert Wiener. Houghton Mifflin Company ($3.00). In his earlier book on cybernetics Norbert Wiener dealt with the theory of communication engineering: how, in effect, machines can be designed that will not only take orders from their masters—men or other machines—but can give themselves orders in response to outer circumstance. In this book he is concerned with the intrinsic meaning of communication, with the social, ethical and economic problems arising from the use of "thinking" machines, with the good to be derived from making machines more human and with the evil of mechanizing men. Wiener exploits the elastic boundaries of his fascinating subject; he writes brilliantly and with characteristic independence about the inhuman use of human beings and other abuses of the contemporary world. But the reader is apt to be dazed, as well as dazzled, by a book which in a brief 200 pages discusses entropy, Mexican frescoes, the Industrial Revolution, Parkinson's disease, the patent system, the logarithmic scale in order-disorder relations, dietary habits, Duncan Phyfe furniture, the relation between law and communication, line noise, Rudyard Kipling, Marxism, secrecy in science, Buddhism, the history of language, Pavlov's dogs, *The Saturday Evening Post,* human morphology, Catholicism, the atomic bomb, Heinrich Heine, high-pressure distillation, the Thirty Years' War, the electric lamp, the prose of Theodore Roosevelt, sequential analysis, and the mediocrity of high-school teachers of English.

THE PAPERS OF THOMAS JEFFERSON: VOL. I (1760-1776), edited by Julian P. Boyd and others. Princeton University Press ($10.00). This is the first volume of an opulent literary undertaking that will include Jefferson's 18,000 letters, his public papers and all that he wrote on law, government, education, philosophy, religion, agriculture, architecture and science, including jottings on subjects as diverse as Archimedes' screw, furniture design, recipes for macaroni, snuff, smallpox, Sophocles and specific gravity. Here will be Jefferson's memoirs and diaries as a traveler, farmer, ambassador, astronomer and politician, his manual on parliamentary practice, his autobiography, his biography of Jesus, his fee books, briefs, maps, surveys, account books, itineraries, meteorological data, literary and linguistic papers, architectural and other drawings; and, in full or in summary, the more than 25,000 letters written to him. This was a man who could draft the Declaration of Independence and invent a cryptographic device a century in advance of his time; who was described, quite inadequately, by James Parton as "a gentleman of thirty-two who could calculate an eclipse, survey an estate, tie an artery, plan an edifice, try a cause, break a horse, dance a minuet and play the violin"; who, as Henry Adams wrote, "aspired beyond the ambition of a nationality and embraced in his view the whole future of man"; whose entire life was dominated by the faith that "the free right to the unbounded exercise of reason and freedom of opinion" were the essential conditions of human progress; who dedicated himself to the realization of these conditions not only in his country but everywhere. For this rare man the scholarship, the editorial discrimination and the format of the splendid Princeton edition are a fitting monument.

COLOURS AND HOW WE SEE THEM, by H. Hartridge. G. Bell and Sons Limited, London ($3.50). These are the 1946-1947 Royal Institution Christmas Lectures, describing simply, with the aid of numerous diagrams and plates, the properties of the spectrum, how colors are produced, how they are seen and used, and many of the strange properties and illusions of color. One of the attractive features of the book is the clear and detailed account of the various lecture experiments; this not only helps to bring the subject alive but, as a result of Professor Hartridge's selection, wherever possible, of experiments which can be performed with common objects, the reader can easily repeat for himself and his children some of these beautiful demonstrations of optical principles.

SCIENTIFIC, MEDICAL AND TECHNICAL BOOKS PUBLISHED IN THE UNITED STATES OF AMERICA: SUPPLEMENT 1945-1948, edited by R. R. Hawkins. R. R. Bowker Company ($10.00). This is the supplement to a standard bibliographical work prepared under the direction of the National Research Council and edited by a leading librarian, describing scientific, medical and technical books published in the U. S. over the past two decades. The first volume covered the period 1930-1944; the supplement, 1945-1948. Besides the customary bibliographic details, there are supplementary notes giving a useful view of the contents of each book. A valuable aid to scientists, writers, librarians, teachers and others concerned with scientific literature.

