SCIENTIFIC AMERICAN

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August 1951

this used to be 32 pieces of metal

If you like to read ads that promise a profit — don't miss this one!

This Apex* washing machine tub assembly once was 32 pieces of hard-to-form, costly-to-assemble metal. Now it's made of tough, molded Fiberglas†—reinforced plastic—*in two pieces, assembled in one operation.* What's more, its washing efficiency has been upped, its weight decreased. It is corrosion-resistant, and won't rust no matter how often it's subjected to water and washing solutions.

Production savings here are obvious!

This is but *one* example of the way a dramatic *young* material is helping build better products and profitable businesses. Fiberglas reinforcements are creating new horizons for industrial design, new concepts of superior performance. For example: boats, both civilian and military, that never need caulking or painting . . . luggage and military instrument cases that shrug off wear . . . electrical laminates that help make motors, generators and transformers last longer, deliver better service.

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*Manufactured by Apex Electrical Mfg. Co.

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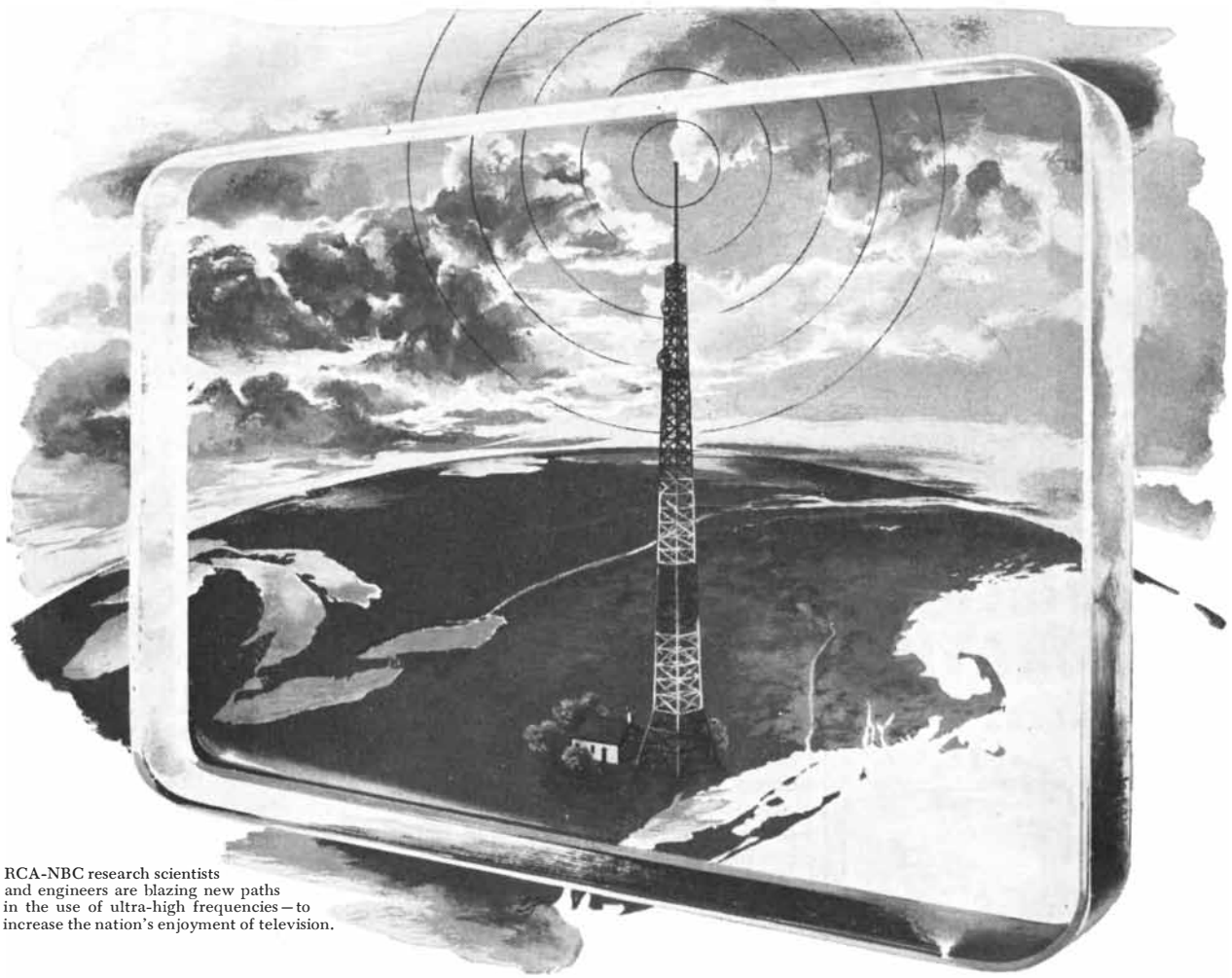

RCA-NBC research scientists and engineers are blazing new paths in the use of ultra-high frequencies—to increase the nation's enjoyment of television.

World's first custom-built **UHF** station —points the way to more **TV** for more people

Although television now reaches 45 million people in more than 12 million homes, thousands of communities are still too far from existing stations to be reached by *any* programs. Moreover, under present conditions, many cities with limited program service want, but can't have, additional TV stations.

In preparation for the establishment of a country-wide television service, RCA has pioneered for many years in ultra-high-frequency (UHF) research.

Today—an experimental station built by RCA at Bridgeport, Conn., is supplying the practical experience and engineering facts needed to design the best UHF equipment—including transmitters, receivers, and converters. NBC programs on the air during the full broadcast day are used by RCA—and other manufacturers, too—for large-scale field tests.

From results of this pioneering, RCA engineers have determined that practical UHF equipment can be built to serve the public, and that present RCA Victor television sets can be readily adapted to give equally fine performance on both UHF and VHF.

* * *

See the latest in radio, television, and electronics at RCA Exhibition Hall, 36 W. 49th St., N. Y. Admission is free. Radio Corp. of America, RCA Building, Radio City, N. Y. 20, N. Y.

Built by RCA at Bridgeport, Conn.,—first UHF transmitter to operate on a regular schedule.

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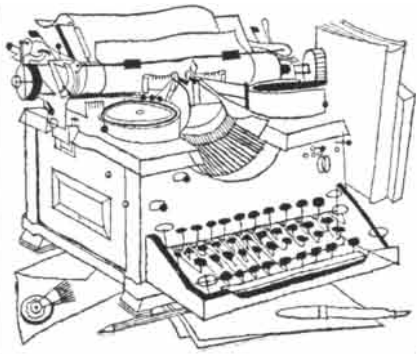

LETTERS

Sirs:

I have read with much interest the article "Moving the Obelisk" which appeared in the June issue of your magazine.

This is a story known to every well-read Italian. What prompts me to write this letter is the fact that the raising of the obelisk in St. Peter's Square on September 10, 1586, gave origin to a famous legend. One source gives the following account:

"It is said that Pope Sixtus V forbade the bystanders to speak, under pain of death, during the critical operation of raising the obelisk, which was witnessed by a very large crowd. At one particular moment, a sailor by the name of Bresca, a native of Bordighera on the Italian Riviera, seeing that the tension of the ropes had not been correctly calculated and that they were giving way under the tremendous weight, transgressed the order by shouting 'acqua alle funi' (wet the ropes), thus averting the catastrophe by his practical advice. The Pope rewarded him by granting his family the privilege of supplying palm branches for the papal ceremony at Eastertime. It is claimed that this is the true origin of the industry, still flourishing in Bordighera, of exporting Easter palms."

PIERO BONELLI

New York, N. Y.

Sirs:

It seems that old statistics neither die nor fade away. I was amused to note in the brief item "Synthesis of a Steroid" in the June issue another repetition of the statement that bile from 40 head of cattle is needed to produce enough cortisone to treat a rheumatoid arthritis patient for one day.

This figure refers to the procedure by which the first samples of cortisone were prepared by L. H. Sarett and J. van de Kamp of Merck & Co. Cortisone is now made by a vastly improved process, with fewer steps (30 or so instead of 37) and better yields at many intermediate points. Had such improvements not been effected, the price would never have come down to the present level.

Merck has made public no figures on cortisone production or yields. Others in the pharmaceutical industry believe, however, that Merck has boosted the over-all yield to about five per cent. Bile from one head of cattle contains an average of seven grams of cholic and desoxycholic acids (both can be, and are, used as cortisone starting materials). Assuming a five per cent yield, this is sufficient to make 350 milligrams of cortisone. The usual daily dose in intensive treatment of rheumatoid arthritis is 300 mg, and the usual daily maintenance dose, 100 mg. In other words, it takes slightly less than the amount of bile that can be obtained from one animal to produce enough cortisone for a day of intensive treatment, and a third of that amount to maintain a rheumatoid arthritic for one day.

While this is only an estimate by Merck's competitors, it is certainly much nearer right than the 40-cows-per-dose figure, and more truly measures the Merck organization's achievement in getting cortisone into production.

LEONARD ENGEL

Larchmont, N. Y.

Sirs:

I enjoyed reading the article "Meteors" in the June issue of *Scientific American*. It occurs to me, though, that the statement in the article about the continuous recordings made at the National Bureau of Standards and the daytime meteor showers in May, June, and

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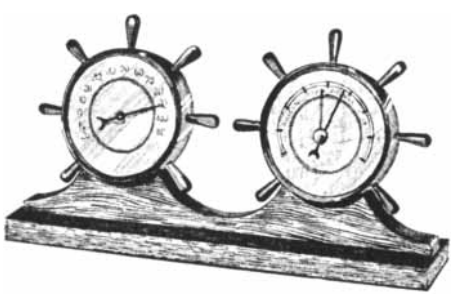
BUSINESS IN MOTION

To our Colleagues in American Business . . .

There is a well-known maker of thermometers, barometers, hygrometers and clocks which has been a Revere customer since 1885. You might suppose that when two companies have been doing business that long, some 66 years, they would be so close that there would be little that either could contribute to the other. Yet both of us recently learned something, which shows how wise it is to avoid taking things for granted.

During the course of a call on the customer, a Revere salesman was told that some difficulties were being experienced with the stamping and drawing of brass into cases and bezels. The Revere Technical Advisory Service was requested to investigate, and made a thorough study of the metal being used, and of factory methods and tools. The inquiry was, of course, conducted with the full consent and cooperation of the customer, who was just as eager as we were to know why, after so many years, the metal he was buying did not seem to give the usual results.



The Technical Advisory Report went into considerable detail. In broad terms, it found that such troubles as puckers, orange peel, and flare were due to a combination of factors, including composition of the brass, its temper, the design of the dies, and the lubricant used on them. New standards were set up for metal specification, covering alloy, temper, gauge. Although Revere does not design dies for fabricators, we made some suggestions for the consideration of the customer's designers.

After studying the report, the company decided to put these Revere recommendations to the proof of actual trial. It was after the correctness of our suggestions had been demonstrated that Revere received a letter of thanks, ending with these sentences: "We are extremely grateful for this information, and it represents a splendid job and one of great value to us. If all our suppliers of other materials had extended to us the type of service we have had from Revere through the years, we would have had far fewer manufacturing problems."

For several years Revere has been saying in this space that suppliers generally are glad to collaborate with their customers as does Revere. Revere considers trouble is a fine introduction, and its solution the beginning of an enduring business relationship. So do other companies in other industries, though some may take a little prodding. After all, it is a supplier's business to know his materials, as well as to make and ship them. Any company worth doing business with spends a lot of time and money learning as much as possible about its goods. When you buy, you pay for not merely so many pounds or feet or gallons or pieces or parts, but also for know-how, intelligence, information. You might as well obtain all you pay for, even if you have to dig a bit to get it. Indeed, it has been our observation that sometimes the information and collaboration that are not itemized on the bill are worth as much, if not more, than the materials themselves. So we again recommend that you take your suppliers into your full confidence, and let them work with you on problems concerning your use of their goods.

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July might give the impression that these showers were discovered here. It should be noted that they were discovered and their radiants delineated by A. C. B. Lovell's group at the University of Manchester.

VICTOR C. PINEO

Central Radio Propagation Laboratory
National Bureau of Standards
Washington, D. C.

Sirs:

We read the recent article on zirconium by Stephen M. Shelton in the June 1951 issue of *Scientific American* with a great deal of interest. Due to the fact that most of your readers might have obtained a few erroneous impressions from the article as presented, we feel it desirable to complement Dr. Shelton's remarks with a few well-known facts.

Ductile zirconium was first manufactured for commercial sale in this country by the Foote Mineral Company in 1939. While it is true that in the early stages of the development of ductile zirconium the sales price was higher than $125 a pound, we currently market the standard zirconium crystal bar at $50 per pound.

There seems to be some misconception in regard to the material produced by the iodide process as compared with the sponge produced by the Kroll process. Actually the raw materials used for the production of the iodide crystal bar can be much less pure than those required by the Kroll process, and we believe that it is equally true that the resultant metal from the iodide process is of greater purity than that currently being produced by the Kroll process. The net result is that there is not currently, and probably will not be in the future, such a tremendous spread in cost between the products produced by the two processes.

The fact remains, that for uses where great purity and ductility are required, the iodide metal is still being employed. The production facilities for the manufacture of high purity zirconium by the iodide process are still the largest in the world. It may be of interest to note that the work done at the University of Pennsylvania by Dr. Bates on the use of zirconium for surgical purposes required a purity and ductility that could be satisfied by zirconium produced from the iodide process only. That metal used in the research work reported by Dr. Shelton in his article was furnished by the Foote Mineral Company. Furthermore, the investigation was stimulated by the Foote Mineral Company.

L. G. BLISS

Foote Mineral Company
Philadelphia, Pa.

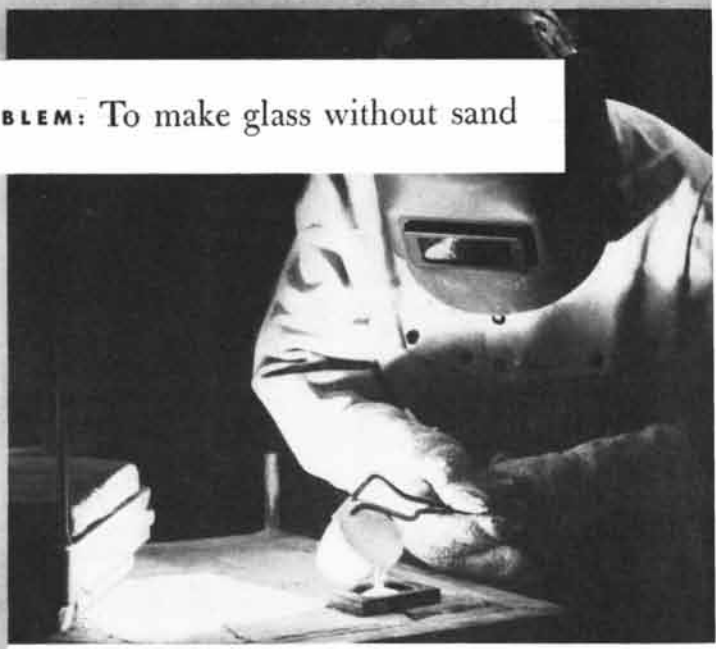
PROBLEM: Does ultraviolet harm eyes?

ANSWER: Eskimos probably never heard of ultraviolet, but they did carve out bone eyescreens to stop snow blindness. Research now indicates that ultraviolet light from skies, snow or water reflections, even when too weak to damage eyes permanently, will temporarily impair seeing efficiency. American Optical has developed UV-absorbing glass for industrial goggles, sun glasses, ski goggles, sport glasses.

PROBLEM: To put a human being under a microscope

ANSWER: Many living cells, cancer tissues, bacteria, are too transparent to be seen clearly under a microscope. Now the *phase microscope* reveals things eyes could not see before. AO scientists spent years helping to develop the basic phase theory into a workable microscope for research use.

PROBLEM: To make glass without sand



ANSWER: Glass not made with sand is as startling as steel not made from iron ore. This new AO glass absorbs ultraviolet, resists weathering, expands little under heat. Its qualities recommend it for many uses, including instrument lenses and hydrofluoric-acid-resisting glass for industry. Write us about your development problems. Address American Optical Co., 11 Vision Park, Southbridge, Mass.

American Optical

SCIENTIFIC AMERICAN

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

AUGUST 1901. "All the leading workers on the subject of radium rays have in turn subjected their own persons to some painful experiments for the advancement of their fascinating branch of science. Giesel placed a radium preparation in a celluloid case on his arm for two hours. The skin showed only a slight reddening at first, but two or three weeks afterward inflammation set in and the skin came off. Becquerel placed a very active radium preparation in his waistcoat pocket for six hours. The resulting sore—which took 10 days to develop—required 39 days to heal. Another sore took 34 days to develop. No action was produced when the tube was encased in lead. Madame Curie underwent experiments of a similar nature. The preparation was in her case enclosed in a thin metallic box, and applied for only half an hour; but the resulting burn took a fortnight to heal."

"Prof. Koch of Berlin, who discovered the bacilli of phthisis, stated at the Tuberculosis Congress at London that he had demonstrated that meat and milk from tuberculosis-infected cattle may be consumed with absolute impunity. His views are warmly combatted by other medical men."

"There will be general sympathy with M. Santos-Dumont, the persistent and plucky aeronaut, in the disaster which overtook him just at the very time when he seemed to have the Deutsch prize within his grasp. He started from St. Cloud and sailed directly for the Eiffel Tower, covering the distance of 9 kilometers, or over 5 miles, in the remarkable time of 9 minutes and 20 seconds. Reports of the trip are somewhat contradictory; but it would seem that, shortly before reaching the tower, the balloon commenced to deflate and the pointed bow began to give way under the end-on resistance of the air. Luckily for the aeronaut, the machine descended upon the roof of one of the taller buildings of Paris and hung there, M. Santos-Dumont being rescued without any injury to himself. Without throwing the least discredit upon the ingenuity, skill and perseverance of M. Santos-Dumont, the recent accident really confirms our opinion that the successful airship must dispense with the gas-inflated balloon. Although the effort of inventors is at present almost entirely directed to the balloon airship, the true solution of the problem would seem to lie in the direction of the aeroplane, a type of airship whose principles are the same as those which underlie the flight of birds. What are the experimentalists in this most scientific and promising field doing in these days?"

"An expedition to Kolymsk, Russia, is being made by Russian scientists in order to bring to St. Petersburg the mammoth which has recently been discovered. It is unique of its kind, its hair, skin and flesh being entirely preserved and there being remains of undigested food in its stomach."

"Two of the Nobel prizes have been awarded after mature deliberation. Dr. Niels Finsen of Copenhagen received one for his discovery of the light treatment for lupus, and the other one was given to Professor Pavlov, the Russian physiologist, for his researches in metabolism. In each case the honor was well deserved."

AUGUST 1851. "The British Association for the Advancement of Science met on July 3 in the Corn Exchange, Ipswich. Sir David Brewster, the president, made an address on resigning the chair to his elected successor, Professor Airy, the Astronomer Royal. He noted in a tone of complaint the neglect shown by the Government to scientific pursuits. He consoled the meeting, however, with the reflection that governments do not last forever, that rays of light will penetrate through darkness, and that even the hide of the rhinoceros is vulnerable at points."

"M. Daguerre, who is recognized as the discoverer of sun painting, and after whom the daguerreotype art is named, died on July 12 at a village near Paris, where he was spending the summer season. He was 65 years old."

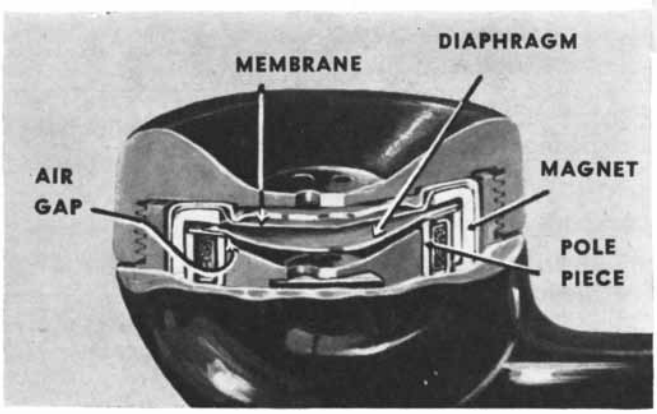
"A great reaping match was held on July 24 in Essexshire, and thither were invited all the reaping machines exposed at the Great Fair. A number were tried but proved abortive in their attempts to work well. It was then the stout but unprepossessing machine of Mr. McCormick made its appearance. Those who estimated the worth of the machines by a polished piece of brass here, and a burnished piece of steel there, shook their heads as the driver mounted his seat; but with a snap of his whip he started his team, applied his hand to the lever of his clutch, and away he went, sweeping a wide swath and raking it up on the platform at one operation, with such a velocity as to elicit repeated cheers from the onlookers. The success of this experiment will lead to the introduction of the American power reaper into Britain."

"A patent has been granted to I. M. Singer, of New York, N. Y., for an improvement in the sewing machine."

"A new extraordinary calculating machine, says the London *Times*, is now placed in the Russian Court. It is the invention of a man named Staffel, a native of Warsaw, and works addition, subtraction, multiplication and division with a rapidity and precision that are quite astonishing. It also performs the operation of extracting the square root and the most complicated sums in fractions."

"At a meeting of the Section on Chemistry of the British Association, Dr. Lyon Playfair read a communication from a Mr. Mercer, 'on a new method of contracting the Fibres of Calico.' Mr. Mercer, who commenced his experiments in 1844, has ascertained that a cold solution of caustic soda—simple a thing as it is—has a peculiar effect on cotton fiber, causing it to contract and remain so permanently after the soda has been washed out. The practical applications of the discovery may be inferred. The first obvious one would be that of converting coarser into finer fabrics. Another application would be the improvement of colors, to which the condensation imparts depth and brilliancy. Mr. Mercer's paper was deemed of sufficient importance to be made the subject of a discussion among such men as Faraday, Dumas and others; and it is proposed that microscopic examinations should be made for the purpose of ascertaining the mode and nature of the change effected in cotton fiber by this new process, which, as the report declares, 'bids fair to exercise an immediate and extensive alteration in the patterns and produce of cotton fabrics.'"

Easy on the ear



More naturally than ever, your voice comes to the ear that listens through the latest telephone receiver developed at Bell Telephone Laboratories. The reason: a new kind of diaphragm, a stiff but light plastic. Driven from its edge by a magnetic-metal ring, the diaphragm moves like a piston, producing sound over all of its area. Effective as are earlier diaphragms of magnetic-alloy sheet, the new one is better, gives more of the higher tones which add that personal touch to your voice.

To work the new receiver, telephone lines need deliver only one-third as much power. So finer wires can do the job. This is another new and important example of the way scientists at Bell Telephone Laboratories work to keep down the cost of telephone service, while the quality goes up.

BELL TELEPHONE LABORATORIES

WORKING CONTINUALLY TO KEEP YOUR TELEPHONE SERVICE ONE OF TODAY'S GREATEST VALUES

THE COVER

The painting on the cover shows a few of the smaller creatures that dwell in the depths of the oceans. Marine biologists and others suspect that these organisms often form a layer so thick that sounding devices record it as a "false bottom" hovering between the surface and the true bottom (*see page 24*). The three fish entering the painting from the upper right are myctophids; along their sides glisten luminescent spots. The three red crustaceans in the center are *Gnathophausia calcarata*. The small white creatures swimming near them are copepods. At the lower left is the luminescent fish *Argyropelecus affinus*. Similar creatures form a cloud in the background. All of those shown in the painting were brought up from deep waters off southern California.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

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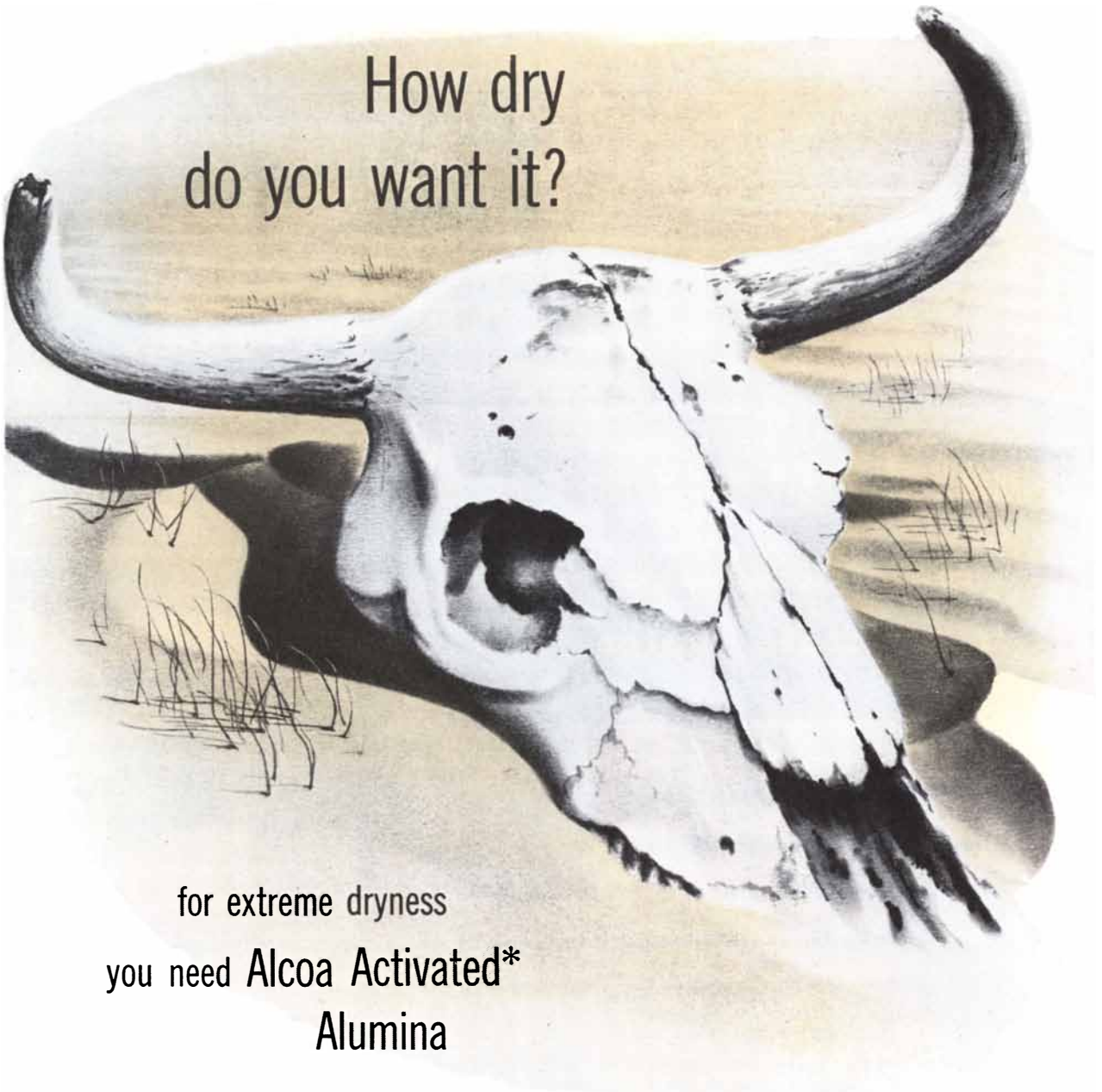

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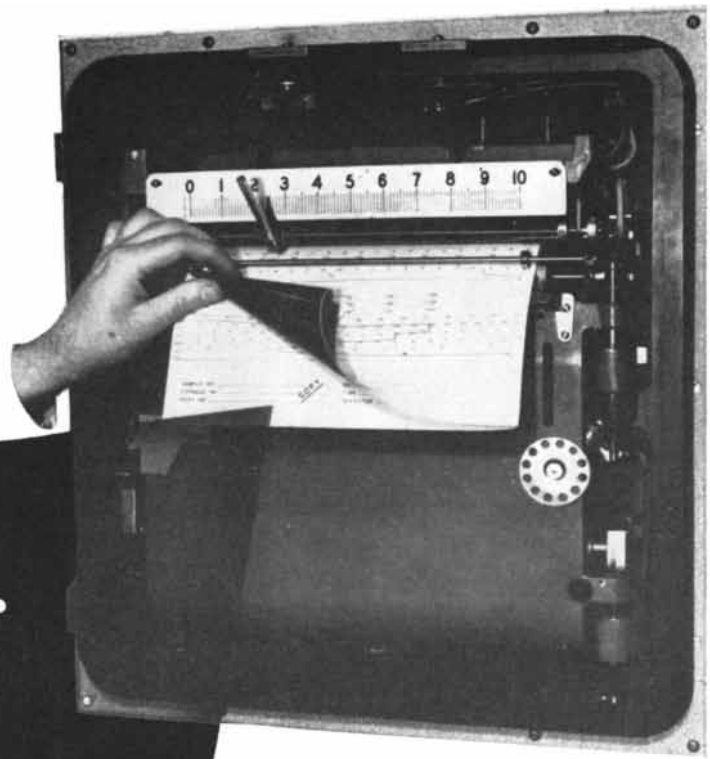

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SCIENTIFIC AMERICAN

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DEPARTMENTS

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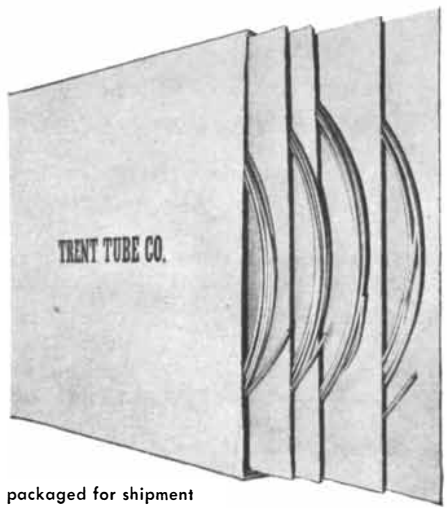
What's New at CRUCIBLE

about Trentweld Beverage Tubing



Beverage tubing packaged for shipment

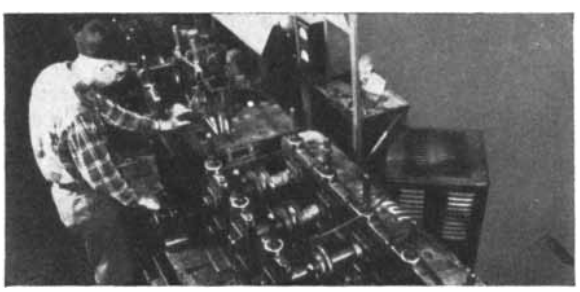
For many years nickel alloys and block tin have been used to make tubing for the soda fountain and beverage industries — applications such as syrup tanks and flavor dispensing lines, carbonated water lines, cooling coils, soda fountain refrigeration coils, beer lines, picnic coolers and tap rods, all requiring corrosion resistant tubing. Due to improvements and changes in processing, nickel alloys have not had satisfactory resistance to withstand the corrosiveness of carbonated water and beverages. This left block tin as the only satisfactory metal from which beverage tubing could be made. Trent Tube, a Crucible subsidiary, was called upon to produce a satisfactory stainless steel tube to meet the demands.

Stainless steel itself is entirely satisfactory from a corrosion standpoint, however, there was much more to the production of a beverage tube than just the metal to withstand corrosion. Second to corrosion, the tubes must be ductile enough to be formed by hand on the job. In order to meet this ductility requirement, Trent made slight changes in the chrome-nickel balance in the analysis and a special annealing practice was developed to obtain maximum ductility for this type of tube. After considerable experimentation on the part of Trent's technical staff, a beverage tube was produced with a Rockwell hardness very near to that of the nickel alloys that had been used in the past.

After the proper analysis and annealing technique had been developed, further experimental work had to be done to insure a bright, clean, sanitary tube on both the inside and outside surfaces. As beverage tubing is usually furnished in 50-ft. lengths, it was difficult to insure a bright oxide-free surface on the inside center of these long lengths. Special bright annealing technique had to be developed to insure absolute absence of oxygen on the inside of the tube during the bright annealing operation.

After a completely bright inside surface was assured, a special passivating technique had to be developed to insure the removal of all free iron on both the outside and inside surfaces of the tube. Free iron on the surface of a tube will result in rusting when placed in service. Rusting of the surface of stainless almost invariably results in setting up a concentration cell, causing a pitting attack which continues until the wall of a tube is penetrated, causing a leak. The special passivating technique developed by Trent insures complete removal of all free iron, and subsequent cleaning operations assure the complete removal of all acids used in these operations. The inside of the tube still remains completely bright.

A unique method of packaging 50-ft. lengths of beverage tubing has found great favor in the beverage industry. The tubing is coiled in compact 30″ diameter coils without appreciably affecting the hardness through cold-working. Four of these coils are placed in cartons, making it very convenient for distributors who sell in small quantities. Five of the small cartons are shipped in a larger carton, making a total of 1,000 ft. per package. These 1,000 ft. packages are convenient for warehouse storage and make it extremely easy to keep inventory records. The small cartons also make it convenient for the ultimate user to store or transport the beverage tubing on the job.



View of Trent machine showing strip as it is formed into tubing

Stainless steel has the characteristic of hardening by cold working which is at a minimum in Trentweld beverage tubing; however, improper handling in making the flares for fittings and in the bending operation may cause trouble. For a detailed brochure on methods of flaring and bending write: TRENT TUBE COMPANY, subsidiary of CRUCIBLE STEEL COMPANY OF AMERICA, General Sales and Operating Offices, East Troy, Wis.

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A REVOLUTION IN ELECTRONICS

The transistor, a superior new means of controlling the flow of electrons, has now been developed in a practical form; it liberates electronics from the limitations of the vacuum tube

by Louis N. Ridenour

ELECTRONICS was born 45 years ago when Lee De Forest invented the first three-electrode vacuum tube—the "audion." The two world wars gave electronics the impetus that made it the huge industry it is today. World War I, during which radio telephony was developed from a laboratory curiosity into a reasonably practical means of communication, gave birth to commercial radio: the first broadcasting station, KDKA, was licensed in 1920. World War II, which opened a new horizon in electronics through the development of radar and its attendant technology, produced television. There had been experiments with television before the war, but it was the wartime advances achieved on behalf of radar that made commercial TV immediately realizable. The story of television's postwar rise is dramatically told in production figures: the number of television receiving sets made in the U. S. rocketed from 6,500 in 1946 to 7,500,000 in 1950. Besides television, World War II produced another major electronic advance: high-speed digital computing machines, which also seem destined to have a profound social impact, though this is still largely in the future.

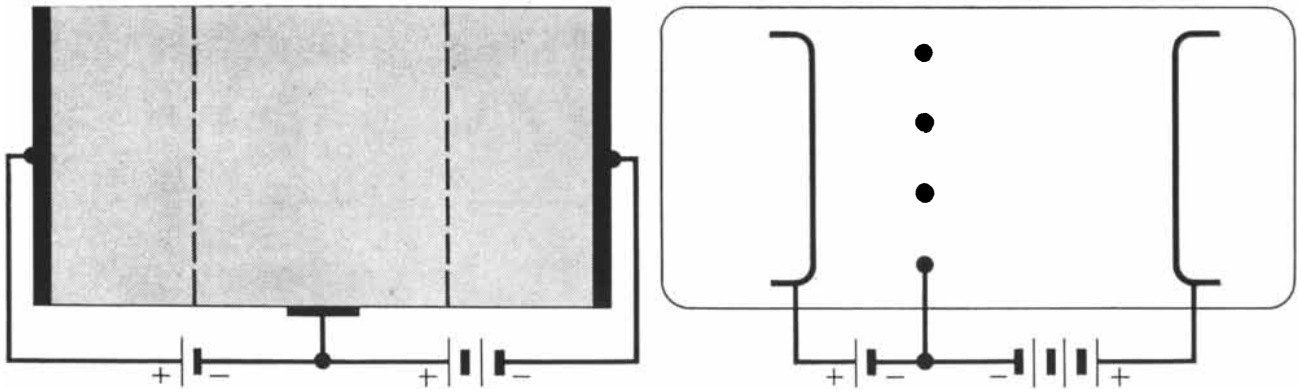
Paradoxically the vacuum tube, which made all this possible, has now become a bottleneck impeding further progress in electronics. The electronics art has reached a stage where a fundamental new development is needed to rescue it from the limitations of the vacuum tube. Just such a development has recently arrived on the scene. It is the transistor, which can perform most of the functions of the vacuum tube and escapes most of its limitations. The transistor promises to revolutionize electronics; indeed, the revolution is already beginning.

TO understand the causes and nature of this revolution, we must first look into what is wrong with the vacuum tube. To begin with, the vacuum tube is inherently rather short-lived and unreliable. This difficulty has been exacerbated by the endemic price competition in the commercial electronics industry. Competing on a price basis for the mass market for radio and television sets, manufacturers have achieved prodigies of economy in design and of efficiency in production. But this has exacted its inevitable toll in quality. Most commercially available vacuum tubes are not as reliable as they could be if more care, meaning more money, were put into their design and manufacture. This shortcoming is inconvenient enough in a 6-tube or 8-tube radio set; it is considerably more inconvenient in a television receiver using 25 to 35 tubes, which quadruples the chances of set failure for a given rate of tube failure. As electronic equipment becomes more complex, the reliability of individual components becomes more and more important.

The telephone system affords an excellent illustration. A transcontinental phone call requires the proper operation of 12,300 vacuum tubes, 112,000 resistors, 97,000 capacitors and large numbers of other components. Hence in the telephone system the reliability of electronic equipment is far more important than its initial cost; a cheap device that requires much maintenance will be much more expensive in the end than a more carefully built apparatus that can work for years with no attention. Because of its extreme concern with reliability, the telephone system has gone to great pains to make the components of its electronic equipment as dependable and long-lived as the state of the art will permit. For the Bell Telephone System the Western Electric Company manufactures equipment to exacting specifications worked out by the Bell Telephone Laboratories. The vacuum tubes it produces are the most durable in the world. In a submarine cable recently laid on the bottom of the sea between Key West and Havana are six repeater amplifiers, each containing three vacuum tubes. They are of course inaccessible for replacement. But if any of those 18 tubes sealed into the cable should fail in the next 20 years, the designers of the cable will be surprised.

Yet there are limits to the reliability that can be built into vacuum tubes even with great care, ingenuity and cost. The telephone system has never been able to use electronic equipment for two important functions—central-office switching and signal amplification on local lines—partly because no vacuum tube is sufficiently dependable.

Reliability in electronic equipment is especially important to the military



JUNCTION TRANSISTOR (*left*) **is compared with a vacuum tube** (*right*). **In the vacuum tube electrons flow from a cathode at left across a grid in center to an anode at right. In one type of junction transistor "holes" flow in a semiconducting material from an electrically positive emitter region at the left through an electrically negative control region in the center to an electrically positive collector region at the right.**

services. The cost of field maintenance of their electronic gear at present is about 10 times the initial cost of the equipment. The Army, Navy and Air Force are using increasingly complicated electronic devices (*e.g.*, radar bombsights) in increasing numbers and putting increasing reliance on them; the Navy, for example, has a bomber aircraft that is not built for an optical bombsight at all—even has no transparent window for one. In the Air Force's B-36 the electronic equipment accounts for about 10 per cent of the total cost of that very expensive airplane, and in the newest all-weather fighters electronic devices make up 20 per cent of the cost of the plane. Hence to the military, as well as to civilians, the reliability of electronic equipment is a matter of urgent concern.

A FURTHER problem in electronic equipment is that of size. As the equipment grows in complexity, it grows more and more bulky. This has led to an attempted solution rather inelegantly called "miniaturization." Vacuum tubes have been designed in miniature and sub-miniature models with essentially the same electrical capabilities as the old standard sizes. Resistors, capacitors, transformers and other circuit elements have been greatly reduced in total volume by radical redesign. "Printed circuits" and other compact schemes for prefabricated wiring have been devised. And the utmost attention has been paid to "designing the air out of" the equipment as a whole: every nook and cranny in the chassis is filled with wiring and components.

One example of this design trend is shown in the photograph on page 17, which compares a radio range receiver before and after miniaturization. The volume of the set of standard design is about 300 cubic inches; that of the miniature set is 55 cubic inches—a six-fold reduction. And this was done in the case of a set which had been rather compactly designed, in terms of conventional materials and construction, to begin with.

There is no doubt of the usefulness of such miniaturization for equipment that must be stowed in a small space. But miniaturization intensifies one of the outstanding deficiencies of the vacuum tube: namely, its heavy power requirement and the large amount of heat dissipated in the tube. The vacuum tube, a grandchild of the incandescent lamp, uses heat produced by electric power to boil electrons off the cathode. Generally speaking miniaturization does not reduce the power requirement: the miniature version of the range receiver pictured in the photograph takes just about as much power as the larger model—some 30 watts. In the larger model, with a volume of 300 cubic inches, power is liberated at the rate of a tenth of a watt per cubic inch; the components are reasonably well separated from one another, so that ventilation is easy, and the temperature rise of the equipment in operation is modest. On the other hand, in the small model, with components packed as tightly as possible, power is dissipated at the rate of more than half a watt per cubic inch, which is the average rate of power expenditure in the ordinary home electric oven. As a result some spots inside the set reach temperatures as high as 400 degrees Fahrenheit.

This high operating temperature, which is typical of most miniaturized electronic equipment, raises a host of new problems. Connections must be made with special high-melting-point solder. Temperatures must be kept below the softening point of the glass in the tube envelope. And the high temperature greatly reduces the operating life of most of the tube's components.

In short, with the increasing complexity of electronic equipment the relatively low reliability of the vacuum tube and its prodigal use of electric power have become major difficulties.

Thus nearly half a century after De Forest's invention of the tube that gave birth to electronics we are brought to the conclusion that there is nothing wrong with electronics that the elimination of vacuum tubes would not fix!

UNTIL 1948 there seemed no way out of this difficulty. But in that year John Bardeen, W. H. Brattain and William Shockley of the Bell Telephone Laboratories announced the invention of the transistor (SCIENTIFIC AMERICAN, September, 1948). At the time the device looked promising but had important practical shortcomings. Transistors could not be produced reliably and with predictable electrical characteristics. They were "noisy," would not operate at frequencies higher than a few megacycles per second and had other deficiencies. But three years of hard work at the Bell Laboratories have removed most of the early doubts and objections. Transistors can now be made so that their performance is within 20 per cent of specifications, which is as close production control as has been achieved in half a century of experience in making vacuum tubes. It is likely that further development will lead to methods for producing transistors that conform to specifications within 10 or even 5 per cent.

The transistor is a device made of a crystalline semiconducting material, usually germanium. In this material the number of atomic electrons in the crystal does not quite match the number needed to produce a normal crystal lattice. If there are a few excess electrons, these can travel through the crystal as readily as free electrons traverse the empty space inside a vacuum tube. If there is a deficiency of electrons, the "holes" representing vacant electron sites also can travel freely through the crystal. At barriers between electron-rich and electron-deficient regions of the germanium, the flow of electrons or holes can be controlled by an applied signal in much the way that the plate current of a vacuum tube is controlled by the voltage applied to the grid. Like the

vacuum tube, the transistor can control a larger power than is applied to it—that is, it can amplify.

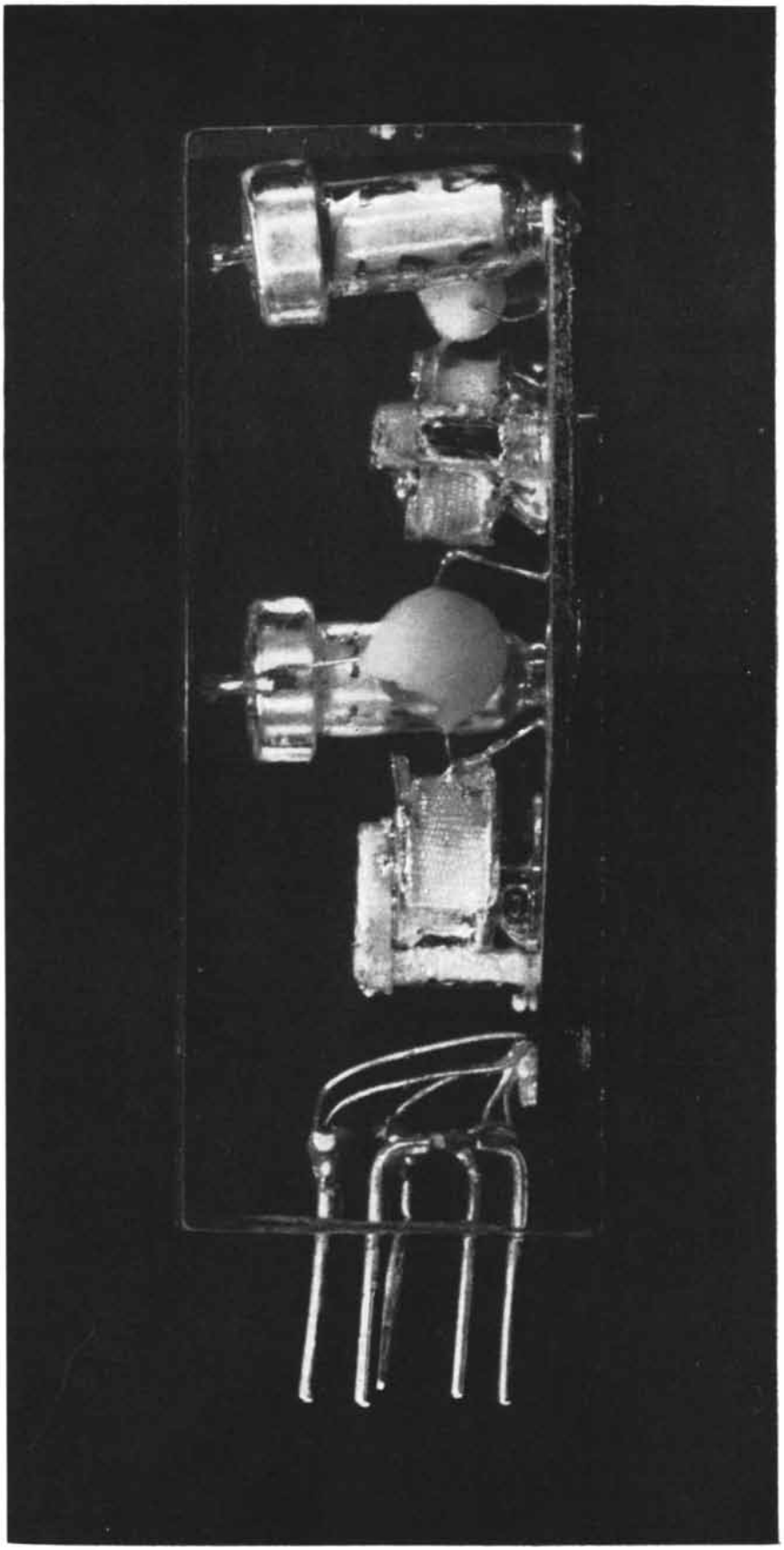
The important practical difference between the transistor and the vacuum tube is that no power whatever is needed to set loose the free electrons or holes in the transistor. There is no need to "boil" electrons out of the solid material; instead, the electrons are controlled as they move inside the solid.

It appears that the durability of transistors, and therefore the reliability of circuits using them, will be excellent. The earliest transistors made had average lifetimes in the vicinity of 70,000 hours, already several times greater than the lifetime of a vacuum tube, and present units are much longer-lived. In principle a properly made transistor should last forever if it is not abused.

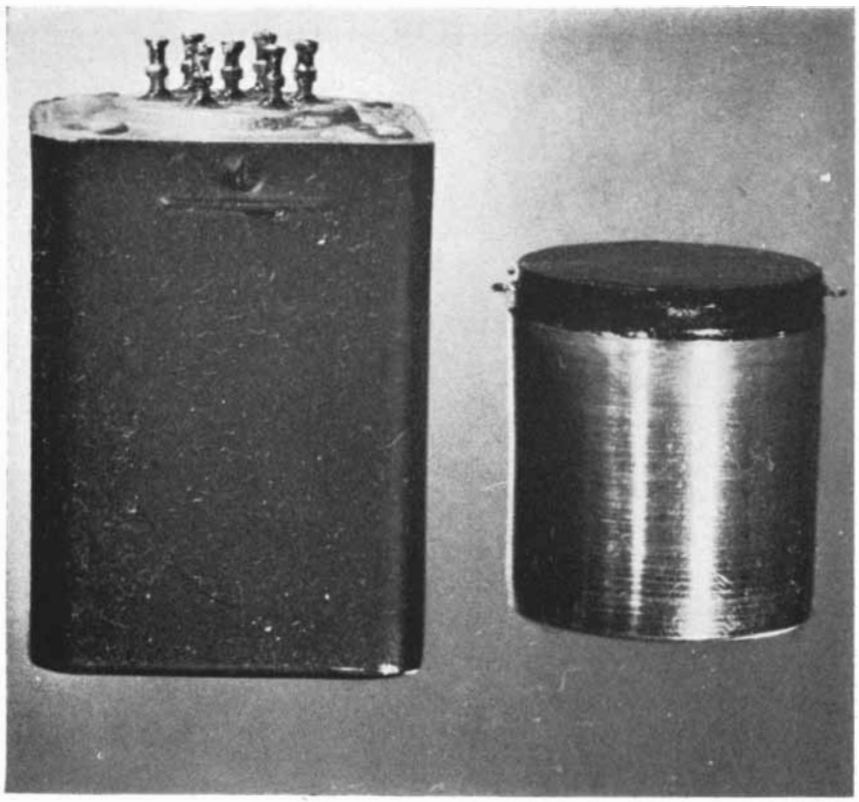
Moreover, transistors are highly resistant to mechanical shock and vibration. They survive very severe shock tests without damage. Everyone knows that tapping on the tubes of a radio set produces an unpleasant ringing. This is due to changes in the electrical properties of the vacuum tubes, produced by the mechanical vibration of their elements. Transistors can withstand high accelerations without being subject to such "microphonic" effects. And in the newer transistors the internal electrical "noise" has been reduced to a level that compares quite favorably with that of vacuum tubes.

A large part of the improvement in the performance of the device is due to the development of a new design called the "junction transistor." The early units consisted of a germanium crystal touched by two closely spaced fine wires —"cat's whiskers." In the junction transistor this point-contact arrangement has been replaced by a large area contact. A thin layer of electrically positive (electron-deficient) germanium is sandwiched between two electrically negative (electron-rich) ends. The transistor action now takes place over the whole area of contact (junction) between the two types of germanium. It therefore operates more efficiently and consumes far less power.