HUMAN ECOLOGY: A THEORY OF COMMUNITY STRUCTURE, by Amos H. Hawley. The Ronald Press Company ($5.00). Ecological investigation concerns "the community, the form and development of which are studied with particular reference to the limiting and supporting factors of the environment." This book contains many useful and interesting data concerning the relationships of human aggregates to their environing circumstances, but it is not distinguished by much more than the data themselves. Such threads as may have started to run through this book were apparently broken en route, and the reader finishes the last page still awaiting a theory of community structure. It is to the author's credit, however, that he recognizes the importance of the "taxonomic task" in ecology, and his desire to determine and classify the data of his field may have provided the groundwork for further theoretical advances in it.

HISTORY OF THE NATIONAL ECONOMY OF RUSSIA TO THE 1917 REVOLUTION, by Peter I. Lyashchenko. The Macmillan Company ($13.00). A work of historical and economic importance by a noted Russian scholar, now first translated under sponsorship of the American Council of Learned Societies. It has the major purpose of "helping to close the intellectual gap between the English-speaking peoples and the Russian people, for which the basic difference in language has been so largely responsible." Bibliographic and chronological index, numerous valuable maps and tables.

MAN THE MAKER, by Robert J. Forbes. Henry Schuman ($4.00). A concise illustrated history of technology and engineering, useful as a general introduction to a vast and complex subject on which only one other satisfactory and comprehensive English book has been written: A. P. Usher's *A History of Mechanical Invention,* unfortunately now out of print.

HISTORIC RESEARCHES: CHAPTERS ON THE HISTORY OF PHYSICAL AND CHEMICAL DISCOVERY, by Thomas W. Chalmers. Morgan Brothers, Ltd., London ($5.25). Here is a reprint of 38 historical articles, originally appearing in the English journal *The Engineer,* on various subjects such as friction, heat, electrodynamics, ether drift experiments, classification of the elements, molecular physics, conduction of electricity through liquids and gases, X-rays, isotopes. Authoritative, lucid, exceptionally interesting.

What GENERAL ELECTRIC People Are Saying

THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

OF THE THOUSANDS of telescopes that have been built by amateurs in the past quarter of a century, no two have been exactly alike. Each instrument, designed by its owner from the basic principles described in *Amateur Telescope Making,* strongly embodies the builder's creativeness and individuality. The resulting variety has been of endless interest.

Of course the amateur telescope maker cannot always choose his ideal telescope. He must take into account the facilities available to him. The two telescopes described below represent extremes in this respect. The builder of the first had access to practically every shop facility he could desire. The second had only a few simple tools. Each did the best he could with what he had.

When a telescope is designed to be stationary rather than portable, it is possible to go all the way toward giving it desirable mass and ruggedness. Thus the first of our two telescopes, the 8-inch $f/8$ reflector shown in Roger Hayward's drawing on this page, is provided with a mounting so uncompromisingly rugged that many would regard it as almost capable of carrying a 16-inch mirror. It was designed and built by Carleton H. Schlesman, 2838 Chew Street, Allentown, Pa., a physical chemist and division head of the Naval Ordnance Laboratory at Silver Spring, Md. "The mounting," he explains, "was built to be rigid enough to permit use of the telescope as a camera. It has proved excellent in this respect, and is probably stiff enough for a 12½-inch telescope used visually.

"The polar-axis shaft, tapered from 2½ inches to 1¾ inches, was turned from a piece of 4-inch shafting. This provided enough diameter of metal to mount the declination axis on Timken grease-sealed automobile rear-axle roller bearings. The 2¼-inch declination axis turns in bronze bushings. The entire tube assembly can be quickly unscrewed at that point and taken indoors for storage. A tin cap protects the mounting from the weather.