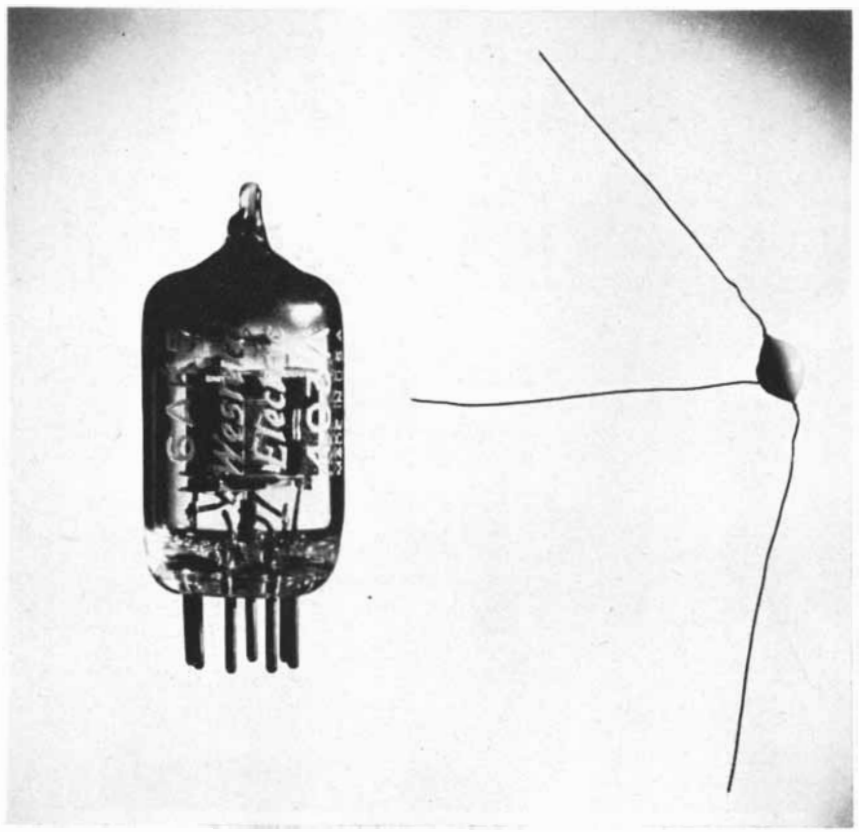
OBVIOUSLY the transistor's most important advantage is the modesty of its power requirements. In the first place, it is ready for instant operation without the lengthy warm-up needed by a vacuum tube, so that power does not have to be applied constantly, as it must in vacuum-tube circuits, to equipment that must be ready to operate instantly on demand. Secondly, the total operating power used in a transistor device may be incredibly small—about one-millionth of the power required by a similar vacuum-tube circuit. Ralph Bown, director of research at the Bell Telephone Laboratories, has dramatized this property of



AMPLIFIER using two junction transistors has a power gain of some 90 decibels. It is embedded in a piece of plastic about two inches high. The transistors, embedded in their own beads of plastic, are at the top and center. Also in the circuit are two tiny transformers and two condensers.



TRANSFORMERS made by Sylvania Electric Products Inc. have the same performance. The one at the right was miniaturized by improvements in core steel and winding technique. It has a volume of one cubic inch.



VACUUM TUBE AND TRANSISTOR of similar performance are compared. At the left is a 6AK5 tube manufactured by the Western Electric Company. At the right is a junction transistor. It is 3/16 of an inch in diameter.

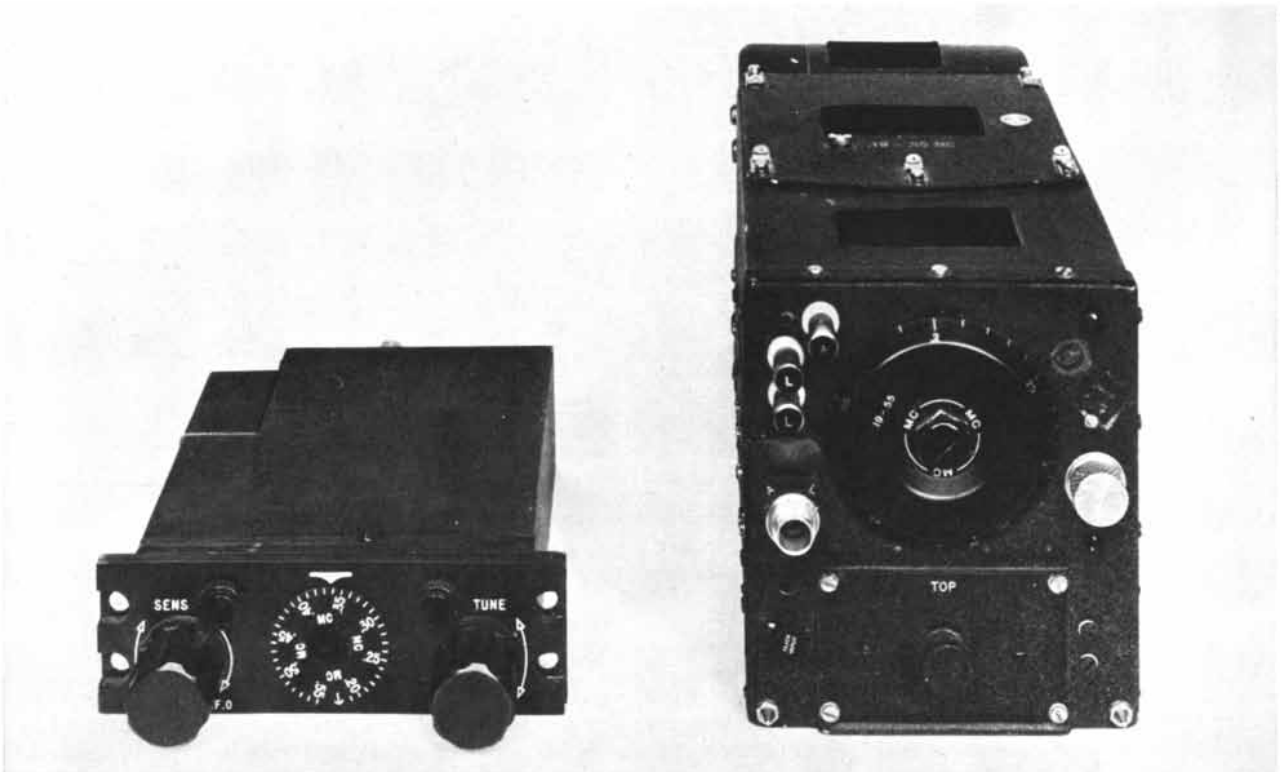
the transistor by a vivid analogy. He points out that to amplify the average signal in most electronic equipment, which is in the neighborhood of a microwatt (one-millionth of a watt), a vacuum-tube system requires the expenditure of a watt of power; this is like sending a 12-car freight train, complete with locomotive, to get a pound of butter. The tiniest hearing-aid tubes, in which electrical performance has been considerably degraded in favor of low power-drain, use about 20 milliwatts. In terms of Bown's simile, this is like sending a 10-ton truck for one pound of butter. The transistor, on the other hand, needs only a microwatt to handle a microwatt.

This million-fold decrease in power requirement is so great that it is hard to appreciate. In a hearing aid a transistor can produce a sound amplification of 45 or 50 decibels at one stage, in contrast to the 25 decibels that can be achieved with low-power-drain vacuum tubes. Yet a transistor hearing aid could run on one set of batteries for about three years, whereas a vacuum-tube hearing aid uses up a set of batteries in a few days. A single transistor amplifier stage could be powered with the energy a flea would expend if it jumped once every eight seconds. We are dealing here not with flea power but rather with lazy-flea power!

In electronic equipment using transistors the problem of high temperature, so serious in the case of vacuum tubes, vanishes altogether. The power required is so small that heating is infinitesimal. The miniaturization of electronic equipment now makes solid sense. The transistor is far more compact than any vacuum tube. A typical transistor occupies only about a two-thousandth of a cubic inch, whereas the smallest subminiature vacuum tube is about one eighth of a cubic inch in volume.

EVEN at the present very early stage of transistor development it seems certain that transistors will replace vacuum tubes in almost every application. What results can we expect from this major revolution in the techniques and capabilities of electronics? Since the revolution is just beginning, we can only speculate.

We can begin by noting the great gain that electronic machines represent over machines of the strictly mechanical type—the distinction, let us say, between an electronic device such as a television receiver and a mechanical contrivance such as a cash register. The most meaningful difference between electronic machines and mechanical machines is in the level of complexity they can attain. A century ago the ingenious English mathematician Charles Babbage designed an analytical engine which in principle was much the same as the large-scale digital computing machines of today. But Bab-



RADIO RANGE RECEIVERS of like performance are compared. The miniature receiver at the right occupies some 300 cubic inches. The subminiature unit at the left, which was recently designed by Gustave Shapiro and his associates at the National Bureau of Standards, occupies about 55 cubic inches. It contains 12 vacuum tubes.

bage found it impossible to build his proposed machine; it was too complicated to be within the capabilities of an all-mechanical design. The realization of devices of this complexity, including high-speed digital computers and long-distance telephone circuits, became possible only when electronics was developed.

Generally speaking, vacuum-tube electronics permits the building of machines about a hundred times more complicated—and therefore at least a hundred times more competent—than the most complex mechanical machine it is practical to make. Electronic machines enjoy another advantage over mechanism: they can work much faster. The typical unit operation in an electronic machine is accomplished in a time of the order of a millionth of a second; the typical unit operation of a mechanical machine takes about a thousand times longer.

But when we get to such a complex electronic machine as the modern digital computer, the shortcomings of the vacuum tube itself become troublesome. The power the vacuum tube requires and its relatively short lifetime pose substantial obstacles to any further increase in complexity. Now the transistor promises to remove these obstacles. Its lifetime is surely long and may be indefinite. Its power requirement is a million times smaller than that of the vacuum tube. Its electrical performance is at least as good, and in many ways better.

All these favorable properties of the transistor suggest that its use as a substitute for the vacuum tube in electronic machines may permit such machines to grow to levels of complexity now unattainable. Just as vacuum-tube electronics permitted a hundred-fold increase in complexity over that permitted by mechanism, at a conservative estimate transistor electronics may allow a hundred-fold increase in complexity over vacuum-tube machines.

FROM the general philosophical standpoint, it is of interest to compare the most complicated machine we can make with the machines we observe in nature, such as the human central nervous system. Warren McCulloch of the University of Illinois Medical School has done this in very entertaining terms. He finds that the Eniac computer, containing about 10,000 basic on-or-off elements, is a million times less complex than the brain, which has 10,000 million neurons. The Eniac, indeed, has about the complexity of the nervous system of the flatworm. It has one advantage: its unit operations are accomplished about a thousand times faster than are the unit operations of the brain. Thus if we made a sort of figure of merit for comparing the competence of man-made and natural machines, taking into account both complexity and speed, we should find the Eniac—for those operations fitted to its very low complexity—only about a thousand times less competent than the human brain.

McCulloch remarks that if we made a vacuum-tube computer as complex as the brain, it would require a skyscraper to house it, the power of Niagara to operate it and the full flow of water over the falls to keep it cool. This is altogether a criticism of vacuum tubes. If, as seems reasonable to suppose, the use of transistors will permit a further hundred-fold increase in the complexity of our machines, we shall be able to build, in no greater space and with smaller power requirements than are needed now for vacuum-tube computers, a device only 10,000 times less complicated than the brain. Since it will work a thousand times faster, such a transistor device may be, for those jobs to which its low complexity suits it, as much as one-tenth as competent as the human brain.

This is an exciting prospect, but it has not yet been achieved. Curiously, its achievement seems to rest on the elimination from electronics of the vacuum tubes which gave electronics birth.

Louis N. Ridenour, professor of physics and Dean of the Graduate College at the University of Illinois, is presently on leave as Chief Scientist of the Air Force.

The Lost Cities of Peru

How aerial photography and the jeep combined to give an overall view of the many cultures that flourished on the north Peruvian coast before the Inca conquest

by Richard P. Schaedel

TWO technological conveniences developed in recent years have become highly useful tools in archaeology. They are the jeep and aerial photography. The jeep, a "mechanical burro" that can go almost anywhere, gives the archaeologist a relatively rapid means of reaching and reconnoitering archaeological sites in out-of-the-way places. Aerial photography adds a new dimension to exploration. Not only does it bring to light ruins in unexplored areas that might never have been discovered otherwise, but it allows the archaeologist a bird's-eye view in addition to the worm's-eye view with which he has had to be content in the past. Exploring the labyrinthine structures of an ancient civilization on the ground, he is apt to become entangled in the details and be unable to see the picture as a whole. Aerial photographs now make it possible to see the shape and scope of entire cities and civilizations of the prehistoric past.

I shall describe here how we used these two new aids to investigate the early civilizations of northern Peru, where Spanish explorers found the home of the fabulous Incas when they first came to South America in the 16th century.

Let us first sketch in what was known about ancient coastal Peru before we began our study. For at least 3,000 years before Europeans discovered them, American Indians who had settled in Peru had been building civilizations of higher and higher complexity. The North Coast of Peru is a 400-mile strip of coast, bounded on the west by the Pacific Ocean and on the east by the bleak, steep foothills of the Andes. It is a narrow ribbon of desert crossed at intervals by small rivers that flow from the hills into the Pacific. The peoples of ancient Peru lived in these river-valley oases, and the small valleys are crowded with the remains of their civilizations.

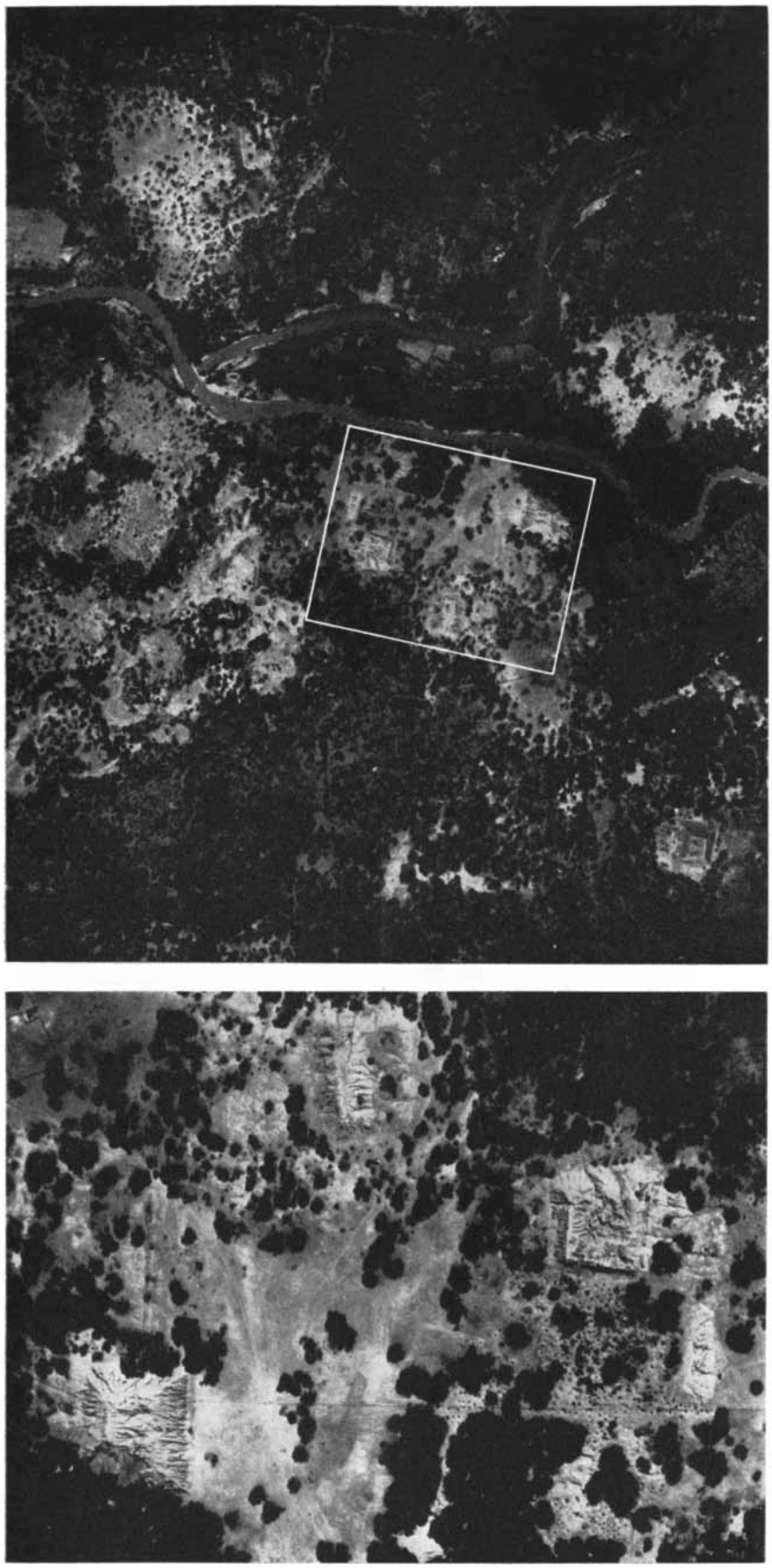
The earliest permanent settlements in the area were small fishing villages; they were in existence by 1500 B.C. or earlier. By about 800 B.C. a new people had come into the region, presumably from the highlands, and introduced an agricultural economy, based on the staples maize and yuca. This phase of the region's civilization is called Chavín. We do not know how long it lasted, but it had practically disappeared by the year A.D. 1, and during the next 1,000 years or so a number of different local cultures developed in the individual valleys. Toward the end of this period one of these cultures, called Mochica because it is believed to have originated in the valley of the Moche River, expanded and conquered much of the region. But about A.D. 1000 it in turn was overthrown by an aggressive culture from the south known as Tiahuanacoid. That occupation was short-lived. The next 200 to 300 years of Peru's history, known as the "middle period," is obscure. By about 1300, however, the picture again becomes clear: under a dynasty called the Chimu the people of the Moche Valley once more conquered the coastal lands. The Chimu empire attained splendid heights, but by 1470 it was subdued by a new invasion from the south, this time by the redoubtable Incas. The Inca occupation of the region lasted until the arrival of Pizarro in 1532.

In short, the chief phases in the chronology of Peru's North Coast were the early fishing settlements, the Chavín period of the first truly agricultural communities, the development of local cultures, the emergence of the Mochica as the dominant culture, a time of invasion and conflict lasting several hundred years, unification of the entire region by the Chimu empire and finally conquest by the Incas.

FROM THE GROUND Galindo, a Chimu ruin near the Moche River, is hard to find. Until it was located on aerial photographs (*see opposite page*) it was unknown to archaeologists or to some people who lived nearby.

IN 1948 I was called to organize an Institute of Anthropology at the University of Trujillo, the provincial capital city in the center of this region. The Peruvian authorities gave me *carte blanche* to do as I pleased, provided that my work shed more light on Peru's past. I came to the conclusion that we should take stock of the total picture before burying our noses too deeply in any one excavation. Most of what was known about the sequence of Peru's civilizations had been constructed from stratigraphic studies of pottery types. We

FROM THE AIR Galindo is the ruin of a teeming city. At the top of the page is the large aerial photograph on which the ruin was discovered; at the bottom is an enlargement made from the same negative. The low ramp in the photograph on the opposite page is in the large rectangular structure at upper right in the enlargement.



BATAN GRANDE was occupied during Chimu times but was built earlier. The photograph at the bottom is an enlargement of the one at the top. The small pits at the lower right of the enlargement were dug by grave robbers.

undertook to make a large-scale survey of the ancient settlements, temples, towns and cities with the aim of determining to what phase each belonged and placing them all in the chronological framework. Fortunately the blueprints from which this broad-scale history might be read were already in existence. Peru had an Aerial Photographic Service which had photographed or was in the process of photographing all but one of the valleys in the North Coast region.

The first phase of the survey—a reading of these photographs to locate all possible ruins in 11 coastal valleys of the North Coast—was carried out in Lima, where the photographs were kept, by Paul Kosok, chairman of the history department of Long Island University, and his son Michael. They were in Peru to study prehistoric irrigation in the very region in which we were interested. For several months the Kosoks, father and son, labored day and night over the photographs until their patience and eyesight were well-nigh exhausted. They examined thousands of prints and wherever they found what looked like walls, buildings or other signs of an ancient community they located the site with the aid of a map and ordered enlargements of the photographs. The work took great patience and skill, but it was richly rewarded; when they had finished, they brought me enlarged photographs of a tremendous number of large ruins, most of which had not been known to archaeologists before.

WITH the photographs in hand, I set out with a field crew in the jeep, which the University had provided, to find the sites and examine the ruins at closer range. Our expedition blazed a trail of many miles of jeep tracks through dense forests, across rock-strewn river beds, along old canal bottoms and over barren wastes of desert. The aerial photographs helped us to avoid most of the natural obstacles, but we had trouble with man-made ones. One of these hazards was bulls (raised for bullfighting) that were pastured near some of the ruins. Another was the numerous craterlike holes dug by "huaqueros," Peru's time-honored grave robbers, who have left few ancient ruins uninvestigated. We found also, to our surprise, that farmers had turned some of the old ruins to their own use. In some places they utilized ancient pyramids as observation towers for watching the progress of crops in the surrounding fields. Occasionally we discovered that a pyramid which had stood for 1,000 years without major alterations had been provided in the 20th century with a circular ramp for the ascent of horse or automobile.

It was surprising how seldom the aerial photographs betrayed us into visiting something that was not a ruin. To be sure, some of the ruins were not

CAJAMARQUILLA, a huge ruin near Lima on the central coast of Peru, was inhabited as late as the Inca conquest. It sheltered some tens of thousands of people. Although the many walled structures of the city appear to be separated by streets, they are not; the people probably moved about by walking on top of the walls.

as impressive on the ground as they were from the air. We were somewhat disappointed, for example, when we reached one ruin in the Lambayeque Valley which the photograph had indicated to be of enormous extent. Its main pyramid proved to be gutted, little was left of its ancient walls and some of the old lines that showed in the photograph were virtually invisible on the ground.

On the other hand, in many places we were very pleasantly surprised to find the structures much more magnificent on the ground than they had seemed in the photographs. One of these was a ruin, previously unknown, in the Nepena Valley. This site, called Punkuri Alto, showed only as a vague outline in the aerial photograph. It stood on a hilltop, and the ruins of its adobe buildings blended with the bare rock on which it was reared. But when we reached it in our jeep, we found an impressive, palace-like building with terraced platforms and a series of corridors leading to upper rooms. We were delighted to discover the remains of a geometric frieze lining one of the corridors.

Among our problems was the fact that it was sometimes not easy to distinguish ruins from farms in the aerial photographs. The farmers of modern Peru have unintentionally camouflaged some of the old ruins by using well-built ancient walls to mark off sections of their fields. Their newer fences and boundary walls often merge with the walls of the old compounds.

WE WERE struck by the fact that often one might ride to within a few hundred feet of truly huge ruins and still be unaware of them. This is partly due to the fact that many of the ancient hillside towns were built on the leveled terraces of the hill, either of adobe or of stone and rubble from the same hill, and few of them had walls high enough to cast large shadows until late afternoon. Thus they were often hard to pick out from the natural hillside, and were also difficult to photograph. Only in late afternoon do Peruvian coastal ruins become photogenic.

Perhaps the most striking case of a large hidden city is the one named Galindo. The main highway to the north highlands in Peru today passes close by these ruins, and the site is within 20 miles of Trujillo. Yet no archaeologist had ever before laid eyes on this ancient town, which runs for about five miles beside the highway. It is effectively blocked

PHOTOGRAPH OF EL PURGATORIO, a massive ruin on the Leche River, shows some structures in sharp outline and others as shapeless masses. The elevated structure at the upper left is some 1,200 feet long.

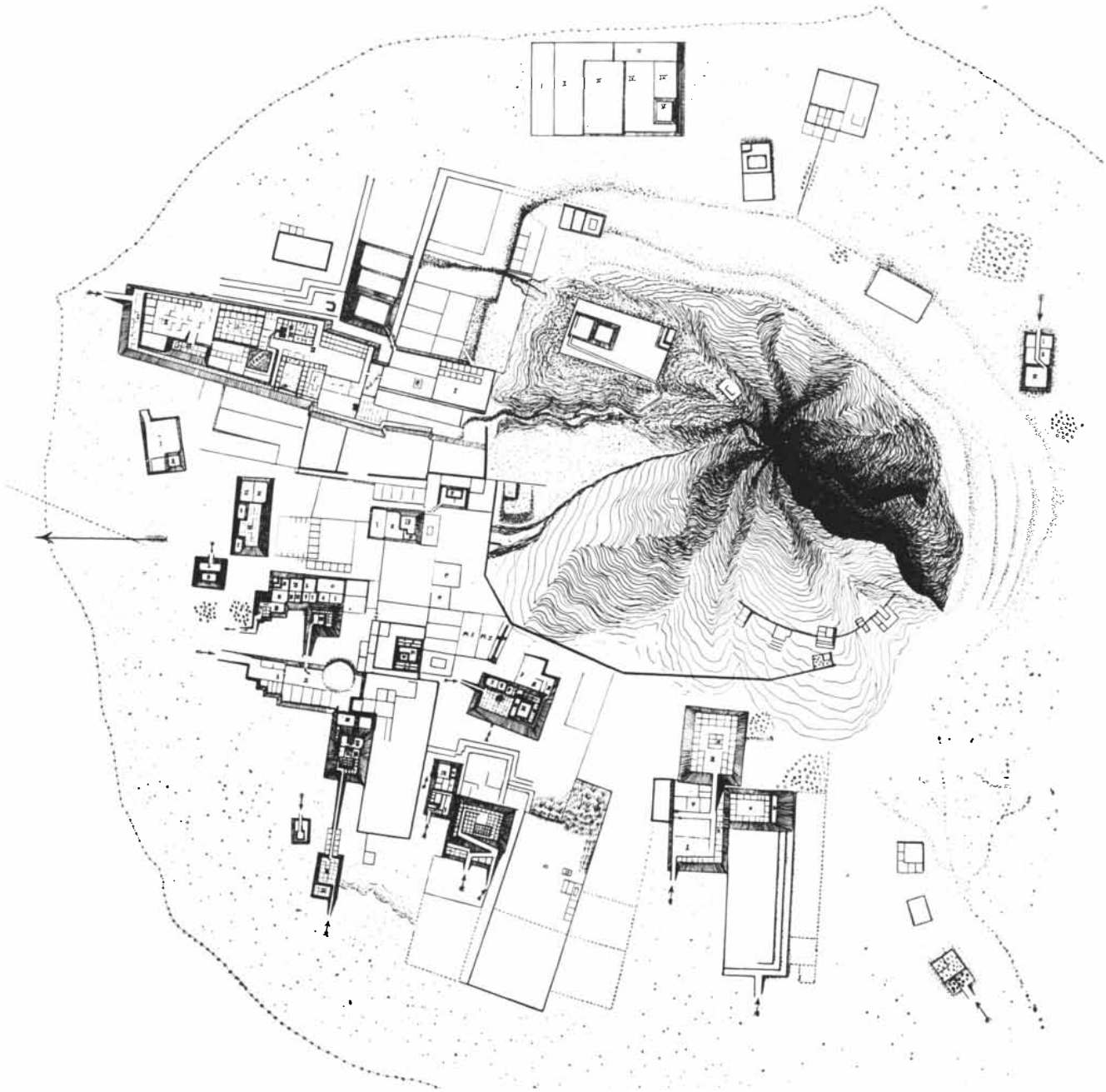
from view by a high fence that borders the highway, and it is also screened off by vegetation, so that the ruin is visible only from one rise in the road, and then only if the observer knows it is there.

After I had shown slides of Galindo before a class of students in the University of Trujillo, one of the girls came up after class to inquire where this town really was. It turned out she had lived within 10 minutes' walk of the ruin all her life and had never heard of it!

BY the time we had finished our reconnaissance, we were able to answer some of the questions we had set out to study. We defined the geographical extent of the Mochica culture and of the later Tiahuanacoid conquest, located the main provincial capitals of the Chimu empire and mapped the locations of the Inca garrisons on the North Coast. We were also able to determine that three main cultures had fought for control of the region during the confused "middle period," and to identify these cultures.

In addition, our reconnaissance yielded some information on a more interesting and important matter—the origin of the first cities in America. The Mochicas and their contemporaries did not build cities, although they did construct some of the largest pyramids in South America. Their typical capital consisted of several large adobe pyramids grouped around a central plaza. Only a limited group of priests, chiefs and artisans lived in these ceremonial centers; the rest of the population dwelt in the countryside. True cities did not arrive until several hundred years later, when the Chimus erected their magnificent metropolis called Chan Chan. The Chimus were the first civilization in the Western Hemisphere to cross the threshold of urbanization.

The towns of the "middle period," between the fall of the Mochicas and the rise of the Chimus, represent the be-



DRAWING OF EL PURGATORIO is a partial reconstruction based on ground surveys and the aerial photograph on the opposite page. The elevated structures of El Purgatorio were built with an eye to defense.

ginnings of city life. And here in coastal Peru we had an unusual opportunity to study how cities began, for the sites of the towns and of the metropolises that came later stand side by side, whereas in the Old World the former are buried beneath the latter. Thus from the data revealed by the aerial photographs we could work out the origin and development of city life in more detail in Peru than anywhere else in the world.

On the basis of these photographs and first-hand reconnaissance at the sites we have been able to draw ground plans of some of the town sites. One of these is illustrated in the photograph and drawing above. This town, called El Purgatorio, is built around a large natural hill in the center of the well-watered plain of the Leche Valley. The main buildings, dating from the "middle period," are clustered at the north end. These large pyramids with numerous room divisions are transitional building types between the solid pyramids of the earlier Mochica period and the later truly urban compounds, in which all the building space was given to rooms. It is likely that they were palaces housing several families of the ruling class, along with servants and craftsmen. At the southern and southwestern sides of the ruin are remains of what appear to be old pyramid complexes.

Until the last decade the quantity, size and complexity of ancient Peruvian towns and cities could only be guessed at. Aerial photography has made it possible for us to comprehend them for the first time in their large-scale significance. Let us hope that the sandy mantle that has covered them for centuries will be lifted soon to reveal the internal functioning of these thriving metropolises of prehistoric Peru.

Richard P. Schaedel was director of the Institute of Anthropology at the University of Trujillo in Peru from 1948 to 1950.

THE DEEP-SEA LAYER OF LIFE

Hundreds of fathoms down in the oceans is a drifting mass that once was called the "false bottom" but now is believed to consist of organisms, identity unknown

by Lionel A. Walford

THE most useful modern instrument in a pilot house is the echo sounder, which measures the depth of the water automatically and continuously as the ship plows ahead at full speed. The machine sends sound waves into the water, receives the rebounding echoes, translates the intervening time into fathoms and with a stylus draws on a moving strip of paper a graphic picture of the sea bottom, called a bathygram. The echo sounder in effect "sees" the bottom. It sees, also, any other things in the water that can deflect the sound and send back echoes, which means anything whose density is in contrast to that of the surrounding or adjacent medium. This, for example, is what made it possible for the salvage ship *Orphir* in 1935 to perform what was then the spectacular feat of locating the *Lusitania* at the bottom of the North Sea. There the echo sounder spotted a sunken object; it showed that the object was hollow and was 780 feet long and about 84 feet high—which were the dimensions of the *Lusitania*.

Fishermen have been using echo sounders to locate schools of fish since early in the 1930s. They can spot them down to depths of 90 fathoms or more and save themselves untold time over the older method of blind scouting. Under favorable conditions some experts can even tell from the record what kind of fish is below. In places where rivers empty into the sea, as at the mouth of the Mississippi, the echo sounder picks up the boundary between fresh water and salt. It will record a layer of colloidal silt overlying the true bottom, as well as the bottom itself. The sound penetrates the bottom, and the echo sounder will show substrata for a considerable distance beneath the bottom. Small wonder that interpreting a bathygram is tricky, and often subject to controversy.

The subject of our story is a "phantom bottom" which long mystified those who explored the sea depths with echo sounders. They often found odd, unexplainable echoes coming from middepths. On some occasions these echoes were distinct enough to inspire reports of shoals in places that later investigation proved to be very deep. Recording machines often marked down a record that looked as though echoes were being sent back by a layer of something suspended at depths from 150 to 450 fathoms down, running more or less parallel with the surface for very great distances. This layer sometimes seemed as much as 300 feet thick. Bathygrams showed a record like this lasting all day long. And then at other times they showed no such layer at all.

For a long time this effect was considered a vagary of the instrument—something like static on a radio. Hydrographers called the layer a "false bottom," or, more dramatically, "the sea's phantom bottom." The phenomenon was more or less dismissed in scientific quarters—until World War II.

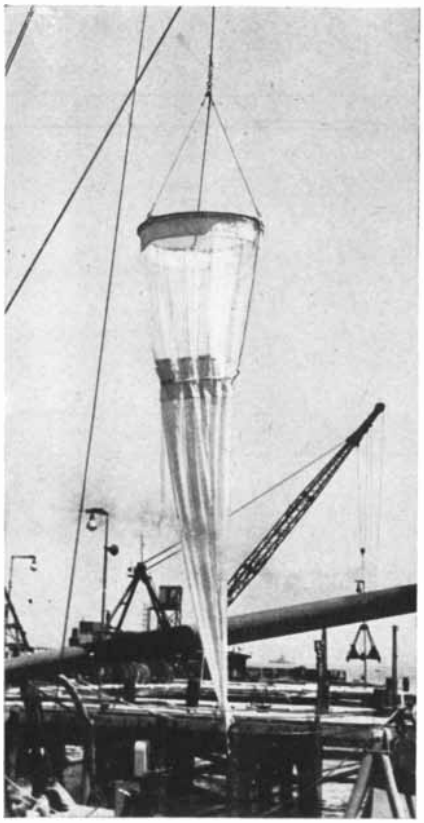
DURING the war the Navy, seeking improvement in the acuity of sounding instruments to help in its battle against submarines, arranged with the Scripps Institution of Oceanography at La Jolla, Calif., to investigate various problems in underwater acoustics. Not long after beginning their studies, scientists working on this project became preoccupied with the mysterious layer. They considered its properties:

It is deep; 150 to 450 fathoms, which means 900 to 2,700 feet, is a long way down. It behaves as though something concentrated there scatters the sound, causing it to reverberate and return many echoes that merge indistinguishably. Those studying it therefore came to call it "the deep scattering layer."

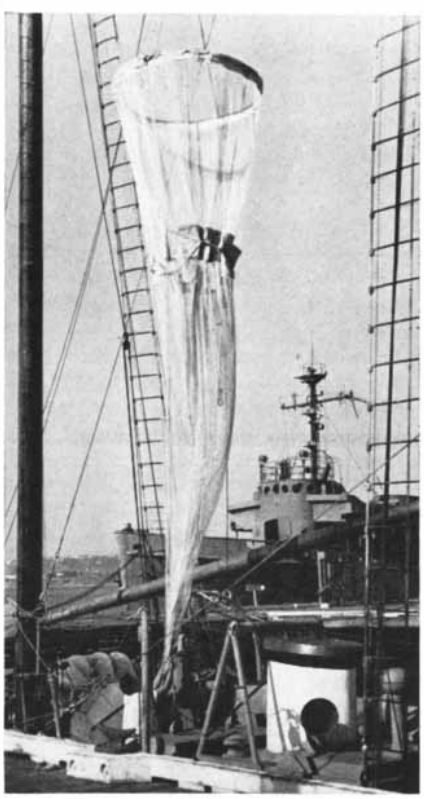
The most fascinating property of this layer was that nearly always it appeared only in the daytime, fleetingly if at all at night. Assuming that the effect was not a peculiarity of the instrument but something in the water, what could it be? One suggestion was that the layer might be composed of inanimate particles of solid matter drifting in suspension, but if this were so, why did it fail to return an echo at night as well as in the daytime?

A more likely suggestion seemed to be that the layer was made up of a mass of living things that somehow migrated at night to upper levels so shallow that the recording of their echo on the bathygram blended with that of the outgoing sound. Three physicists at Scripps Institution, Carl Eyring, Ralph Christensen and Russell Raitt, put this question up to their colleague Martin Johnson, a biologist who specializes in studying the nature and habits of plankton, the mass of drifting plant and animal life that dwells in the sea ("Food from the Sea," by Gordon A. Riley; SCIENTIFIC AMERICAN, October, 1949).

Johnson knew that animals of the plankton migrate toward the surface in the evening and descend again to lower depths in the early morning. Hence it was very possible that plankton might account for the mysterious layer. He suggested a day-and-night watch of the plankton's vertical migrations by echo sounder. On June 26, 1945, Johnson and the three physicists took the research vessel *E. W. Scripps* out about 20 miles off Point Loma, over a submarine canyon

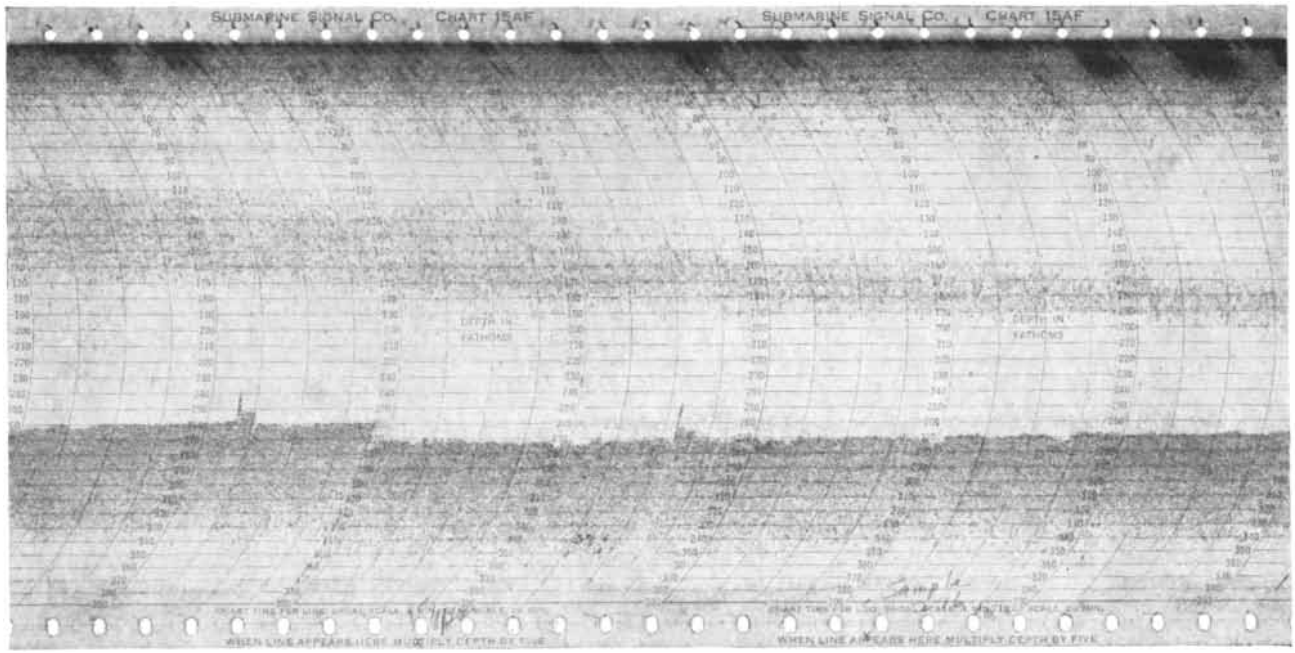


ONE-METER NET was used to bring plankton from deep waters to deck of the *E. W. Scripps* last summer.



SIX-FOOT NET was also used to catch plankton. It is rigged for opening and closing while in the water.

NET WITH OPENING SIX FEET SQUARE is hung over the side of the *E. W. Scripps.* This oceanographic vessel of the Scripps Institution was cruising in deep waters off San Diego, Calif., when these pictures were made.



THE DEEP SCATTERING LAYER is shown by the faint trace running across the middle of this echo-sounder recording. The stronger trace below it is the bottom of the sea. The depth of the scattering layer is indicated in fathoms by the numbers on the recording. The trace of the bottom, however, has been adjusted so that it is brought closer to that of the scattering layer. Actually the bottom is at the depth shown plus 400 fathoms.

which in some places is close to 4,000 feet deep.

After they had got into deep water, the echo sounder registered a scattering layer about 900 feet down. It remained there all day until evening; then it moved upward at the rate of about six feet a minute until it merged with the surface trace. All night no trace of the layer appeared, but very early the following morning it separated itself from the surface trace on the bathygram and descended to about the level it had occupied the day before.

DURING the two days that the investigator observed the bathygrams, they combed with nets the level where the instrument showed the layer to be located and the regions above and just under it. The nets were the kind of gear generally used for collecting plankton, that is, funnels of fine silk tapering down to a closed bag. They were rigged so they could be opened at the desired depth, and then closed and hauled to the surface without picking up material in other zones.

Johnson and his colleagues caught plankton at all levels down as far as they fished, but not in uniform quantities. The animals tended to concentrate in zones. Those shorter than two millimeters were found in two zones: one within the first hundred yards of the surface, the other in or just under the deep scattering layer. The larger animals, mostly about an inch long, were most abundant at about the level of the layer. Johnson concluded cautiously that "there appears to be some direct correlation of the plankton animals with the scattering layer."

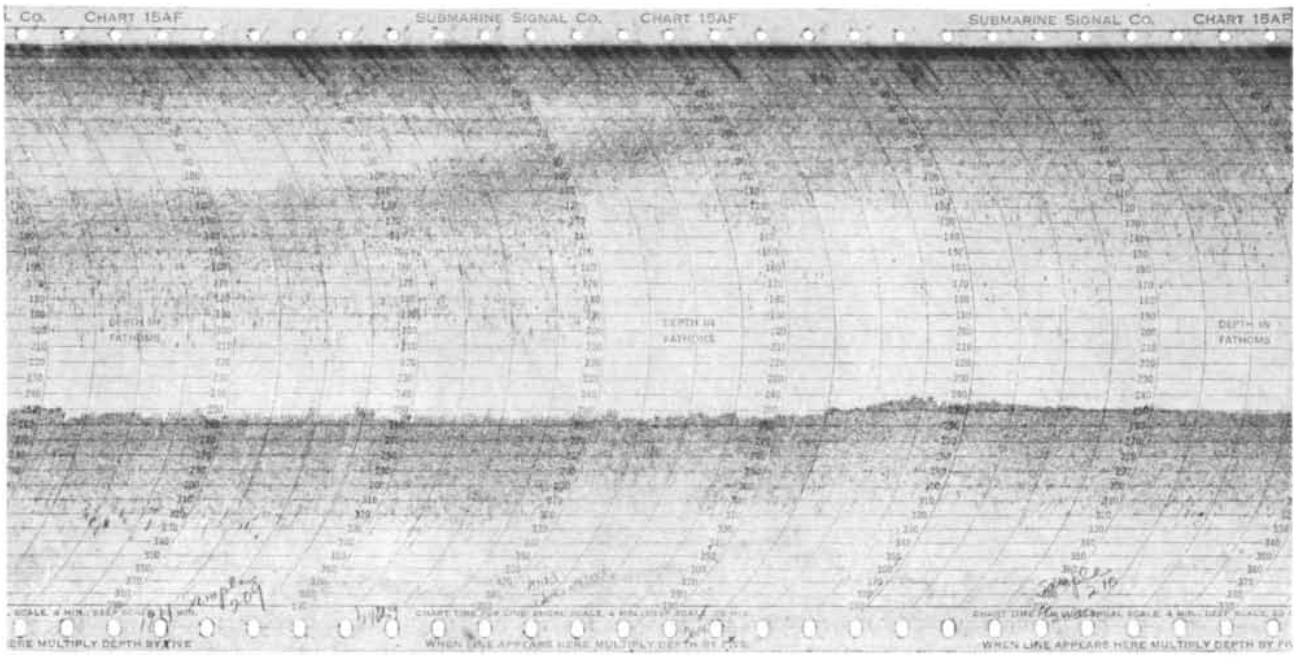
The animals themselves were familiar kinds that had long been known to marine biologists. Most of them were the small buglike crustaceans called copepods. There were some comb jellies, seaworms and a few euphausiid shrimps, which are the chief food of the whalebone whales. The largest animals were arrow worms, which look like thin rods of colorless, transparent glass.

Were these small-fry the objects that scattered the echo sounder's signals? It seemed doubtful that they had the right acoustic properties, for most of them were too small to scatter sound waves of 18 kilocycles effectively. More likely there were some larger predatory forms down there, too fast to be caught by the nets—large prawns, say, or deep-sea squids. Any of those might be abundant enough to account for the scattering layer.

SINCE that expedition oceanographers have studied echo-sounding records all over the world. They have found the D.S.L. (as they have come to call the deep scattering layer, in keeping with this alphabetical age) to be much more uniformly distributed than anyone had ever believed to be true of plankton. It is widespread throughout the Pacific, Atlantic and Indian Oceans, as well as in the Mediterranean and Red Seas. Conflicting reports have come from the Antarctic. Robert Dietz of the U. S. Navy Electronics Laboratory, who sounded the Antarctic in the U.S.S. *Henderson*, found no D.S.L. during the polar midsummer, a time of continuous daylight, but detected one as the day-night cycle returned toward the end of January. On the other hand, M. P. Tchernia of the French Hydrographic Service on one cruise found the D.S.L. just as common in the Antarctic as elsewhere. This disagreement may be explained by the fact that he used sound of a shorter wavelength than that of Dietz (24.8 kilocycles as compared with 18 kilocycles) and therefore was able to measure organisms too small to be detected by the wavelength Dietz had used.

A. C. Burd and A. J. Lee of the Fisheries Laboratory at Lowestoft, England, have detected layers behaving like the D.S.L. in the comparatively shallow waters (*e.g.*, 240 feet) of the English Channel, the southern North Sea and the Barents Sea near Bear Island. They believe, therefore, that the scattering layer should be called "sonic" rather than "deep."

By now accumulated observations have shown that the scattering layer has the following properties: It is probably universal throughout all seas. It is not a single thing. There is one principal layer which persists at a characteristic depth all day and executes a day-night vertical migration. Other layers may form for relatively brief periods. Some of these may behave like the principal layer, others quite differently. Some layers migrate toward the bottom at night instead of toward the surface; some show no pronounced daily movement. The principal scattering layer itself varies in daytime depth at various places in the



THE SCATTERING LAYER RISES toward the surface at the end of the day. The slight dip at the left end of the scattering-layer trace on the opposite page is the end of its descent at the day's beginning. The trace with which the scattering-layer trace merges at the right is made by the outgoing signal of the recording device. The pencil notations on both pictures were made on shipboard to record events in the exploration of the scattering layer.

world. In very transparent tropical waters, as around Bermuda, it is 1,500 to 2,100 feet down; in less transparent coastal waters, as along the coast of California, it is at 900 to 1,500 feet. Finally, the layers apparently vary greatly in density.

Virtually everyone who has studied the phenomenon believes it to be caused by planktonic animals. But what kind of animals, and how many of them? These questions are still in the realm of speculation, owing to the difficulties of studying plankton. Almost all we can learn directly about plankton depends on what we manage to catch in tow nets. When a biologist hauls a net through a layer of water, he would like to think he is getting a representative sample of all the creatures within the range of his net, but unfortunately a great many things work against his coming close to that ideal.

What happens in the depth when a plankton net drops at the end of a wire and is drawn through the water at a rate of two or three feet per second? What effect does this lumbering, insentient object have on the cosmos down there? Does it stir up a cloud of light in its path as it pushes ahead myriads of the small luminous creatures that inhabit the sea? And as these concentrate in the net, transforming it into a terrifying cone of luminosity, do larger creatures dart out of its way to escape? Then for what distances around the net is the order of things disturbed? Is there any order of things down there or are the components of the plankton only randomly distributed? We can only assume that as the net is hauled through the various swarms of animals, it takes from among them those so unwary, so inagile or simply so unfortunate as to get into it. When it is at last emptied into a pan on deck, how can anyone reconstruct from that chaotic jumble of organisms the pattern of life below? How can anyone know what species and what quantities escaped?

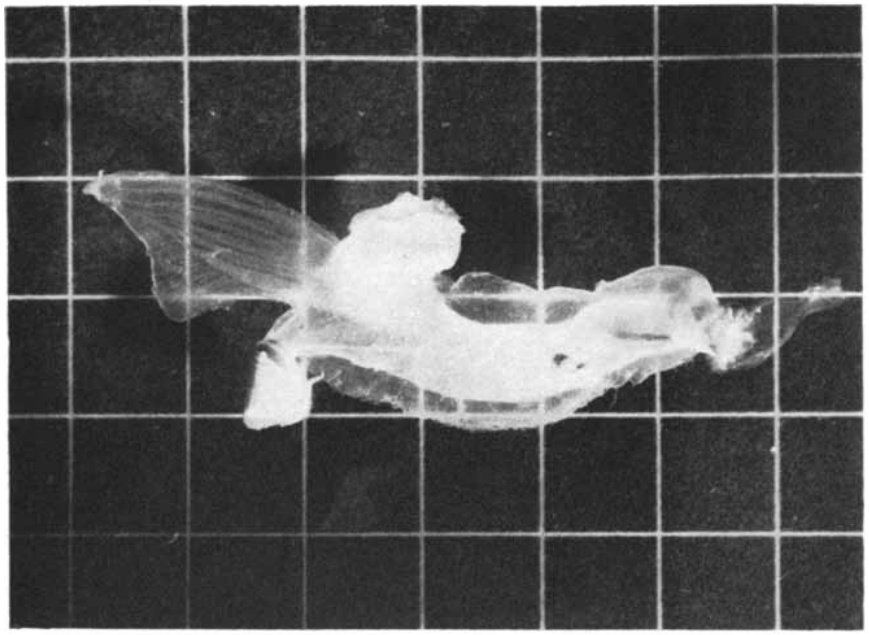
BIOLOGISTS are working to solve these problems. Owing to the tremendous resistance of the water against wire and nets, ordinary plankton nets and small fish-trawls move too slowly to take the fast swimmers. Against this difficulty, several marine laboratories have developed new types of trawls that can be towed faster. But even at best it is still impossible to tell just how representative the catches are.

Meanwhile the literature on the theoretical composition of the scattering layer is growing rapidly. Physicists are trying to identify the scattering animals on the basis of the fact that they must be comparable in size to the wavelength they affect. The method of measurement is to vary the wavelength of the sound signal and observe the resulting variation in scattering. J. B. Hersey of the Woods Hole Oceanographic Institution has developed a method of recording scattering in several frequency bands simultaneously. So far his evidence suggests that there is much variation in the composition of the layers. He believes that the kinds of animals commonly taken in plankton nets (euphausiid shrimps, fish, and so on) can account for the echoes that have been recorded, and that there is probably no heavy concentration of animals longer than about 12 inches in the scattering layer, at least in the Western Atlantic areas where he has been working.