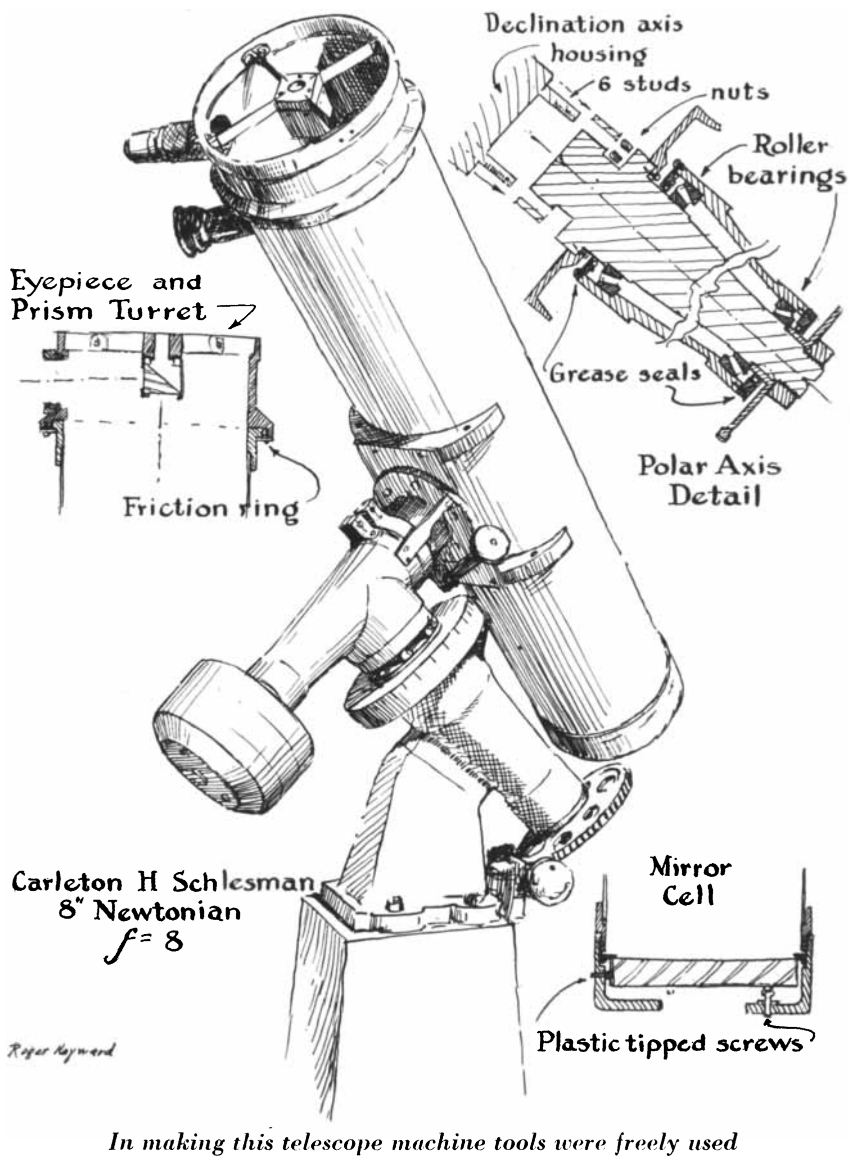
"The polar axis is driven through a 4,000-to-1 double worm-gear reduction from a reversible two-speed electric motor through a shaft with universal joints. The motor is in a watertight box on the side of the pier.

"The head of the declination axis is terminated in a nose thread of the lathe-spindle type having six turns per inch. The saddle that carries the tube is bolted to a standard lathe chuck plate, which screws on the end of the declination axis. The tube can be unscrewed from the telescope mounting in 30 seconds, yet it is very rigid when in place.