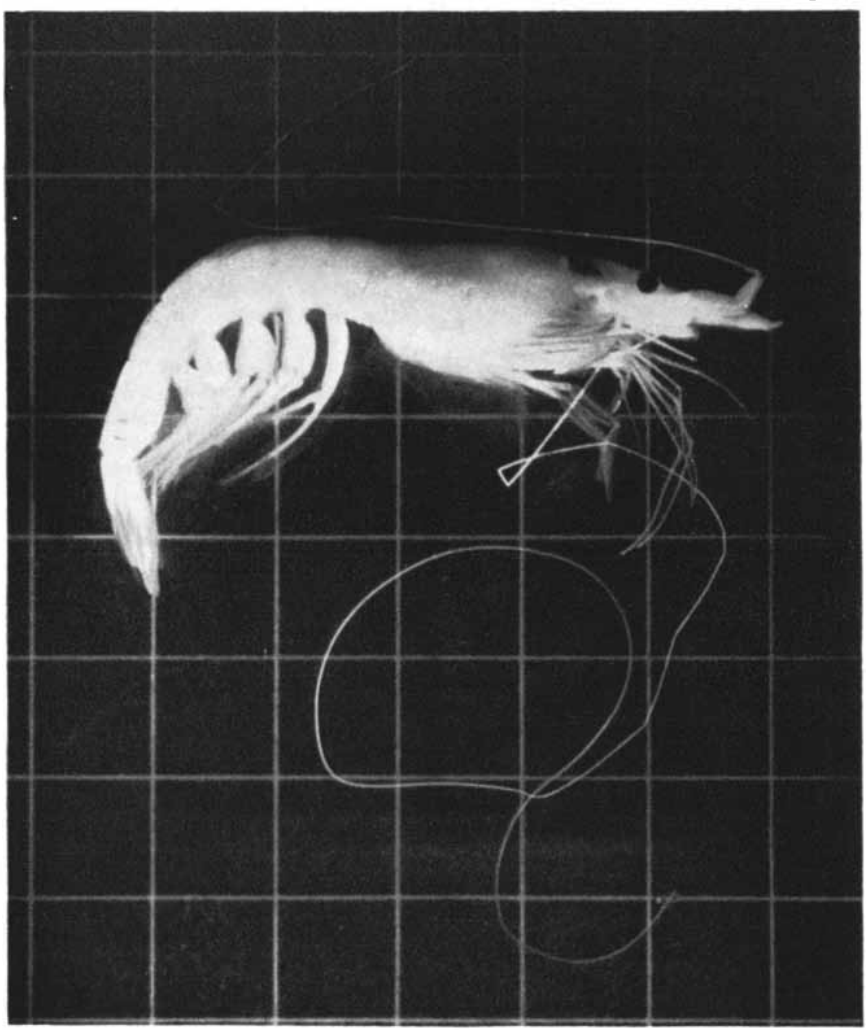
Biologists for their part are considering the question from the viewpoint of what kinds of animals have characteristics that best correspond to the behavior of the principal scattering layer. These are some of the requirements: they must be concentrated by day at depths of 900 to 2,700 feet; they must be large enough and strong enough to swim as fast as six to eight feet a minute; they must be ocean-wide in distribution; they must have some physical structure that reflects sound, such as a swim bladder, gas bubble, oil globule or hard skeleton.

Hilary Moore of Miami University finds that euphausiid shrimps, which are the dominant crustacean at the depths of the principal layer, best meet the requirements. Brian Boden, fishing in the scattering layer with plankton nets off the California coast, caught these animals more consistently than anything else. He believes that these creatures, "or organisms intimately associated with them," may well be the cause of the sounding echoes.

What kind of organisms might those others be? Fish, perhaps. Boden, like everyone else who has worked in the Pacific, noticed the ubiquitous sauries. These little fish, which grow to be 12 to 14 inches long and look like very slender mackerel, appear at the surface at night almost anywhere in the Pacific that one



HETEROPOD, a mollusk with an almost vestigial shell and a foot that has been modified into fins, was brought up from the deep waters of the San Diego Trough. The lines of the grid in the background are half an inch apart.



SHRIMP was also brought up from the waters of the San Diego Trough. These crustaceans and others like them are characteristic of hauls made at between 1,200 and 1,800 feet. The lines of the grid are half an inch apart.

puts a light over the side of the ship. They seem to be among the most abundant and widely distributed fishes in the sea and might be important contributors to the echoes coming from the scattering layer.

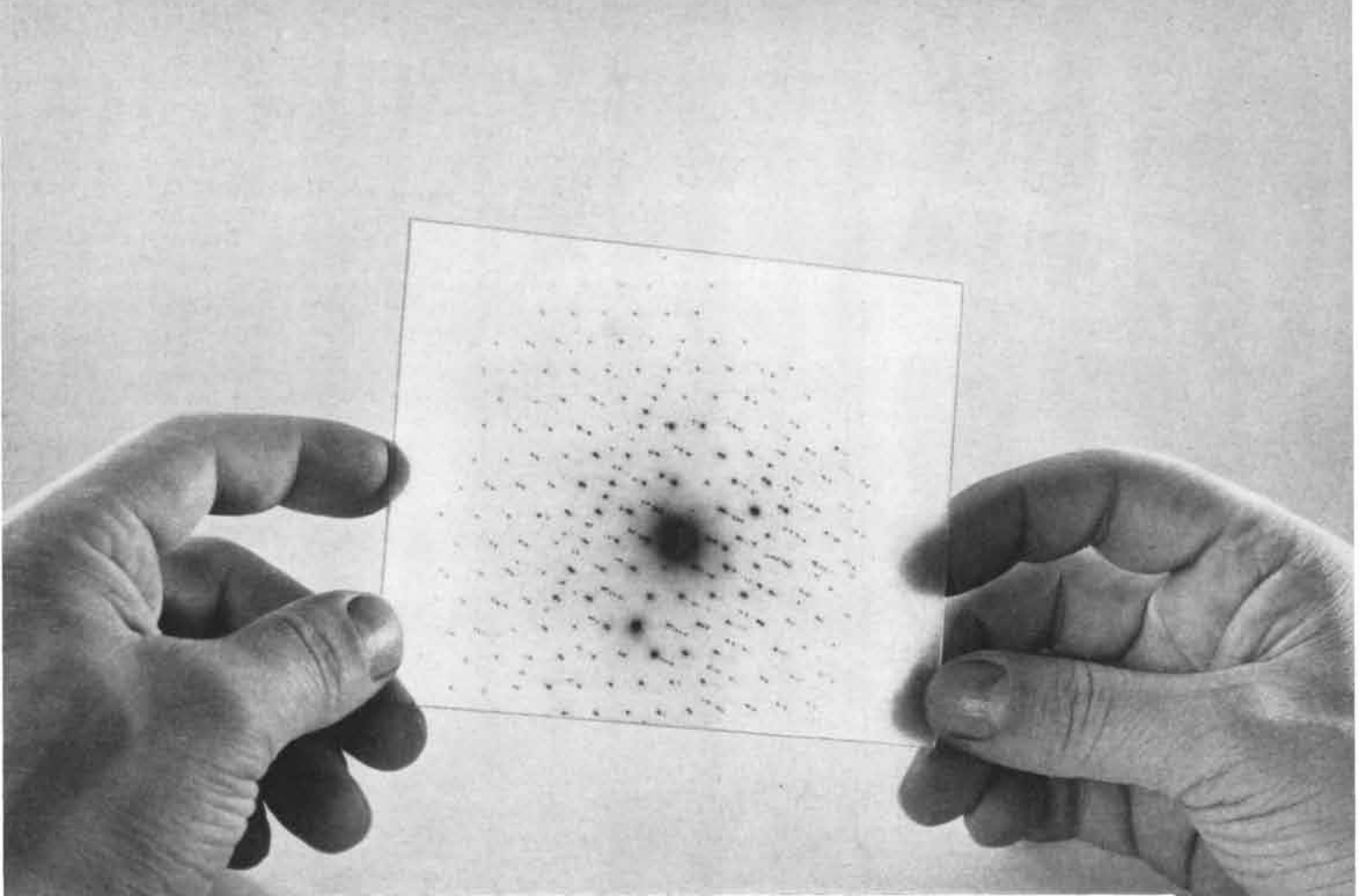
Then there are the hundreds of species of grotesque-shaped, luminescent deep-sea fishes, many of which inhabit the deep water by day and rise toward the surface at night. Gordon Tucker, working on the *E. W. Scripps* off California, estimated from his catches that there were as many as 20,000 to 40,000 of them concentrated in the part of the layer within the cone of sound sent down by his echo sounder.

John Lyman of the U. S. Hydrographic Office argues very cogently that the sound scatterers may also be squids. In other words, they can be, and probably are, many of the creatures composing the plankton.

YET all the evidence that has been amassed satisfies no one. Oceanographers continue to discuss the deep scattering layer as an unsolved mystery. And so I believe it will remain until some way is found to look at it in its abiding place. It is 17 years since William Beebe published his book *Half Mile Down,* describing the descent that he and Otis Barton made in the deep water off Bermuda. They went down 3,028 feet in a spherical steel diving chamber which they called a bathysphere. Through its fused quartz windows, three inches thick, they peered at such wonders as have never been caught in nets or on lines, and so have not been seen by anyone else. Unfortunately the scattering layer was not known then, and Beebe has given us no useful quantitative observations that bear on the question. He did, however, write: "Every descent and ascent of the bathysphere showed a fauna rich beyond what the summary of all our 1,500 nets would lead us to expect. Bermuda is in the Sargasso Sea, which is accounted an arid place for oceanic life, but my observations predicate, at least, an unsuspected abundance of unknown forms."

Conclusive proof of the reality of this unsuspected abundance is what many people hope for, since it might become a new source of protein food. That hope, vain though it may prove to be, should, even if the search for knowledge alone were not enough, justify finding somehow, somewhere, enough money to make the bathysphere available again to biologists. If the financial and technical means were found to try it, it is even possible that the deep scattering layer might be made visible by television.

Lionel A. Walford is Chief of the Branch of Fishery Biology in the U. S. Fish and Wildlife Service.



The electrons landed here...

. . . and the diffraction pattern they left on this plate measures the splitting of the laminae in a 1000-Angstrom-unit-thick sheet of bent mica through which they passed.

For industry, electron diffraction patterns are revealing and identifying oxides on non-ferrous metals, the faint beginnings of corrosion on steel, scale in distillation equipment, crystal formations in chemical processes—thin films of all kinds.

A host of fine instruments that are serving science and industry today are built around the simplicity, the economy, the easy reproduction, and the incontrovertibility of photographic recording. We make the specialized sensitive materials they require—for electron diffraction and electron micrography, for spectrochemistry, for x-ray diffraction, for mass spectrography, for work in the infrared and the deep ultraviolet, for autoradiography with radioisotopes, for capturing tracks of cosmic ray primaries in the upper atmosphere and mesons in the great nuclear accelerators, for analyzing the stuff that distant galaxies are made of.

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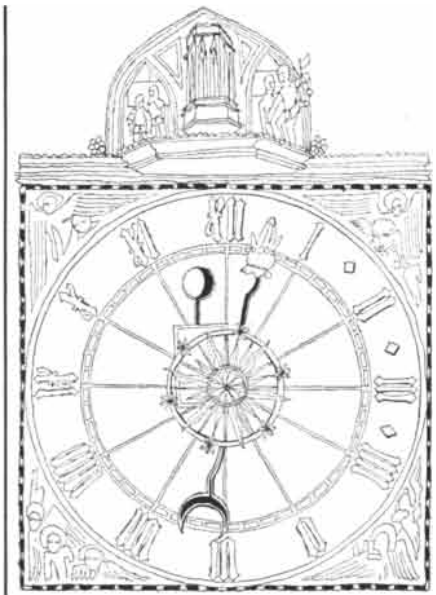


Arthritis Germ?

IN spite of the spectacular headway made against rheumatoid arthritis by treatment with cortisone and ACTH, the cause of this disease remains a deep mystery. There have been various theories: that it is due to a fault of metabolism, to an unknown microbe, and so on. What looks like one of the most exciting leads yet has just been reported by Thomas McPherson Brown, a pioneer in the study of rheumatic diseases. Brown has discovered important evidence to support the germ theory, and he thinks he may have identified the guilty organism. It is a tiny bacterium, almost as small as a virus, of the group known as pleuropneumonia organisms. Brown and his associates at the George Washington University School of Medicine have not only figured out the complicated mechanism by which this microbe, called the L-organism, may produce the swellings, pain and crippling of arthritis, but they have also found that some of the antibiotic drugs are effective in treating the disease.

The L-organisms have long been known to be responsible for a highly contagious lung plague of cattle. The first indication that they might be the cause of human rheumatic diseases came when these organisms, which are too small to be seen in the tissues where they do their damage, were isolated from the saliva, throats and genito-urinary tracts of rheumatic patients.

When it turned out that L-organisms could be killed in the test tube by gold salts, long used with some effect as a treatment for arthritis, the researchers became even more interested.

Brown and his group believe that L-organisms act upon the body tissues as antigens, causing the body to produce antibodies, and it is the reaction between the organisms and the antibodies that produces the pain, swelling, fever, stiffness and crippling of rheumatic disease. After laboratory tests showed that the antibiotics terramycin, aureomycin and Chloromycetin could kill L-organisms in the test tube, the George Washington group tried these drugs in treatment of arthritic patients. Terramycin particularly proved potent in controlling the disease. It was effective, however, only when given in very small doses; large doses produced a flare-up of the rheumatic symptoms. Brown suggests that this may be due to the fact that the large doses kill the organisms too rapidly and cause them to flood into the spaces between cells, where they produce an extensive reaction with antibodies.

Apparently the reason that cortisone relieves arthritis is that it blocks the meeting of the L-organisms and antibodies and thus prevents the reaction that produces symptoms. This may explain why cortisone has only a temporary effect. Albumin, a component of normal blood serum, has a similar blocking effect and also relieves arthritis, the investigators found.

The new approach opened by Brown's discoveries offers for the first time the possibility of a cure, rather than mere relief, for the rheumatic diseases.

Alcohol and Death

ALCOHOL makes some people gay and some sad, some violent and some stupid, some helpless and some dangerous. But whatever its effects on your personality, it nearly always brings you a little closer to violent death. This conclusion was convincingly documented in a report published recently in *The Journal of the American Medical Association.*

David M. Spain, Victoria A. Bradess and Andrew A. Eggston, of the Medical Examiner's office of Westchester County, made a study of the connection between drinking and violent deaths in that county. Westchester County, contrary to a common impression, is not merely a suburb inhabited by commuters to New York City; it has industries, cities and towns of its own, and its 600,000 population represents various economic and ethnic groups. In this county the Medical Examiner's office has made it a practice to perform an autopsy on every person who dies a violent death and to analyze the liver or brain for alcohol content, *i.e.*, evidence as to whether the person had been drinking before his death.

The three investigators took all the cases of violent death that had occurred in the county in 1949 from causes other than industrial accidents or the like.

There were 246 such deaths that year. Of these victims 78 had been killed in automobile accidents; 82 had died of nonindustrial accidents (burns, falls, drownings, and so on); 78 were suicides and 8 had been killed in brawls. The autopsies showed that 87 per cent (7 out of 8) of the homicide victims, 46 per cent of those who died in auto accidents, 24 per cent of those in other accidents and 19 per cent of the suicides had been drinking before they were killed. Altogether alcohol was responsible or a contributing factor in 27 per cent of the total of 246 violent deaths.

Most of the victims were not drunk in the commonly recognized sense: they had only a moderate alcohol content in their organs and may not have appeared intoxicated on casual examination. The physicians explained: "These are the persons most prone to get into trouble because their reflex actions, coordination and sense of judgment are impaired and yet they can get around and do not realize the extent of impairment." People who are really drunk, the doctors added, are less likely to get into serious trouble because they are "too far gone" to move about. Most of the drinkers killed in auto accidents "were not chronic alcoholics but people who had been drinking at a cocktail party, a tavern, a wedding or a holiday celebration."

Still Expanding

THE 200-inch Hale telescope on Palomar Mountain has given a tentative answer to one of the main questions it was built to explore: Does the universe continue to expand with increasing speed out beyond the seeing limits of earlier telescopes? The answer seems to be yes. With the new telescope astronomers at the Palomar Observatory have now looked 50 per cent farther into the depths of space than man had ever seen before, and they find that star systems out there appear to be moving away from us at the accelerated rate predicted by the expanding-universe theory. At a distance of 360 million light-years, the limit of the 200-inch's penetration so far, the nebulae apparently are receding from the earth with a velocity of 38,000 miles per second—one-fifth the speed of light.

These results, obtained in the first significant test of the expanding-universe hypothesis with the new telescope, were announced by Milton L. Humason of the Mount Wilson and Palomar Observatories. The estimates of speeds are based on the amount of red shift in the spectra of the nebulae. The red shift, which represents the apparent lengthening of

wavelengths of light reaching the earth, has long been interpreted to be a "Doppler effect" that indicates the speed of recession of the distant nebulae. At the spectrographic limit of the old 100-inch Mount Wilson telescope—250 million light-years—the speed of the receding nebulae is 25,000 miles per second, according to the red shift. Pushing farther with the 200-inch, Humason found that the red shift increased in direct proportion to the distance as far as the most distant nebulae so far observed, *i.e.*, at 360 million light-years. The skies are being searched for more remote nebulae so that the observations can be carried out to the spectrographic limit of the 200-inch, which is 500 million light-years. The instrument can actually photograph nebulae at a distance of 1,000 million light-years, but the spectrographic limit of a telescope is only half its photographic limit.

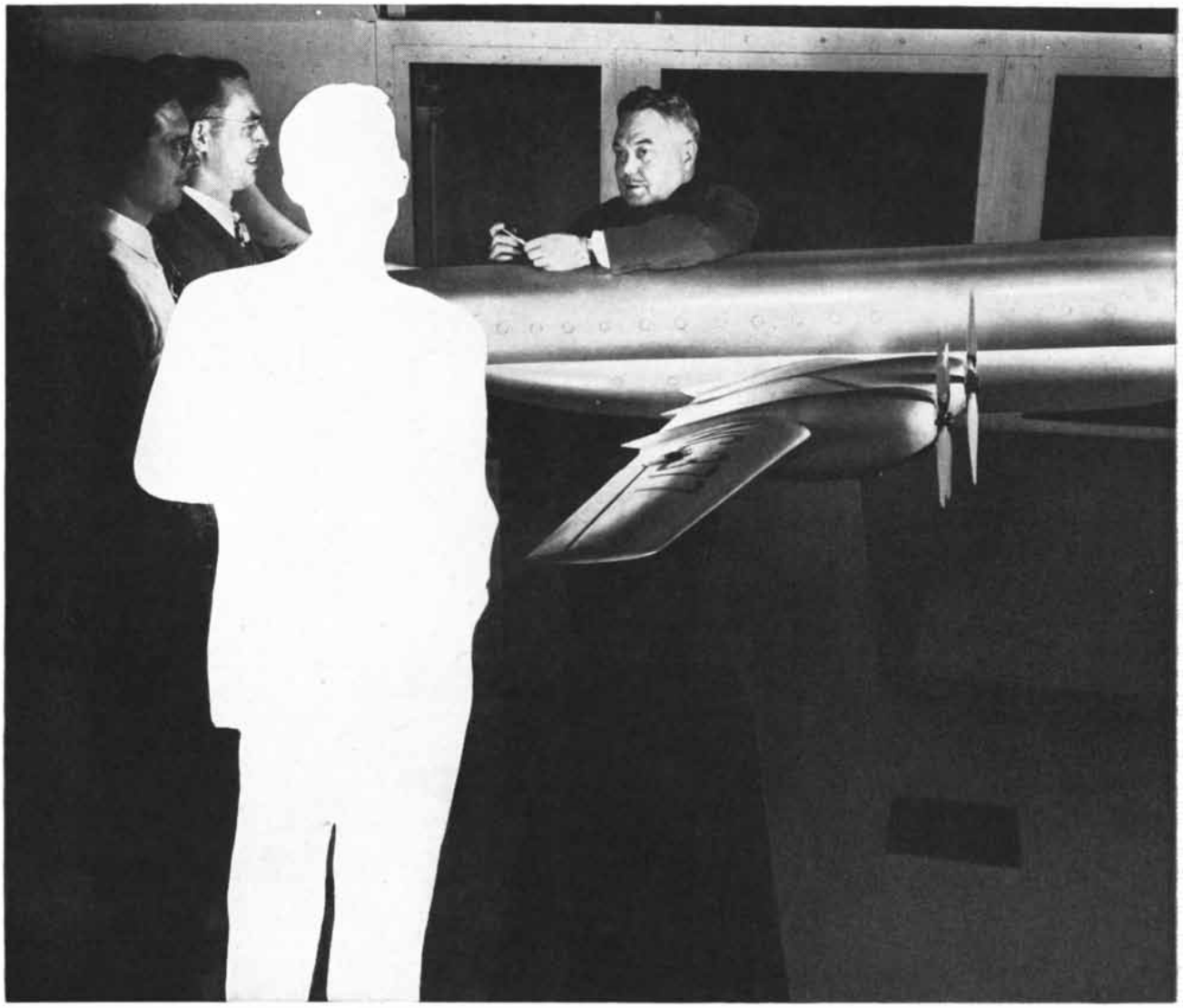
Corkscrews and Pleated Sheets

AN average protein molecule may consist of some 5,000 atoms. When this intricate structure is broken down, the wreckage is made up of amino acids—much smaller molecules of perhaps 20 atoms. It is generally assumed that the amino acids of a protein are joined end to end in chains. One of the major problems on which investigators of proteins have been working is to determine the shape of the chains and how they are assembled in the noble architecture of the protein molecule.

Now Linus Pauling and Robert B. Corey of the California Institute of Technology propose some sweeping solutions to the problem. For many years Pauling and Corey and their associates have studied such features of amino acids as how they are joined together, the distances between their atoms and the angles of their chemical bonds. In the May issue of the *Proceedings of the National Academy of Sciences* Pauling and Corey reported they had found evidence that amino acids are assembled into larger structures in four ways.

Two of the structures are in the form of a corkscrew, or helix. The first of them has 3.7 amino acids in each turn of the helix; the second, 5.1. The other two structures are in the form of a "pleated sheet" and a complicated helix made up of three amino-acid chains twisted together. These structures are not only consistent with the geometry of amino acids, say Pauling and Corey; they also explain many cryptic features of the patterns made by X-rays when they are diffracted by protein crystals. Thus the four structures might account for the architecture of a whole array of proteins.

In the opinion of the Caltech workers the helix with 3.7 amino acids per turn represents the structure of one form of keratin, the protein of which hair is made. The pleated sheet appears to be



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present in a protein of silk. The helix of three amino-acid chains may correspond to the structure of collagen, the principal protein of skin and bone. A protein found in feathers could consist of double layers of 3.7 helixes sandwiched between pleated sheets. The muscle protein myosin may have different structures at different times: When it is relaxed, it possibly assumes the shape of a pleated sheet; when it contracts, it may become a double layer of 3.7 helixes.

All these proteins are fibrous. The fibers constitute one of the two great protein families; the proteins of the other family are globular. These proteins, suggest Pauling and Corey, may also be made of the four structures. They report evidence that the 3.7 helix is present in hemoglobin, the oxygen-bearing protein of blood.

Turmoil Among the Bees

DDT and the other powerful new insecticides are not an unmixed blessing, as agriculturalists have often pointed out. One of their most susceptible victims is the useful bee. Recently German biologists made a direct study of the effects of such poisons on bees and discovered some remarkable facts, not only about the devastation caused by the poisons but about the bees themselves.

Beekeepers had noticed that bees contaminated by insecticides sometimes passed the poison on to other bees. Workers at the state agricultural college of Bavaria decided to study this further by controlled experiments. They marked some test bees with a white spot for identification and exposed them to flowers dusted with E-605, an insecticide that attacks the nervous system. Then they watched developments when the poisoned bees returned to their home hives.

It turned out that as these bees spread their poison, the other bees soon recognized them to be a menace and attacked them. They drove the poisoners out of the hive and killed them, but during the fighting more and more of the defenders were poisoned and in turn were attacked. The hive disintegrated into disastrous civil warfare. The excited bees battled in and around the hive, blocked the entrance to keep those outside from entering and on one occasion even killed the queen bee. Eventually the area around the hive was covered with dead bees. Ten poisoned bees, the experimenters found, could poison up to 1,000 others in a hive and thus destroy the whole colony.

Reporting the German investigators' findings in the journal *Agricultural Chemicals*, E. E. Leppik of Augustana College, South Dakota, remarked that this type of insecticide could be useful against such pests as wasps and ants, on which it has the same effect as on

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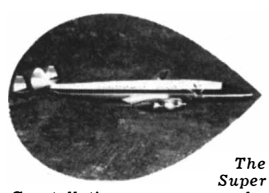

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bees. But he warned that care must be taken not to use the insecticides where they will poison bees and other valuable plant pollinators. "The improper mass use of such toxicants," he said, "can lead to unpredictable losses to agriculture and horticulture."

The Taste of Mosquitoes

"WHILE . . . some individuals are more attractive to mosquitoes than others, little attempt has been made to . . . see whether any particular age group is more attractive than others," writes R. C. Muirhead-Thomson in the *British Medical Journal.* This thought stimulated Muirhead-Thomson to make such an investigation in Jamaica, where malaria is borne by the mosquito species *Anopheles albimanus.*

He began by counting the mosquito attacks on the members of a Negro family named Bailey, consisting of father, mother and six children of various ages. The family members were watched for half-hour periods as they sat together outdoors at sundown. Whenever a mosquito settled on one of the Baileys and attempted to bite, it was picked off by a sucking tube, and the attempt was recorded as a "bite." Muirhead-Thomson found that during the period of observation the father was "bitten" 302 times and the mother 74 times. The children were bitten much less often than the father and most of them less often than the mother. But the most remarkable finding was that the youngest child, a year-old baby, was bitten only twice during the entire period of observation.

The investigator noted that the baby was extremely sensitive even to mosquitoes settling on her skin. The insects, on the other hand, were also sensitive about attempting to bite the baby; they would spend a long time probing around before they ventured to try to feed, whereas when they settled on the father or one of the older children they bit immediately.

Muirhead-Thomson repeated this observation on two other families in Jamaica and four in Trinidad. In each family the adults were bitten most, the babies almost never. Muirhead-Thomson's tentative conclusion is that very young children probably are much better protected against malarial infection than older people. The Bailey baby and two other young children in the family, aged 2½ and 5½, showed no sign of malarial parasites in their blood during the eight-months' period of study. The investigator suggests that the study should be extended to the biting habits of other species of mosquitoes in other parts of the world. From what he has observed, he concludes that the "commonly accepted idea that young children form the main reservoir of malarial infection may need considerable revision."

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SINCLAIR—A Great Name in Oil

HYBRID CORN

Vigorous new crosses of the ancient cultivated plant have revolutionized the agriculture of the Corn Belt. An account of their development and its consequences

by Paul C. Mangelsdorf

HYBRID CORN, a man-made product developed during the past 25 years, may prove to be the most far-reaching contribution in applied biology of this century. With its accompanying improvements in farming methods, it has revolutionized the agriculture of the American Corn Belt. Because of it U. S. farmers are growing more corn on fewer acres than ever before in this country's history. The new abundance of food brought by hybrid corn played a significant role in World War II and in the rehabilitation of Europe after the war. Now this product, spreading to Italy, to Mexico and to other countries where corn is an important crop, promises to become a factor of considerable consequence in solving the world food problem.

What is hybrid corn and how has it made possible these substantial contributions to the world's food resources?

In a broad sense all corn is hybrid, for this plant is a cross-pollinated species in which hybridization between individual plants, between varieties and between races occurs constantly. Such natural, more or less accidental hybridization has played a major role in corn's evolution under domestication. But the hybrid corn with which we shall deal here is a planned exploitation of this natural tendency on a scale far beyond that possible in nature.

The biological basis of hybrid corn is a genetic phenomenon known as "hybrid vigor." It means simply that crossed animals or plants have greater vigor or capacity for growth than those produced by inbreeding. This fact has been known since Biblical times. The ancient Near Eastern peoples who mated the horse and the ass to produce a sterile hybrid, the mule, were creating and utilizing hybrid vigor. The mule is an excellent example of the practical advantages that often follow crossing. This animal, said to be "without pride of ancestry or hope of posterity," has greater endurance than either of its parents; it is usually longer-lived than the horse, less subject to diseases and injury and more efficient in the use of food. Hybrid corn resembles the mule (indeed, it used to be called "mule corn") in being more useful to man than either of its parents.

Early Experiments

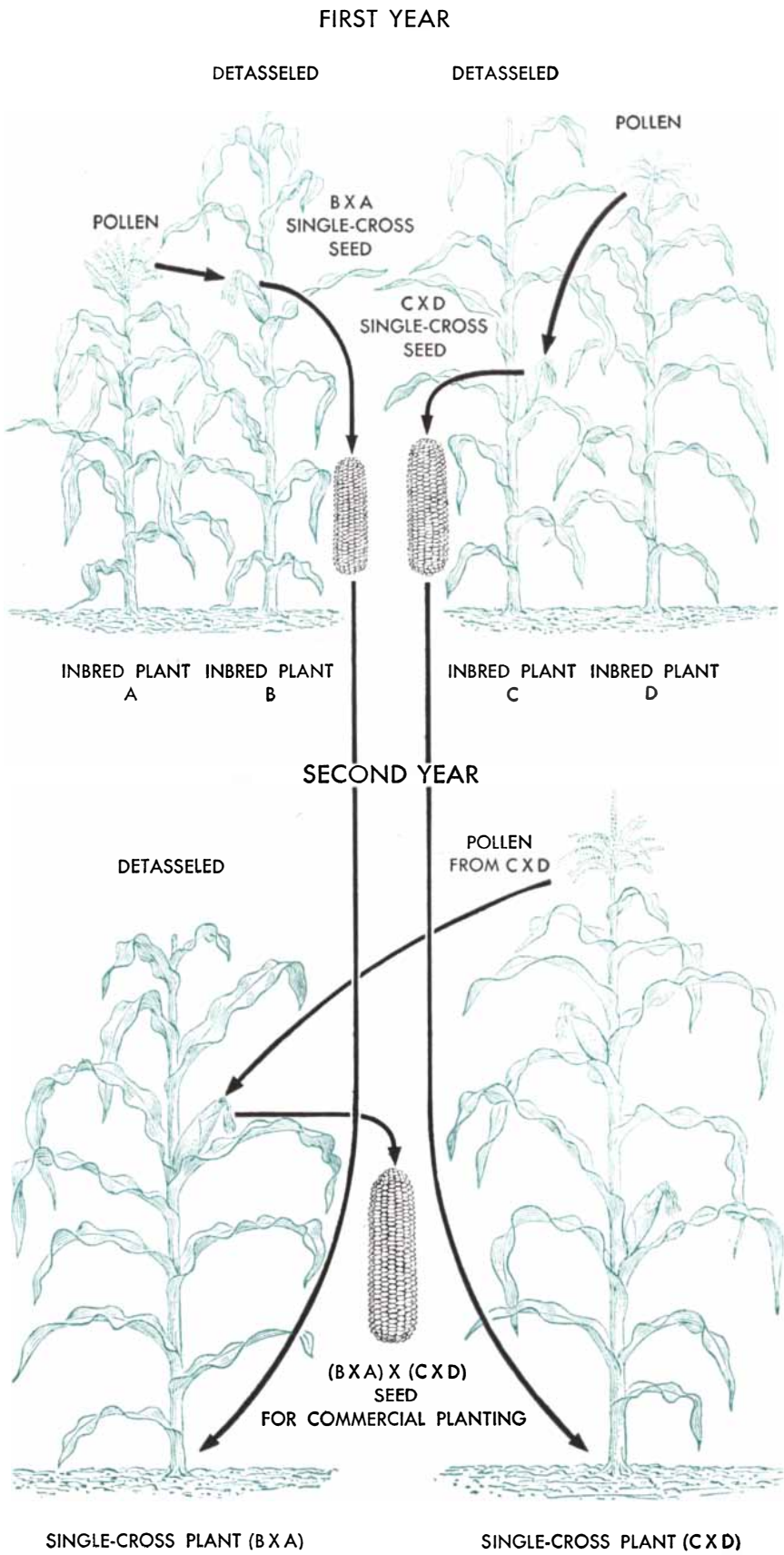
The idea of crossing varieties of corn is as old as some of the early American Indian tribes, who regularly planted different kinds of corn close together to promote hybridization and increase yields. Cotton Mather, of witch-hunting fame, published in 1716 observations on the natural crossing of corn varieties, and James Logan, onetime Governor of Pennsylvania, in 1735 conducted experiments which demonstrated natural crossing between corn plants.

But it was Charles Darwin who made the important studies of hybrid vigor in plants which open the story of modern hybrid corn. He investigated the effects of self-pollination and cross-pollination in plants, including corn as one of his subjects. His were the first controlled experiments in which crossed and self-bred individuals were compared under identical environmental conditions. He was the first to see that it was the crossing between unrelated varieties of a plant, not the mere act of crossing itself, that produced hybrid vigor, for he found that when separate flowers on the same plant or different plants of the same strain were crossed, their progeny did not possess such vigor. He concluded, quite correctly, that the phenomenon occurred only when diverse heredities were united. These researches, together with his theory of evolution, inspired the studies on heredity which eventually led to the discovery of the principles underlying the production of hybrid corn.

Darwin's experiments were known, even before their publication, to the American botanist Asa Gray, with whom Darwin was in more or less constant communication. One of Gray's students, William Beal, became, like Gray, an admirer and follower of Darwin. At Michigan State College Beal undertook the first controlled experiments aimed at the improvement of corn through the utilization of hybrid vigor. He selected some of the varieties of flint and dent corn then commonly grown and planted them together in a field isolated from other corn. He removed the tassels—the pollen-bearing male flower clusters—from one variety before the pollen was shed. The female flowers of these emasculated plants then had to receive their pollen from the tassels of another variety. The seed borne on the detasseled plants, being a crossed breed, produced only hybrid plants when planted the following season.

The technique Beal invented for crossing corn—planting two kinds in the same field and removing the tassels of one—proved highly successful and is still essentially the method employed today in producing hybrid seed corn. But as a device for increasing corn yield his operation of crossing two unselected varieties, each of mixed inheritance, was ineffective: the gain in yield was seldom large enough to justify the time and care spent in crossing the plants. The missing requirement—the basic principle that made hybrid corn practicable—was discovered by George H. Shull of the Carnegie Institution.

His discovery was an unexpected by-product of theoretical studies on inheritance which he had begun in 1905. Shull's contribution grew from certain earlier studies made by two great scientists: Darwin's cousin Francis Galton and the Danish botanist Wilhelm Ludwig Johannsen. Galton had recognized that the result of the combination of parental heredity could take two forms: an "alternative" inheritance, such as the coat color of basset hounds, which came from one parent or the other but was not a mixture of both, and a "blended" inheritance, such as in human stature. He observed that children of very tall parents are shorter than their parents, on the average, while children of very short parents tend to be taller. These observations led Galton to the formulation of his "law of regression," which holds that the progeny of parents above



DOUBLE CROSS made the experimental hybridization of corn a practical reality. First two pairs of inbred corn plants are crossed (*top*); then the process is repeated with their hybrid descendants (*bottom*). The second cross greatly multiplies the number of seeds produced by the first.

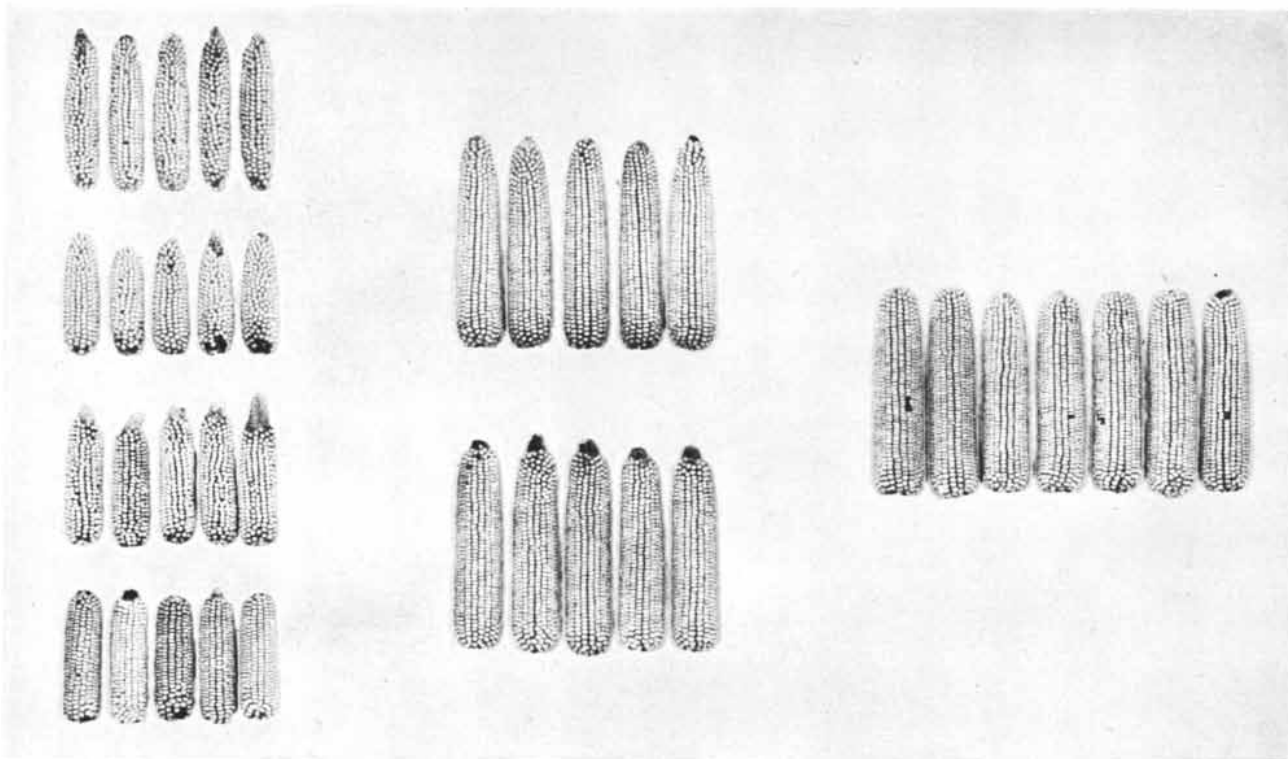
or below the average in any given characteristic tend to regress toward the average.

This regression is seldom complete, however, and Johannsen saw in that circumstance an opportunity for controlling heredity through the selection in successive generations of extreme variations. He tested the possibility by trying to breed unusually large and unusually small beans by selection. He found that, although selection apparently was effective in the first generation, it had no measurable effect whatever in later generations. Johannsen concluded that in self-fertilized plants such as the bean the progeny of a single plant represent a "pure line" in which all individuals are genetically identical and in which any residual variation is environmental in origin. He postulated that an unselected race such as the ordinary garden bean with which he started his experiments was a mixture of pure lines differing among themselves in many characteristics but each one genetically uniform. Johannsen's pure-line theory has been widely applied to the improvement of cereals and other self-fertilized plants. Many of the varieties of wheat, oats, barley, rice, sorghum and flax grown today are the result of sorting out the pure lines in mixed agricultural races and identifying and multiplying the superior ones.

Inbreeding

Shull's contribution was to apply the pure-line theory to corn, with spectacular, though unpremeditated, results. He started with the objective of analyzing the inheritance of quantitative or "blending" characteristics, and he chose the number of rows of kernels in an ear of corn as an inherited quantitative characteristic suitable for study. Through self-pollination he developed a number of inbred lines of corn with various numbers of rows of kernels. These lines, as a consequence of inbreeding, declined in vigor and productiveness and at the same time each became quite uniform. Shull concluded correctly that he had isolated pure lines of corn similar to those in beans described by Johannsen. Then, as the first step in studying the inheritance of kernel-row number, he crossed these pure lines. The results were surprising and highly significant. The hybrids between two pure lines were quite uniform, like their inbred parents, but unlike their parents they were vigorous and productive. Some were definitely superior to the original open-pollinated variety from which they had been derived. Inbreeding had isolated, from a single heterogeneous species, the diverse germinal entities whose union Darwin had earlier postulated as the cause of hybrid vigor.

Shull recognized at once that inbreed-



EARS of corn illustrate the effects of the double cross. At the left are the ears borne by the plants of four inbred strains. If the strains are divided into pairs, and one plant in each pair is allowed to pollinate the other, the latter bears ears like those shown in center. If a plant grown from a seed in one of the two center groups pollinates a plant grown from a seed in the other, the latter bears ears such as those on the right.

ing followed by crossing offered an entirely new method of improving the yield of corn. In two papers published in 1908 and 1909 he reported his results and outlined a method of corn breeding based upon his discoveries. He proposed the isolation of inbred strains as a first step and the crossing of two such inbred strains as a second. Only the first-generation cross was to be used for seed for crop production, because hybrid vigor is always at its maximum in the first generation. Shull's idea of growing otherwise useless inbred strains of corn solely for later crossing was revolutionary as a method of corn breeding, but it eventually won acceptance and is now the basis that underlies almost the entire hybrid seed-corn enterprise.

However, Shull's suggestion for the second step—the crossing of two weak inbred strains, known as a single cross—proved impractical as a method of seed production. Because the inbred strains are relatively unproductive, hybrid seed obtained in this way is too expensive except for certain special purposes.

The Double Cross

One further major development was needed to make hybrid corn practicable and the great boon to agriculture that it has become. This contribution came from the Connecticut Agricultural Experiment Station by the end of the second decade of this century. The story begins in 1906, when Edward M. East arrived there from the University of Illinois, where he had participated in corn-breeding experiments with some of Beal's former students. At the Connecticut Station, East began a series of studies of the effects of corn inbreeding and crossbreeding which were to continue to this day and yield a great deal of information about corn, including the effects of selection on its chemistry. It was East who called attention to the need for developing a more practical method for producing hybrid seed. It remained for Donald Jones, one of East's students, who assumed charge of the Connecticut experiments in 1915, to invent a method which solved the problem.

Jones' solution was simply to use seed from a double cross instead of a single cross. The double cross, which combines four inbred strains, is a hybrid of two single crosses. For example, two inbred strains, A and B, are combined to produce the single cross A×B. Two additional inbred strains, C and D, are combined to produce a second single cross C×D. All four strains are now brought together in the double cross (A×B) × (C×D). At first glance it may seem paradoxical to solve the problem of hybrid seed production by making three crosses instead of one. But the double cross is actually an ingenious device for making a small amount of scarce single-crossed seed go a long way. Whereas single-crossed seed is produced from undersized ears borne on stunted inbred plants, double-crossed seed is produced on normal-sized ears borne on vigorous single-cross plants. A few bushels of single-crossed seed can be converted in one generation to several thousand bushels of double-crossed seed. The difference in cost of the two kinds of seed is reflected in the units in which they are sold: double-crossed seed is priced by the bushel, single-crossed seed by the thousand seeds. Double-cross hybrids are never as uniform as single crosses, but they may be just as productive or more so.

Jones made a second important contribution to the development of hybrid corn by presenting a genetic interpretation of hybrid vigor. Shull and East had suggested that hybrid vigor was due to some physiological stimulation resulting from hybridity itself. Shull was quite certain that something more than gene action was involved. He thought that part of the stimulation might be derived from the interaction between the male nucleus and the egg cytoplasm. Jones proposed the theory that hybrid vigor is the product of bringing together in the hybrid the favorable genes of both parents. These are usually partly dominant. Thus if one inbred strain has the genes *AA BB cc dd* (to use a greatly oversimplified example), and the other has the genes *aa bb CC DD*, the first-generation hybrid has the genetic constitution, *Aa Bb Cc Dd*. Since the genes

MANY STRAINS OF CORN are tested for their value in hybridization. This photograph shows a field of the De Kalb Agricultural Association of De Kalb, Ill. On it are a number of strains illustrating the evolution of corn.

A, B, C and *D* are assumed not only to have favorable effects but to be partially dominant in their action, the hybrid contains the best genes of both parents and is correspondingly better than either parent. Jones' theory differs from a similar earlier theory in assuming that the genes involved are so numerous that several are borne on the same chromosome and thus tend to be inherited in groups. This explains why vigor is at its maximum in the first generation after crossing, and why it is impossible through selection in later generations to incorporate all of the favorable genes into a new variety as good or better than the first-generation hybrid. The ideal combination *AA DD CC EE,* which combines all of the favorable genes, is impossible to attain because of chromosomal linkage. For example, the genes *B* and *c* may be borne at adjacent loci on the same chromosome and thus be inseparably joined in their inheritance. Although Jones' theory is not universally accepted, and it now seems probable that hybrid vigor involves still other genetic mechanisms, it nevertheless gave great stimulus to practical hybrid corn breeding.

How It Is Produced

Historically, then, hybrid corn was transformed from Shull's magnificent design to the practical reality it now is when Jones' method of seed production made it feasible and his theory of hybrid vigor made it plausible. This combination proved irresistible to even the most conservative agronomists. Soon after 1917 hybrid corn-breeding programs were initiated in many states. By 1933 hybrid corn was in commercial production on a substantial scale, and the U. S. Department of Agriculture had begun to gather statistics on it. By 1950 more than three fourths of the total corn acreage of the U. S., some 65 million acres, was in hybrid corn.

This immense achievement stems from the work of many corn breeders, variously associated with the U. S. Department of Agriculture, state experiment stations and private industry. Among the pioneers in the breeding of corn were Henry A. Wallace, Herbert K. Hayes and Frederick D. Richey.

Hybrid corn is usually produced now by a process that involves three principal steps. To understand them we must consider briefly how corn produces progeny. The corn plant is unique among the major cereals in bearing its male and female flower clusters separately on the same plant. One cluster, the ear, bears only female flowers—several hundred or more enclosed in husks, each with its silk to receive the male pollen. The other, the tassel, bears only male flowers, usually more than a thousand in number. Each male flower contains three anthers, or pollen sacs, and each anther contains about 2,500 pollen grains. A single corn plant sheds several million pollen grains during its flowering period. These are so small and light and so easily carried by the wind that they seldom fall upon the silks of the same plant. As a consequence, under natural conditions cross-pollination is the rule. In experimental or seed-production plots special arrangements are made to control pollination. Experimental pollinations are usually made under bags. The young ears bearing the female flowers are covered with glassine or parchment bags before the silks have appeared. At the same time or a few days later the tassels also are bagged, for the collection of pollen. A single pollination produces an ear bearing several hundred seeds. A single bagged tassel produces enough pollen to pollinate several hundred ears.

The first step in the production of hybrid corn is the isolation of inbred strains. This is still accomplished, as in Shull's and East's experiments, by self-pollination. Hundreds of thousands of self-pollinations in corn are made each year, and tons of paper bags are consumed in the process. The manufacture of special corn-pollinating bags has become a recognized minor industry.

Self-pollination is a form of inbreeding approximately three times as intensive in its effects as matings between brothers and sisters in animals. The same plant is literally both the father and the mother of the offspring. Some plants—wheat, rice, barley and oats, for example—are naturally self-pollinated and suffer no deleterious effects from the process. But corn, a naturally cross-

LONG ROWS OF TASSELS stretch across a single-cross field of the Pioneer Hi-Bred Corn Company of Des Moines, Iowa. The tassels have been removed from two out of three rows; double-cross tassels are farther apart.

pollinated plant, responds to inbreeding with conspicuous effects. First, in the early generations many inherited abnormalities appear—defective seeds, dwarfs, albinos, stripes and a host of other chlorophyll deficiencies. These abnormalities were once supposesd to be the degenerative products of the "unnatural" process of inbreeding, but it is now known that inbreeding merely brings to light deleterious characters already present, which have previously remained hidden because they are recessive traits. Inbreeding actually helps the corn breeder, for it reveals hidden defects and allows the breeder to remove them permanently from his stocks.

After five or six generations of inbreeding the inbred strains have become remarkably uniform, much more uniform than any variety of corn occurring naturally. All the plants of a single strain are genetically identical, or almost so; and their genetic uniformity is reflected in a remarkable uniformity in all perceptible characteristics, physical and physiological. But even the best of these uniform strains yield no more than half as much as the open-pollinated varieties from which they were derived, and many yield much less. Their only value is as potential parents of productive hybrids.

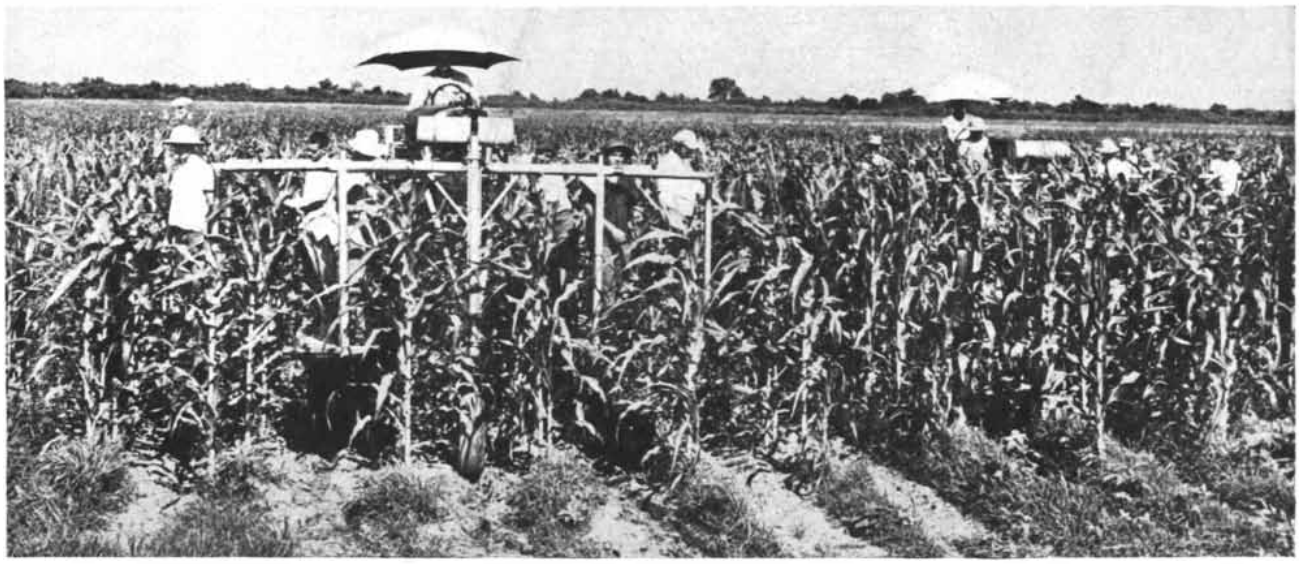
Built-In Characteristics

Inbreeding accompanied by selection has given the corn breeder a remarkable degree of control over corn's heredity. Much of the breeding work today is aimed not only at greater yields but also at improvements in other characteristics. Almost all the corn now grown in the Corn Belt has been bred to possess stiff stalks that remain upright far into the fall—an important quality for mechanical harvesting. Some breeders, shaping the corn to the machines, are developing hybrids bearing two or three small ears instead of a single large one. Resistance to drought was recognized as an important characteristic during the hot dry summers of the 1930s and has been incorporated into many hybrids. Hybrid corn has also been bred for resistance to various diseases. Through selection corn varieties can even be developed to withstand the depredations of insects. Some inbred strains of corn are quite resistant to chinch-bug injury. Others are either unattractive to root worms or survive their assaults. The Southern corn breeder uses corn with long tight husks, which protect the ears against the inroads of ear worms and weevils. Corn breeders in Argentina claim to have isolated lines that contain a bitter substance rendering the foliage unattractive to grasshoppers. This same corn has been used in the U. S. in an attempt to develop new strains possibly resistant to the European corn borer. Strains resistant to corn-borer damage are frequently also unpalatable to aphids.

After inbreeding, the second step in the production of hybrid corn is the testing of the inbred lines in various crossing combinations to determine their hybrid performance. Usually the lines are first screened by crossing all to a common parent—an open-pollinated variety. This comparison allows the corn breeder to eliminate many of the poorer strains. The more promising ones are then tested further in single or double crosses. Of each hundred lines isolated, usually not more than one or two prove satisfactory for use in hybrids.

The final step in producing hybrid seed is to combine the selected strains into commercial hybrids. In sweet corn, especially for canning, where uniformity in the size and shape of the ears is a more important consideration than the cost of the seed, the product is usually a single cross. In field corn the cost of the seed is paramount, so all the seed produced for use is double-crossed. A given amount of land and labor will yield two to three times as much double-crossed seed as single-crossed.