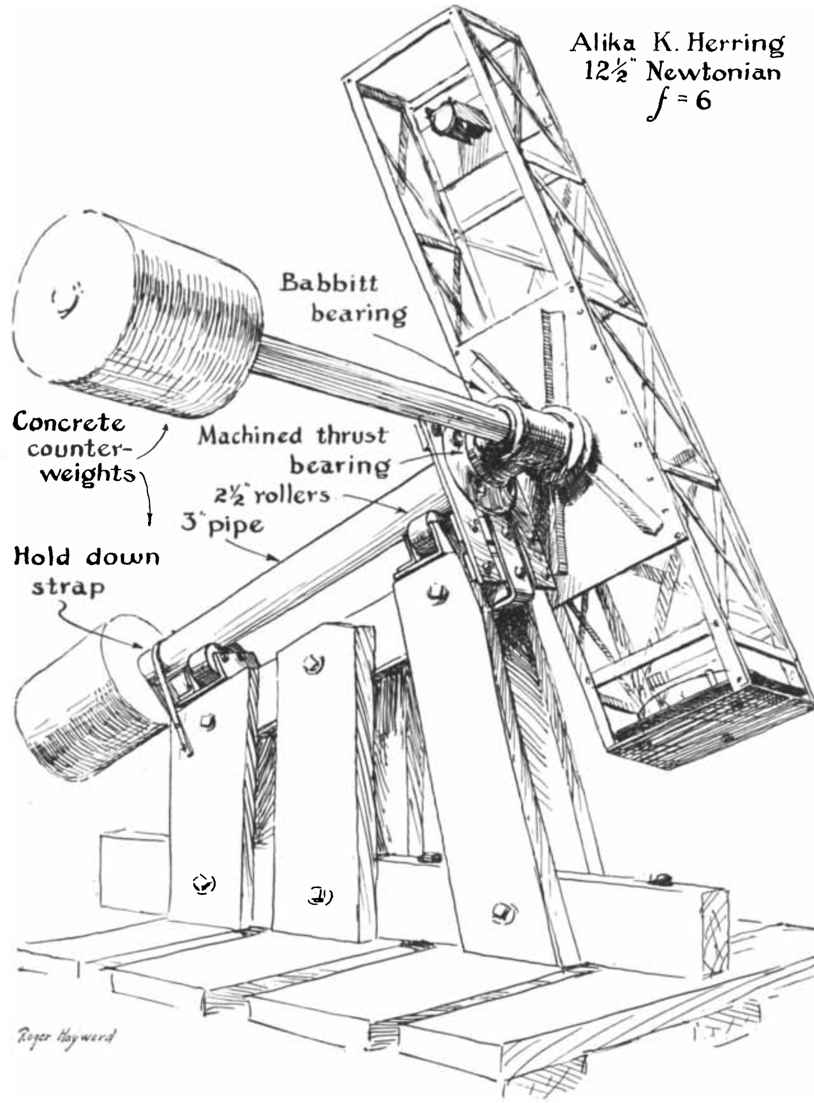
"The saddle may not look very rigid, but it has proved to be very stiff. Stiffness requires attention to the fastenings. The rectangular plate of steel that connects the circular lathe chuck plate to the lunes of the saddle is 5/16-inch steel 4 inches wide. To attach it to the lunes a silver-solder ribbon was placed between the surfaces, small screws serving to make the joint fit, and the solder was melted with a torch. Thus for practical purposes the saddle became one piece.

"The hand-made sheet-iron tube, rolled and welded by a tinsmith, was a source of endless trouble. It was not quite round, and threw the turret ring at its top out of round when forced into place. If commercial tube selected for roundness cannot be purchased, a finishing cut should be taken in the turret ring after the tube has been forced into place. This can be done on a lathe if the tube can be lined up on the carriage, with the tool in a holder, mounted on a face plate.

"The eyepiece revolves on an aluminum rotating turret that affords comfortable viewing angles however the tube is pointed. Since its outer end rotates on a diameter of about 24 inches, the observer can avoid climbing a ladder by looking up into the eyepiece for



In making this telescope machine tools were freely used



A minimum of machine work was required for this instrument

stars near the zenith and down into it when they are near the horizon.

"The rotating aluminum turret was designed to obtain ruggedness with light weight. It turns on an aluminum ring which is carefully machined to a shoulder and attached to the tube with cap screws. The turret is machined with a corresponding close-fitting groove. It drops over the shoulder and is held in place by a clamp ring attached with flat screws. Once these screws have been tightened to give a little friction drag they may be forgotten.

"Thus far the work has been a simple lathe job. The 2½-inch hole for the eyepiece was carefully centered and bored, and the eyepiece flange was threaded to take the focusing collar. A turned ring on the back of the flange lines up the eyepiece. Four small bosses, or pads, are left on the back of the flange to level it up. These are drilled for cap screws. This avoids any trick machining except on the bosses.

"Below the eyepiece is the right-angle finder eyepiece, which swivels in trunnions for convenience and has a lighted reticle.

"No adjustment is provided for the diagonal. The saw-steel knife-edge supports are silver-soldered into slits cut into the corners of a square piece of brass. They were checked for equal length and silver-soldered into four slotted T-shaped blocks, two screws holding each to the turret ring. The diameter of the diagonal support system was purposely made slightly smaller than the inside diameter of the turret ring, so that the screws would stretch the assembly under considerable tension before the blocks bottomed. This tension makes the support very stiff.

"The entire system supported by the turret ring was then set up in the lathe face plate and the central alignment hole in the central brass support block was faced off and accurately bored concentric with the turret-rotating surface.

"The diagonal was aligned on the bench with a bronze mating block held in place by four machine screws. The prism is held in an aluminum box and located by accurate 45-degree shoulders on the sides.

"The diagonal mounting block that supports the aluminum block is bolted into place without any adjustment. The turret face and center hole of the diagonal support were bored at a single setting of the job on the lathe. The prism holder has a locating pin to line it up with the hole in the mounting block. This arrangement has been very successful; the eyepiece may even be horsed around without losing sight of a star.