Because the second-generation progeny of a hybrid decline markedly in yield and uniformity disappears, only one crop of corn is grown from the crossed seed. Hence the farmer must buy new hybrid seed each season. The production of hybrid seed corn has become a huge and highly specialized enterprise comparable to the pharmaceutical industry. Hundreds of different hybrids, adapted to a wide variety of soils and climates, are produced. Like



TASSELS ARE PULLED by mechanized hand labor near Vincennes, Ind. Here there are two rows of tassel plants and four rows of plants from which the tassels are removed by workers on a platform moved by tractor.

vaccines and serums, they cannot be identified by their appearance. It is their inherent genetic qualities that distinguish hybrids from one another, and farmers have learned to buy hybrid seed on the basis of these qualities.

The almost universal use of hybrid corn in the U. S., and the prospective wide adoption of it in other parts of the world, is not without its dangers. Chief among these is that farmers as a rule are no longer growing the open-pollinated varieties. These varieties, from which all inbred strains are ultimately derived, may therefore become extinct. Already more than 99 per cent of the corn acreage in several of the Corn Belt states is in hybrid corn; in Iowa it is 100 per cent hybrid. The loss of the original source of breeding material would mean not only that improvement of the present strains would be restricted but that new types of hybrid corn could not be developed to cope with new diseases or insect pests suddenly become rampant. Our corn would also lose the ability to adapt to climatic changes. Open-pollinated varieties of corn, in which cross-pollination is the rule, are admirably contrived for maintaining genetic plasticity and would be capable of surviving rather drastic changes in the environment. Hybrid corn, a small, highly selected sample of the original genetic diversity, has lost this capability.

The U. S. Department of Agriculture, recognizing the danger, has taken steps to maintain the open-pollinated varieties of the Corn Belt. It is also important, however, to preserve the indigenous corn varieties of other parts of the U. S. and of the countries of Latin America. Many of the U. S. varieties had their origin in Mexico, and Mexican corn in turn has ancient affinities with the corn of Central and South America. The indigenous varieties of the countries to our south may one day become of critical importance as sources of new genes to improve, or perhaps even to save, the corn of the U. S. The National Research Council is therefore planning, in cooperation with the Department of Agriculture, the State Department and other agencies, to collect and preserve the native corn varieties in the principal corn-growing countries of this hemisphere.

Future Development

What does the future hold for hybrid corn? To a large extent this will hinge on basic research in corn genetics. Unfortunately new discoveries have not kept pace with practical utilization. Corn breeders, like applied scientists in other fields, have been spending the accumulated capital of theoretical research of the past without taking adequate steps to create new capital. Still unsolved, for example, is the problem of the genetic basis of hybrid vigor, which is clearly of more than academic interest to the practical corn breeder.

Some advances can still be made by the application of present knowledge. Already a trend has begun toward developing highly specialized types of corn for particular purposes. There are special white corn varieties (lacking the pigment carotene) which are used for the manufacture of hominy; a "waxy" corn containing large amounts of the carbohydrate amylopectin has been developed for industrial purposes, including the making of tapioca; for feeding meat-animals breeders have produced a corn with a high protein content. It is possible that corn may be bred with a higher content of the pellagra-preventing vitamins of the B complex, especially niacin, in which corn is now notoriously deficient.

The methods of production no doubt also will be improved. Two techniques for creating uniform strains without prolonged inbreeding are under trial. One is now being tested by Sherret Chase at Iowa State College. This method involves the use of "haploid" plants, which contain only half of the normal number of chromosomes. Such plants occur spontaneously. Haploid plants are weak, often sterile and of no value in themselves. But their chromosomes can be doubled by treatment with the alkaloid colchicine, or they may double spontaneously. When this happens, they produce offspring containing the normal number of chromosomes. Since all the chromosomes come from a single original parental germ cell, plants derived in this way are completely pure for all of their genes and are even more uniform than strains resulting from inbreeding.

A second short-cut method for obtaining uniform strains has been suggested by Charles R. Burnham of the University of Minnesota. By treating seed with X-rays Burnham is attempting to produce an artificial stock of corn in which the chromosomes are broken and so "scrambled" that they will no longer form normal pairs with the chromosomes in normal plants when hybridized with them. Such hybrids, when self-pollinated, should produce three kinds of plants, of which one should have only normal chromosomes and be pure for all of its genes. Plants of the latter kind would be the equivalent of inbred strains.

The operation of detasseling as a prelude to crossing is also destined to be simplified. Detasseling has been called the "peskiest and most expensive" part of producing hybrid seed corn. Each

summer the seed industry must find and train thousands of temporary workers, many of them high-school students, to perform this essential task. One firm alone employs more than 20,000 laborers during the detasseling season, and it has been estimated that on the peak day of the season some 125,000 persons in the U. S. are engaged in removing tassels from corn plants. Many attempts have been made to simplify this operation or eliminate it entirely, but until recently none was notably successful. Now what promises to be a partial solution to the problem has been discovered. It involves a certain form of sterility in corn which prevents the tassels from shedding pollen but which is transmitted only through the seeds. Marcus Rhoades of the University of Illinois has shown that this kind of sterility is inherited not through the chromosomes but through the cytoplasm of the germ cells. Jones and I have found that it can easily be incorporated into any inbred strain of corn by crossing, and that it is an excellent substitute for detasseling. A sterile inbred crossed to a fertile inbred produces a sterile single cross. A sterile single cross grown in a crossing field requires no detasseling. The resulting double cross also is sterile; that is, it produces no pollen. But it can be pollinated by planting it with a certain proportion of a comparable fertile double cross. Another method of obtaining a crop from it is to prevent the double cross from being sterile by incorporating in it an inbred strain carrying fertility-restoring genes. This scheme, which has proved completely successful in Jones' experimental cultures, is the last word in the biological manipulation of the corn plant. It employs hereditary factors in the cytoplasm to make corn sterile when sterility is a distinct asset, and uses hereditary factors on the chromosomes to make it fertile when fertility is essential. Hybrid seed produced in this way is being grown on a commercial scale for the first time in 1951.

Hybrid corn well illustrates the importance of the free interplay of theory and practice. The practical motive of improving corn has played its part, but the development of hybrid corn is due in even greater measure to fundamental research aimed only at increasing theoretical knowledge in genetics. Progress of the kind represented by this development is most likely to occur in a free society where truth is sought for its own sake and where there is no undue emphasis on utilitarian aspects. In the case of hybrid corn breeders actually had to go back before they went forward: the first step, inbreeding, led not to immediate improvement but to a drastic reduction in yield. To avoid having to defend this paradoxical procedure of "advancing backwards," corn breeders sometimes took the precaution of plant-

TASSEL IS REMOVED from "female" plant. Detasseling is one of the biggest jobs in growing hybrid seed. One firm employs 20,000 detasselers a season.

EAR IS BAGGED in an experimental plot. By bagging both the ear and the tassel on a small scale, experimenters can completely control pollination.

FERTILE TASSEL possesses many anthers, the pollen-bearing organs.

STERILE TASSEL has only aborted anthers, therefore sheds no pollen.

ing their experimental plots of stunted inbred corn in out-of-the-way places where the public was not likely to see them.

Impact on Food Supply

Hybrid corn's greatest significance lies in the contributions which it and similar developments in applied genetics can make to the world food supply. What hybrid corn has already accomplished toward this end is illustrated by two dramatic examples. During three war years, 1942 to 1944, the American farmer, though afflicted with an acute labor shortage and unfavorable weather, produced 90 per cent as much corn as he had during the previous four years of peace, themselves years of unprecedented production. In other words, hybrid corn enabled him to add a 20 per cent increase to the previous gains. Thanks to hybrid corn, the U. S. suffered no real food shortages at home, was able to ship vast quantities of food abroad to her Allies, and still had enough surplus grain to use large quantities in the manufacture of alcohol, synthetic rubber, explosives and other materials of war.

At the end of the war the American food surplus served a more peaceful but no less important purpose. In the year ending June 30, 1947, the U. S. shipped to hungry and war-torn Europe 18 million long-tons of food. Very little of this was corn, but the food actually sent represented, in terms of calories, the equivalent of 720 million bushels of corn. In the same year, through the use of hybrid corn, the corn crop of the U. S. had been increased by approximately 800 million bushels. That is, the U. S. gain in this one crop was sufficient to meet Europe's food deficit during the first postwar years, with food to spare.

Hybrid corn has proved to be a catalyst affecting the entire agricultural economy wherever it has touched it. Even the most skeptical farmers, once they have proved to their own satisfaction the superiority of hybrid corn, turn to the experiment stations for other innovations growing out of agricultural research. The higher cost of hybrid seed is an inducement to strive for maximum yields, and in the U. S. this has led to the adoption of improved agricultural practices, including the use of fertilizers, crop rotations and the growing of soil-improving crops of soybeans and other leguminous plants that gather soil-enriching nitrogen from the atmosphere. The result of all this is that the increases in corn yields obtained by American farmers on their own farms have been much larger than in experiment stations. Whereas hybrid corn grown in controlled experiments usually yields about 20 to 30 per cent more than the original open-pollinated corn from which it derives, the average farm yield of corn per acre in the U. S. has increased by about 50 per cent: from about 22 bushels in the early 1930s, when hybrid corn first began to be used commercially, to approximately 33 bushels in the late 1940s, when it occupied some 75 per cent of the total corn acreage. Under favorable conditions, yields of 100 bushels per acre for hybrid corn are common, and yields exceeding 200 bushels are regularly reported. This substantial increase can be attributed to the use of fertilizers and other soil-improvement practices as well as hybrid corn.

The success of hybrid corn in the U. S. promises to be repeated in other parts of the world where corn is an important plant. One of the first countries to benefit is Italy, which fortunately has been able to use hybrids developed in the U. S. Corn hybrids are usually so well "tailored" to a particular environment that it is seldom possible to move them successfully from one country, or even from one region, to another. Italy has proved to be an exception to this rule and is now importing hybrid seed corn from the U. S. on a substantial scale—enough to plant approximately a million acres in 1950.

In the countries of Latin America, in many of which corn is a basic food plant, new hybrids especially adapted to local conditions are being developed. Corn-breeding programs aimed at this objective are in progress in Mexico, Guatemala, El Salvador, Costa Rica, Cuba, Colombia, Venezuela, Brazil, Uruguay, Argentina, Peru and Chile. The corn-breeding program in Mexico, a cooperative project of the Mexican Government and the Rockefeller Foundation, has been particularly successful. Begun in 1943, it has already made itself felt in the Mexican economy; in 1948, for the first time since the Revolution of 1911, Mexico produced enough corn to feed her own population.

To Mexico hybrid corn is perhaps even more important than to the U. S. In the U. S. three fourths of all corn is fed to livestock and is transformed into meat, milk, eggs and other animal products before reaching the ultimate consumer. In Mexico corn is used directly; it is literally the staff of life of millions of people—the daily bread, which, eaten 365 days a year, fuels most of the human metabolism. Corn has an almost sacred significance to the Mexican farmer, as it had to his ancestors for centuries past. It turns out, however, that the Mexican farmer, for all of his inherent conservatism, is, like his American counterpart, willing to try new kinds of corn.

What has been done in corn to utilize the phenomenon of hybrid vigor can be done in any crop plant that lends itself to mass hybridization. Plants of the gourd family are especially easy to hybridize. Like corn, they bear male and female flowers separately on the same

plant. They are therefore easily self-pollinated to produce inbred strains and readily emasculated to effect crossing. Hybrid forms of cucumbers, squashes and watermelons are now grown. Like hybrid corn, they are characterized by vigor, productiveness and uniformity.

Plants in which both the male and female elements occur in the same flower present greater difficulties. In some, like the tomato, whose flower parts are relatively large and whose fruit contains a large number of seeds, hand pollinations to produce hybrid seed are feasible. In other species, such as onions and sugar beets, whose flowers are much too small and delicate to permit emasculation on a commercial scale, forms of cytoplasmic pollen sterility, similar in their effect to that described above for corn, have been used for some years. Since onions and sugar beets are grown for their vegetative parts, the problem of restoring fertility in the final hybrid is not involved. Other crop plants in which hybrid vigor is either being used or tested are alfalfa, barley, rye and sorghum.

Hybridized Animals

Work on the development of hybrid vigor has also been extended to domestic animals. The production of hybrid chickens has already become an enterprise second in importance only to the hybrid seed-corn industry. Hybrid pigs are coming into common use, and hybrid sheep and cattle are well along in the experimental stage. In farm animals the problem of crossing is simple, because the animals are bisexual and can reproduce only by cross-fertilization. But the problem of producing inbred strains is more difficult than in plants. Inbreeding by matings between brothers and sisters—the most intensive form possible in bisexual animals—is only one third as effective as self-pollinations in plants. Since individual animals are more valuable than individual plants, inbreeding on the vast scale on which it is practiced in plants is not yet feasible. The results so far obtained, however, have been very promising. Hybrid chickens grow faster and lay more eggs. Hybrid pigs make more pork with less feed. Hybrid cattle produce more beef in less time. The animal breeder, like the corn breeder, has found hybrid vigor a powerful force to be harnessed in raising the physiological efficiency of organisms.

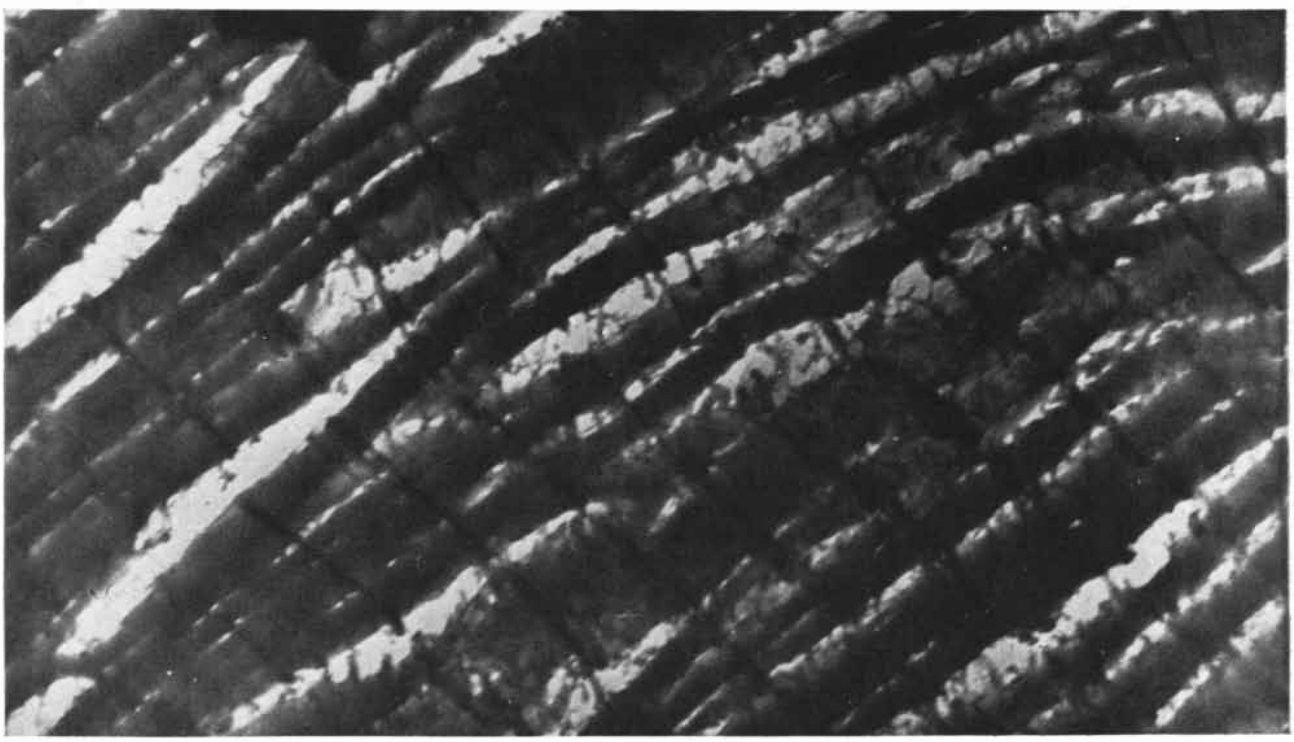
The time is rapidly approaching when the majority of our cultivated plants and domestic animals will be hybrid forms. Hybrid corn has shown the way. Man has only begun to exploit the rich "gifts of hybridity."

Paul C. Mangelsdorf is professor of botany at Harvard University.

FERTILE TASSEL FIELD in Connecticut has had tassels removed from most of its rows. The tasseled rows appear in center and at left and right.

STERILE TASSEL FIELD in Connecticut has tassels on every row. Plants bearing fertile tassels are planted only in the rows where they are needed.

HEART FIBRILS of a mouse run from upper right to lower left in this micrograph. The fibrils are crossed by bands. The granules among the fibrils are enzyme-bearing sarcosomes. Magnification: 10,000 diameters.



ABDOMINAL MUSCLE of a mouse lacks the profusion of sarcosomes found in heart muscle. As in heart muscle, however, the bands crossing the fibrils appear to link them together. Magnification: 10,000 diameters.

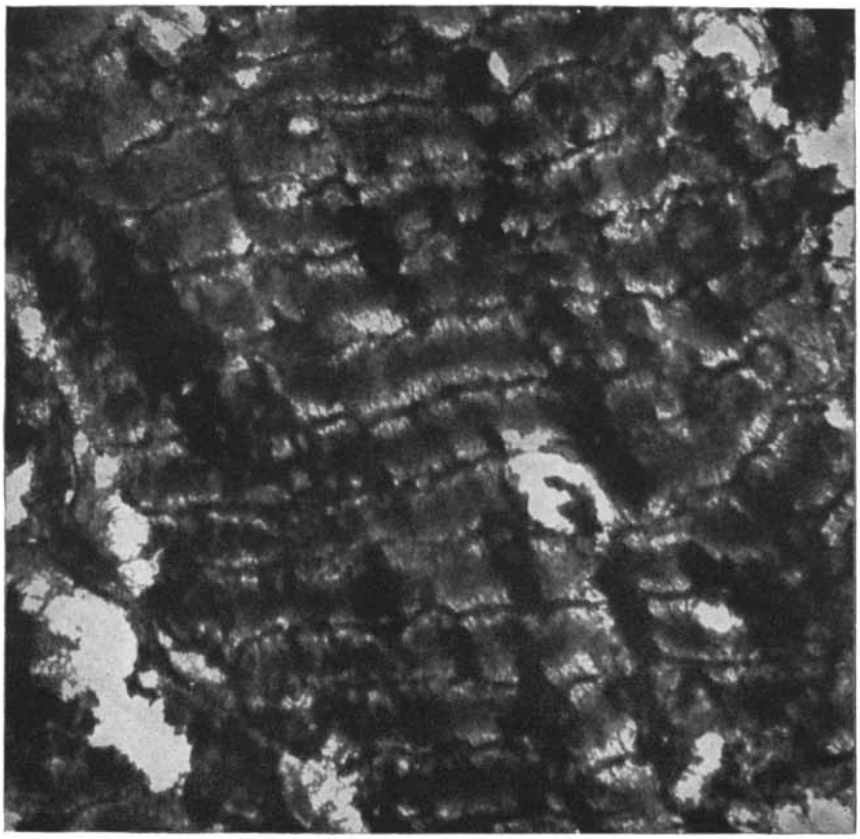
HEART MUSCLE

Structure underlying function is shown by electron micrographs

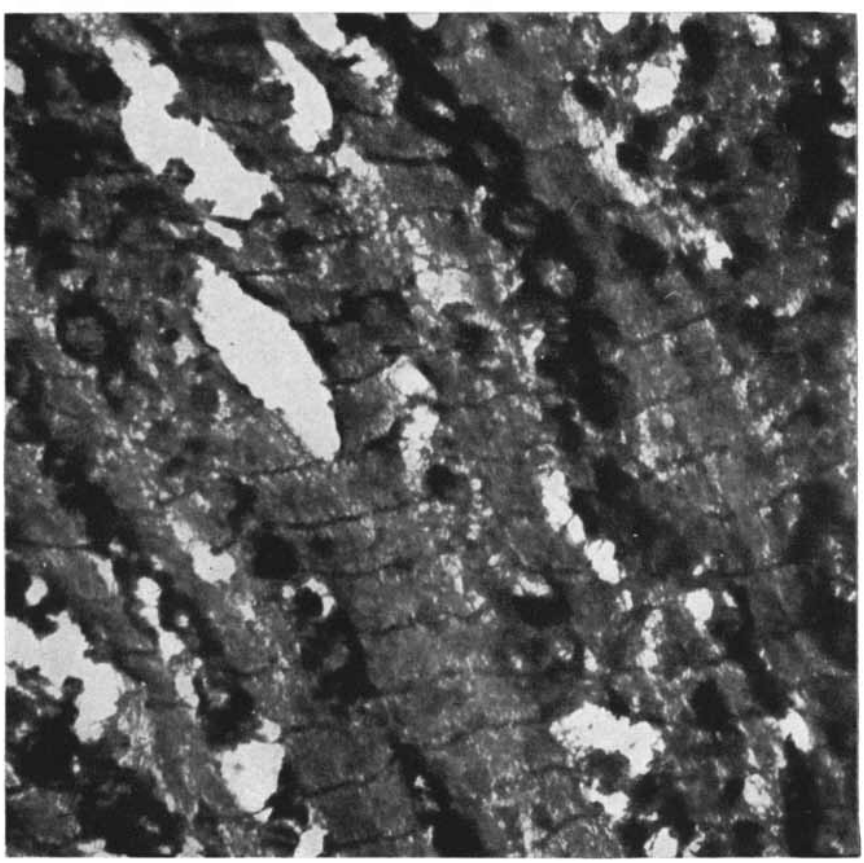
HOW does the heart beat without tiring? This momentous question recently led Bruno Kisch, research associate in cardiology at New York's Mount Sinai Hospital, to make a fundamental study of heart muscle with the electron microscope.

Heart muscle, like other striated muscle, is made up of slender fibers. These in turn are composed of tiny fibrils. At regular intervals the fibrils are crossed by bands. Dr. Kisch's electron micrographs of mouse heart muscle, which were made in collaboration with Joan Bardet of the Interchemical Corp., indicate that the bands connect the fibrils and hold them in place as they contract and relax.

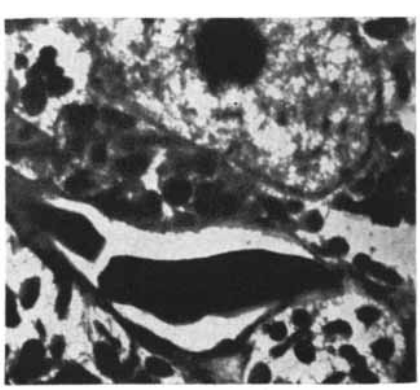
The micrographs also show that heart muscle differs from other muscle in two important respects. The first is that the capillaries that carry blood to the heart muscle actually penetrate the muscle fibers; in other muscle the capillaries have only been observed on the surface of the fibers. The second is that among the fibrils of heart muscle are an unusually large number of small granules called sarcosomes, which in other cells are known to contain enzymes. Dr. Kisch believes that this rich network of capillaries, together with the number and location of the sarcosomes, are the principal reasons why the heart is able to beat a lifetime without resting.



RELAXED heart muscle of a mouse, shown in thin section like the other tissues on these two pages, has transparent areas along the bands that cross fibrils.



CONTRACTED heart muscle lacks transparent areas along the bands crossing the fibrils. The magnification of both micrographs: 10,000 diameters.



CAPILLARY with two red cells penetrates fiber (*bottom*). Top: a nucleus.

Experiments in Perception

Some remarkable optical illusions show that what we perceive does not directly correspond to reality; it is a subtle blend of the external world and the many lessons of our experience

by W. H. Ittelson and F. P. Kilpatrick

WHAT is perception? Why do we see what we see, feel what we feel, hear what we hear? We act in terms of what we perceive; our acts lead to new perceptions; these lead to new acts, and so on in the incredibly complex process that constitutes life. Clearly, then, an understanding of the process by which man becomes aware of himself and his world is basic to any adequate understanding of human behavior. But the problem of explaining how and why we perceive in the way we do is one of the most controversial fields in psychology. We shall describe here some recent experimental work which sheds new light on the problem and points the way to a new theory of perception.

The fact that we see a chair and are then able to go to the place at which we localize it and rest our bodies on a substantial object does not seem particularly amazing or difficult to explain—until we try to explain it. If we accept the prevailing current view that we can never be aware of the world as such, but only of the nervous impulses arising from the impingement of physical forces on sensory receptors, we immediately face the necessity of explaining the correspondence between what we perceive and whatever it is that is there.

An extremely logical, unbeatable—and scientifically useless—answer is simply to say there is no real world, that everything exists in the mind alone. Another approach is to postulate the existence of an external world, to grant that there is some general correspondence between that world and what we perceive and to seek some understandable and useful explanation of why that should be. Most of the prominent theories about perception have grown out of the latter approach. These theories generally agree that even though much of the correspondence may be due to learning, at some basic level there exists an absolute correspondence between what is "out there" and what is in the "mind." But there is a great deal of disagreement concerning the level at which such innately determined correspondence occurs. At one extreme are theorists who believe that the correspondence occurs at the level of simple sensations, such as color, brightness, weight, hardness, and so on, and that out of these sensations are compounded more complex awarenesses, such as the recognition of a pencil or a book. At the other extreme are Gestalt psychologists who feel that complex perceptions such as the form of an object are the result of an inherent relationship between the properties of the thing perceived and the properties of the brain. All these schools seem to agree, however, that there is some perceptual level at which exists absolute objectivity; that is, a one-to-one correspondence between experience and reality.