"The mirror is mounted in a threaded cell, a heavy-walled aluminum casting, which is ventilated through a 4-inch hole in the back. It was simple to make and is easy to unscrew, but could be improved. It screws by a thread of about 9-inch pitch diameter and 10 threads per inch to an aluminum ring that is permanently attached to the tube.

"The mirror rests on four setscrews tipped with Lucite plugs, with its sides against four similar screws around the periphery, permitting collimation and centering.

"The mirror cell has never given trouble. The threads must be lubricated to prevent sticking. If the cell is screwed up too tight the star will not remain exactly on the cross-hairs of the finder; this indicates that a spring-loaded backing plate would improve the situation. A good cell is a delicate piece of design.

"Calculations indicate that there is too much glass in a prism big enough for an instrument of this size, and an aluminized flat is being substituted to improve photographic performance."

Close study of the Schlesman telescope increases one's realization of its sound design, simplicity and ruggedness. Note that almost no provisions were made for adjustment after assembly, even in the diagonal unit, which often incorporates several such provisions. This is the hallmark of precise machine work; the parts are expected to go together correctly the first time.

The ruggedness of the axes is shown by the insert drawing of the polar-axis detail. The taper between the two bearings is from 2½ inches to 1¾ inches, as stated above; but farther up, above the right ascension circle, the axis is a full 4 inches in diameter. The drawing truthfully represents this part as cut away to nearly half-diameter, but the whole truth is that it is a section through two recesses, each .7-inch deep, for the six studs and nuts; between these recesses the shaft has a full 4-inch diameter.

Now we turn to the second of our two telescopes, this one built with a minimum of shop facilities. Alika K. Herring of Middletown, Ohio, built the mounting shown on page 64 for a 12½-inch *f*/6 telescope. He writes that "the entire job, of necessity, was planned to reduce the need for machine tools to a minimum. I had to beg or borrow the use of a drill press and reduce the number of trips to it by careful planning. Lathe work was required for two very minor operations that any machine shop would perform for a small fee. The total cost of the telescope was less than $60, most of which went into the materials for the optics. The mounting itself cost about $5, mostly for pipe fittings, strap iron and bolts. The wood cost me nothing."

The telescope was the outcome of Herring's success with a smaller one that he made and used for several years. This rational approach to telescope making enabled him to become acquainted with telescopes and discover faults to avoid before attempting a larger instrument. His telescope starts at the earth with a creosote-soaked "footer" of crossed planks that is simply laid on the ground. Bolted to this is a 5-by-5 oak scantling to which are through-bolted six upright members of 2-by-8 planks, these in turn being bolted to the top of a sloping 5-by-5. There is no further lateral bracing. Though the telescope weighs 400 pounds, it has proved to be rigid in both directions.

The polar axis is a length of 3-inch pipe and the declination axis is 2-inch pipe. "For bearings," Herring writes, "I used heavy steel rollers on axles of ½-inch bolts between angle irons bolted to the mounting. These rollers were turned and bored on the lathe from 2½-inch round stock. The other lathe job was boring out the pipe flanges, one for the end-thrust bearing on the polar axis and two others for spacers on the declination axis. These spacers ensured that when the tube was revolved it would clear the supports for that bearing."

The declination axis is babbitted into a 3-inch pipe T for its bearing. "Before inserting the pipe I wrapped the shaft with a collar of sheet metal the length of the T to provide a steel-to-steel bearing surface, since babbitt metal would eventually wear. Then I stuck the shaft through the T, lined it up meticulously, banked the ends of the T with sand and poured in the babbitt. After it cooled I drove the T off the shaft, cleaned up the ends, smeared a little fine Carborundum mixed with lubricating oil inside, reinserted the shaft and worked it around until it was a smooth-sliding fit in the T."

The concrete counterweights were cast around the axes in paint pails used as forms. While the counterweight on the polar axis could be dispensed with if the footer were lengthened, its use makes a much better balanced telescope by adding mass and therefore steadiness. It also simplifies the lower bearing.

"It would be difficult," Herring states, "to devise a simpler telescope that would fulfill all requirements and still be stable. I recommend it to others who have no machine tools and a weak budget." Herring, who comes from Hawaii, asks whether he is not the first Polynesian to make a telescope.

INDEX OF ADVERTISERS

DECEMBER 1950

AN INDEX OF ARTICLES AND AUTHORS

The following index lists all the articles and authors that appeared in Scientific American *during 1950. It also lists book reviews written by authors other than the editors.*

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