This belief is basic to current thinking in many fields. It underlies most theorizing concerning the nature of science, including Percy W. Bridgman's attempt to reach final scientific objectivity in the "observable operation." In psychology one is hard put to find an approach to human behavior which departs from this basic premise. But it leads to dichotomies such as organism *v.* environment, subjective *v.* objective. Stimuli or stimulus patterns are treated as though they exist apart from the perceiving organism. Psychologists seek to find mechanical relationships or interactions between the organism and an "objectively defined" environment. They often rule out purposes and values as not belonging in a strictly scientific psychology.

THE experiments to be described here arose from a widespread and growing feeling that such dichotomies are false, and that in practice it is impossible to leave values and purposes out of consideration in scientific observation. The experiments were designed to re-examine some of the basic ideas from which these problems stem.

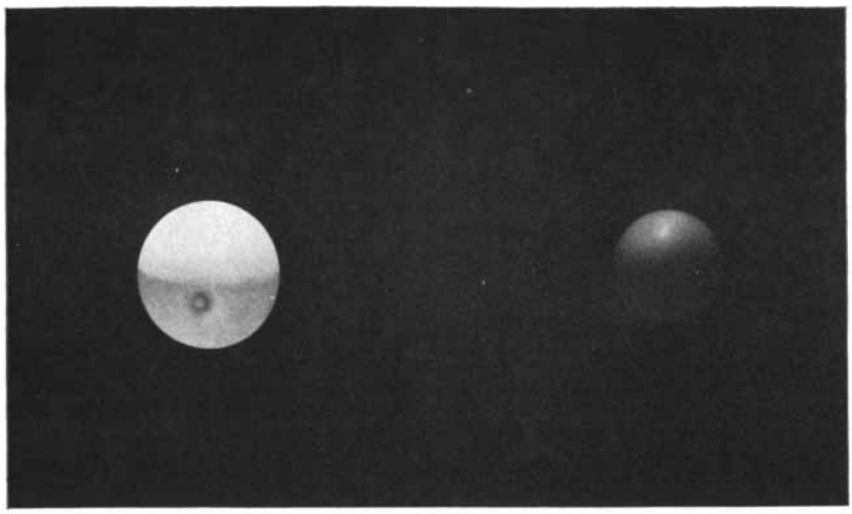
During the past few years Adelbert Ames, Jr., of the Institute for Associated Research in Hanover, N. H., has designed some new ways of studying visual perception. They have resulted in a new conception of the nature of knowing and of observation. This theory neither denies the existence of objects nor proposes that they exist in a given form independently, that is, apart from the perceiving organism. Instead, it suggests that the world each of us knows is a world created in large measure from our experience in dealing with the environment.

Let us illustrate this in specific terms through some of the demonstrations. In one of them the subject sits in a dark room in which he can see only two star points of light. Both are equidistant from the observer, but one is brighter than the other. If the observer closes one eye and keeps his head still, the brighter point of light looks nearer than the dimmer one. Such apparent differences are related not only to brightness but also to direction from the observer. If two points of light of equal brightness are situated near the floor, one about a foot above the other, the upper one will generally be perceived as farther away than the lower one; if they are near the ceiling, the lower one will appear farther away.

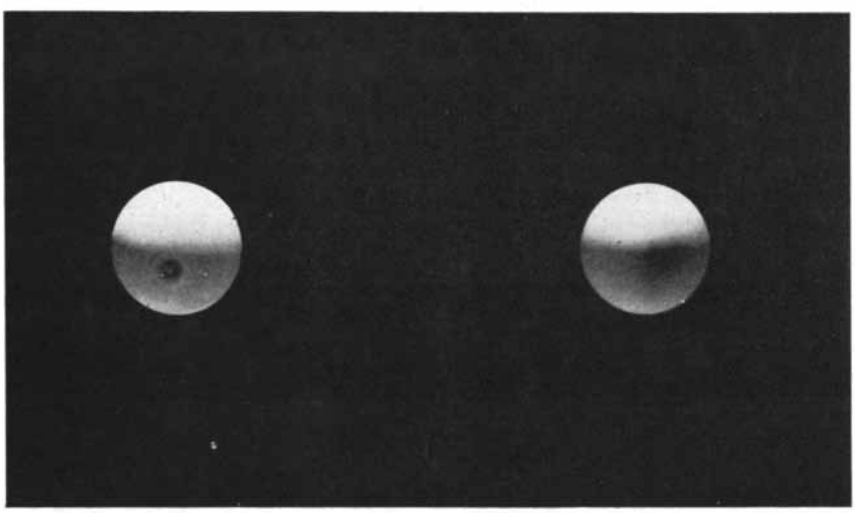
A somewhat more complex experiment uses two partly inflated balloons illuminated from a concealed source. The balloons are in fixed positions about one foot apart. Their relative sizes can be varied by means of a lever control connected to a bellows, and another lever controls their relative brightness. When the size and brightness of both balloons are the same, an observer looking at them with one eye from 10 feet or more sees them as two glowing spheres at equal distances from him. If the brightnesses are left the same and the relative sizes are changed, the larger balloon appears to nearly all observers somewhat nearer. If the size lever is moved continuously, causing continuous variation in the relative size of the balloons, they appear to move dramatically

FIGURES ARE DISTORTED when they are placed in a specially constructed room. The woman at left appears much smaller than the one at right because the mind "bets" that the opposite surfaces of the room are parallel.

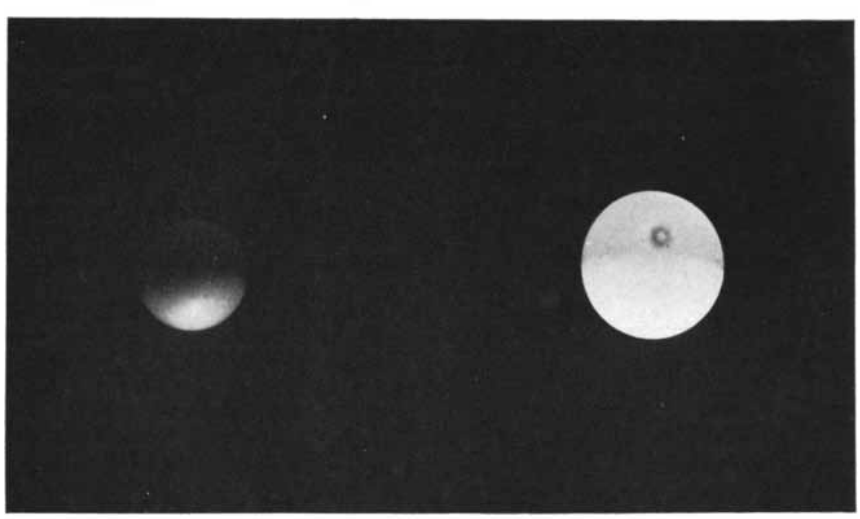
HEADS ARE DISTORTED by the same process. The head of the man at the left appears to be much smaller than the head of the man at the right because the mind assumes that all the windows are the same height.



LEFT BALLOON APPEARS CLOSER because it is larger and brighter than the balloon at the right. Both balloons, however, are at same distance.



BALLOONS APPEAR EQUIDISTANT when they are the same size and brightness. The qualities are manipulated with levers in the demonstration.



RIGHT BALLOON APPEARS CLOSER when it is larger and brighter. The demonstration shows that size and brightness are cues for distance.

back and forth through space, even when the observer watches with both eyes open. The result is similar when the sizes are kept equal and the relative brightness is varied.

With the same apparatus the effects of size and brightness may be combined so that they supplement or conflict with each other. When they supplement each other, the variation in apparent distance is much greater than when either size or brightness alone is varied. When conflict is introduced by varying size and brightness in opposition to each other, the relative change in distance is considerably less than when they act in combination or alone. Most people, however, give more weight to relative size than they give to brightness in judging distance.

THESE phenomena cannot be explained by referring to "reality," because "reality" and perception do not correspond. They cannot be explained by reference to the pattern in the retina of the eye, because for any given retinal pattern there are an infinite number of brightness-size-distance combinations to which that pattern might be related. When faced with such a situation, in which an unlimited number of possibilities can be related to a given retinal pattern, the organism apparently calls upon its previous experiences and assumes that what has been most probable in the past is most probable in the immediate occasion. When presented with two star-points of different brightness, a person unconsciously "bets" or "assumes" that the two points, being similar, are probably identical (*i. e.*, of equal brightness), and therefore that the one which seems brighter must be nearer. Similarly the observed facts in the case of two star-points placed vertically one above the other suggest that when we look down we assume, on the basis of past experience, that objects in the lower part of the visual field are nearer than objects in the upper part; when we look up, we assume the opposite to be true. An analogous explanation can be made of the role of relative size as an indication of relative distance.

Why do the differences in distance seem so much greater when the relative size of two objects is varied continuously than when the size difference is fixed? This phenomenon, too, apparently is based on experience. It is a fairly common experience, though not usual, to find that two similar objects of different sizes are actually the same distance away from us. But it is rare indeed to see two stationary objects at the same distance, one growing larger and the other smaller; almost always in everyday life when we see two identical or nearly identical objects change relative size they are in motion in relation to each other. Hence under the experimental conditions we

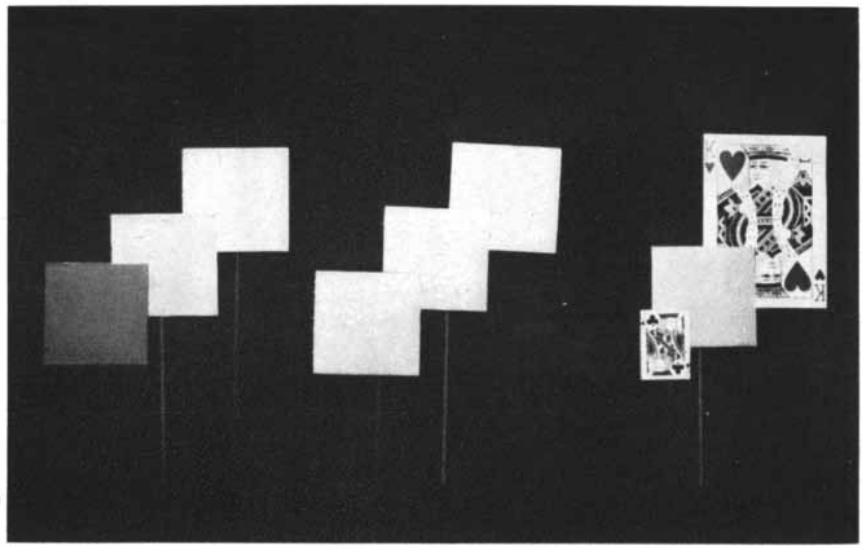
are much more likely to assume distance differences in the objects of changing size than in those of fixed size. In other words, apparently we make use of a weighted average of our past experience in interpreting what we see. It seems that the subject relates to the stimulus pattern a complex, probability-like integration of his past experience with such patterns. Were it not for such integrations, which have been labeled assumptions, the particular perceptual phenomenon would not occur. It follows from this that the resulting perceptions are not absolute revelations of "what is out there" but are in the nature of probabilities or predictions based on past experience. These predictions are not always reliable, as the demonstrations make clear.

VISUAL perception involves an impression not only of *where* an object is but of *what* it is. From the demonstrations already described we may guess that there is a very strong relationship between localization in space ("thereness") and the assignment of objective properties ("thatness"). This relationship can be demonstrated by a cube experiment.

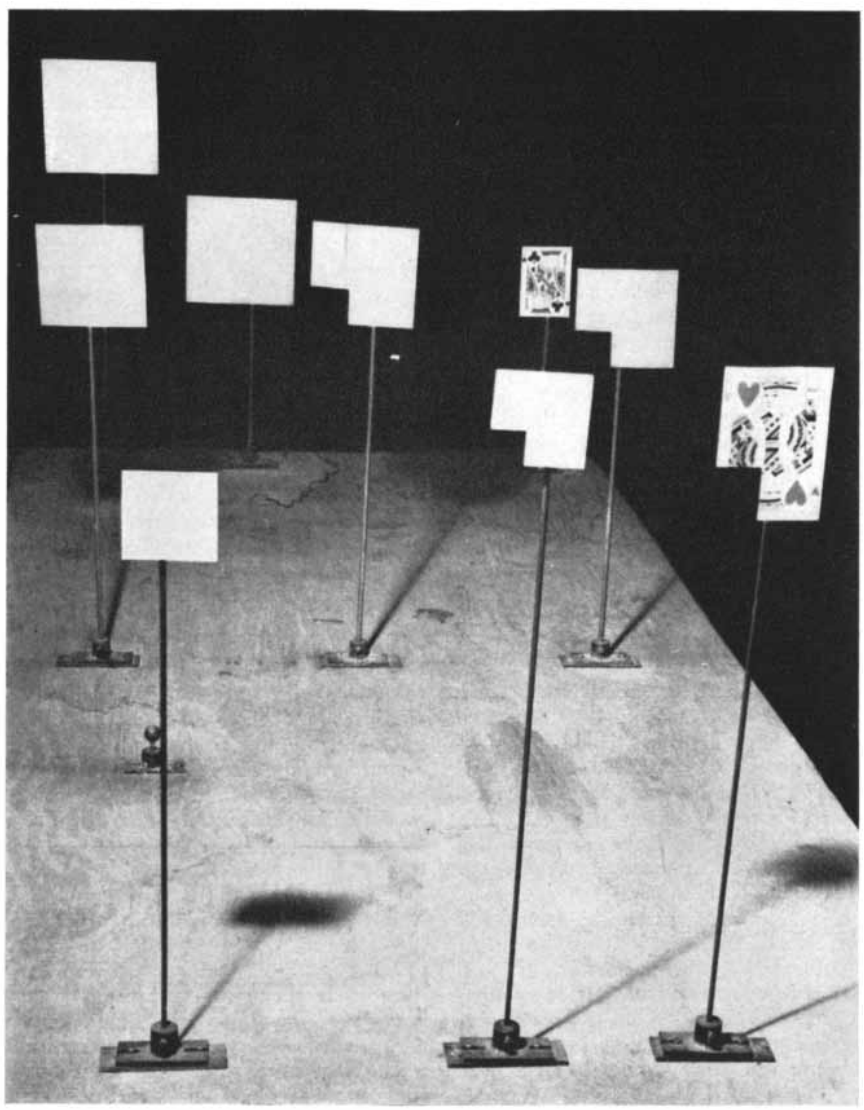
Two solid white cubes are suspended on wires that are painted black so as to be invisible against a black background. One cube is about 3 feet from the observer and the other about 12 feet. The observer's head is in a headrest so positioned that the cubes are almost in line with each other but he can see both, the nearer cube being slightly to the right. A tiny metal shield is then placed a few inches in front of the left eye. It is just big enough to cut off the view of the far cube from the left eye. The result is that the near cube is seen with both eyes and the far cube with just the right eye. Under these conditions the observer can fix the position of the near cube very well, because he has available all the cues that come from the use of the two eyes. But in the case of the far cube seen with only one eye, localization is much more difficult and uncertain.

Now since the two cubes are almost in line visually, a slight movement of the head to the right will cause the inside vertical edges of the cubes to coincide. Such coincidence of edge is strongly related to an assumption of "togetherness." Hence when the subject moves his head in this way, the uncertainly located distant cube appears to have moved forward to a position even with the nearer cube. Under these conditions not only does the mislocated cube appear smaller, but it appears different in shape, that is, no longer cubical, even though the pattern cast by the cube on the retina of the eye has not changed at all.

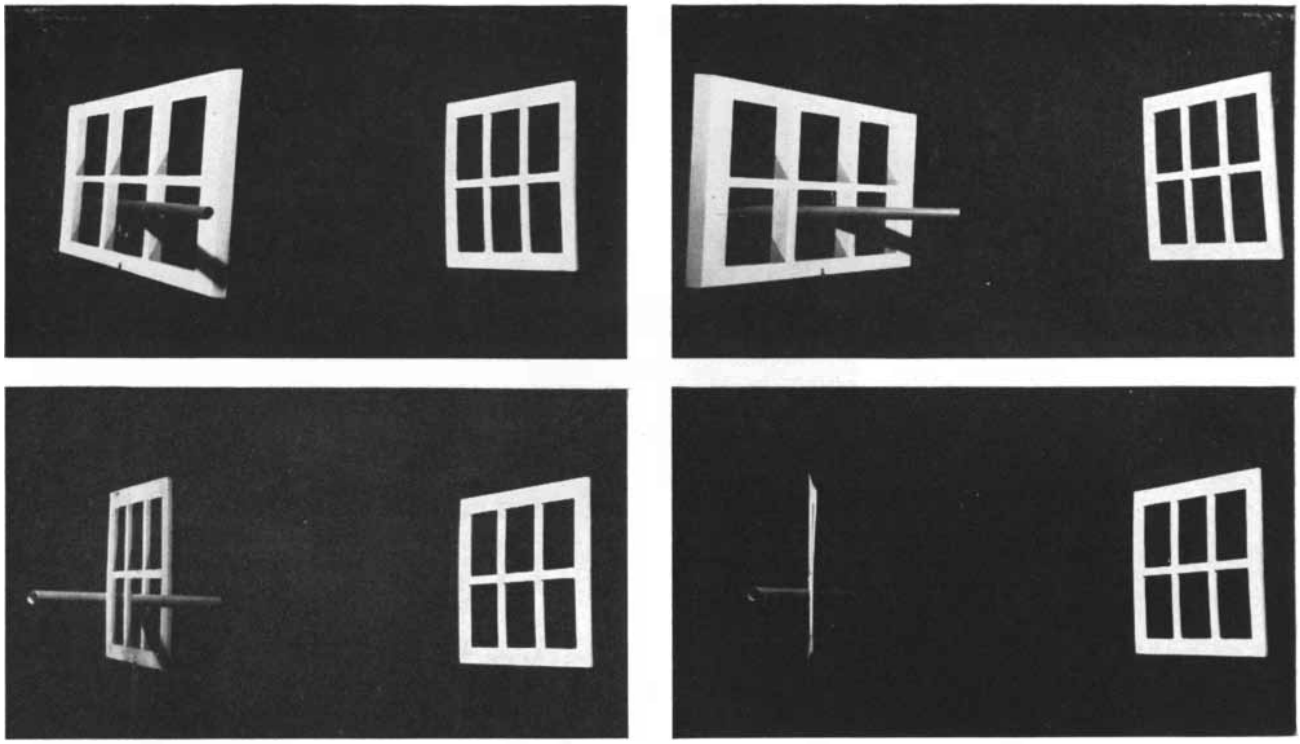
The same point can be illustrated most dramatically by experiments in which the subject wears a pair of glasses



LEFT CARDS APPEAR CLOSER than those at the center and right in each of the three rows in this picture. The illusion is revealed below.



RIGHT CARDS ARE CLOSER in the rows at the center and right. Here the cues are size and the fact that the cards appear to overlap.



PERCEPTION OF MOVING OBJECTS was investigated with a rotating window. At the right in each of the eight pictures on these two pages is a rectangular window; at the left in each picture is a trapezoid painted to

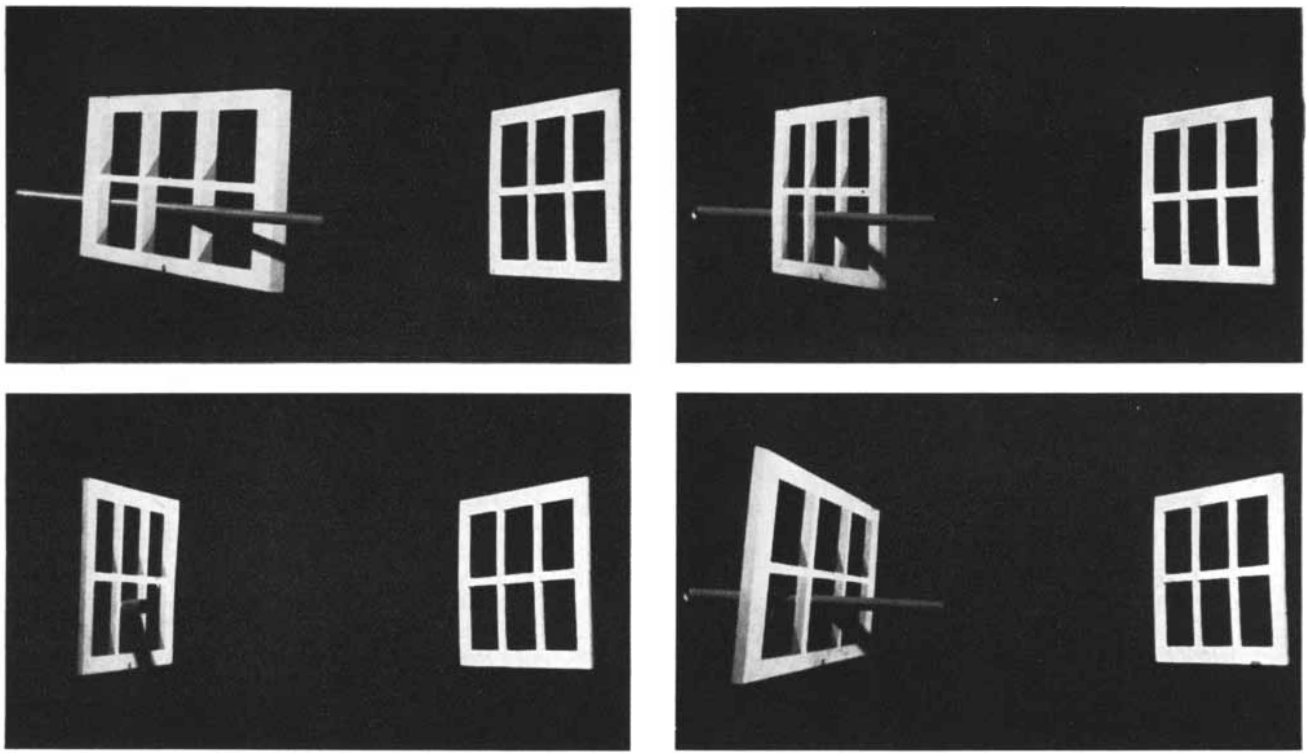
fitted with so-called aniseikonic lenses, which are ground in such a way that they give images of different size and shape to the two retinas. This produces very marked distortions of any objects which the subject visualizes mainly through the use of two-eyed stereoscopic vision. In an ordinary environment there are generally enough one-eye cues, such as shadow, overlay, familiar objects of known size, and so on, to suppress the binocular cues and hold the visual world "in shape." But in an environment poor in one-eye cues the observer is forced to rely on binocular cues, and under these circumstances the distortion is enhanced for anyone wearing such glasses. It has been found that if an ordinary square room is lined with tree leaves, which reduce monocular cues to a minimum by covering the flat wall spaces, most observers looking through aniseikonic lenses perceive a great deal of distortion of the room and the leaves. To an observer looking at the room as a whole through certain glasses of this type the walls appear to slant inward from floor to ceiling, the ceiling seems much lower than it is and its leaves look very small. The floor, which is the object of interest in this particular analysis, appears to be much farther away than its true position, and the leaves covering it look huge. Now, if the observer wearing the same glasses looks at just the floor instead of the room in general, the floor changes markedly in appearance. It appears to be much nearer than before, and instead of being level it seems to rise from front to back at a pitch of about 45 degrees. The leaves, however, now look more nearly normal in size.

THESE perceptions can be explained in terms of the geometry of stereoscopic vision. The stimulus patterns on the retinas of the eyes are the geometric projections of an external surface. But identical projections may be produced by surfaces of different kinds. In this case a distant surface that is nearly horizontal, a closer surface that is slightly tipped and a very near surface that is sharply tipped all produce the same steroscopic stimulus patterns. When the observer looks at the whole room, he "chooses" the nearly horizontal faraway floor surface as the focus of perception, probably because he cannot make a room out of the pattern if the floor is sharply tipped up. When he limits his gaze to the floor, he no longer needs to make a room of what he is looking at, and he sees the floor sharply tipped, perhaps because the leaves now appear more nearly the size he assumes them to be.

In the everyday environment outside the laboratory the wearing of these glasses produces similarly interesting illusions. For example, a large body of water such as a lake appears horizontal and farther away than its real position, but a large expanse of level lawn looks tipped and nearer than its real position. Presumably this happens because the observer brings to these occasions the assumptions, based on past experience, that the probability of a lake surface being other than horizontal is almost zero, while the probability of a grass surface being a slope is fairly high.

The most reasonable explanation of these visual phenomena seems to be that an observer unconsciously relates to the stimulus pattern some sort of weighted average of the past consequences of acting with respect to that pattern. The particular perception "chosen" is the one that has the best predictive value, on the basis of previous experience, for action in carrying out the purposes of the organism. From this one may make two rather crucial deductions: 1) an unfamiliar external configuration which yields the same retinal pattern as one the observer is accustomed to deal with will be perceived as the familiar configuration; 2) when the observer acts on his interpretation of the unfamiliar configuration and finds that he is wrong, his perception will change even though the retinal pattern is unchanged.

Let us illustrate with some actual demonstrations. If an observer in a dark room looks with one eye at two lines of light which are at the same distance and elevation but of different lengths, the longer line will look nearer than the shorter one. Apparently he assumes that the lines are identical and translates the difference in length into a difference in position. If the observer takes a wand with a luminous tip and tries to touch first one line and then the other, he will be unable to do so at first. After repeated practice, however, he can learn to touch



look like a rectangular window seen in perspective. When the trapezoid rotates, the assumption that it is rectangular causes a straight tube to do strange things. The sequence reads horizontally across the two pages.

the two lines quickly and accurately. At this point he no longer sees the lines as at different distances; they now look, as they are, the same distance from him. He originally assumed that the two lines were the same length because that seemed the best bet under the circumstances. After he had tested this assumption by purposive action, he shifted to the assumption, less probable in terms of past experience but still possible, that the lines were at the same distance but of different lengths. As his assumption changed, perception did also.

THERE is another experiment that demonstrates these points even more convincingly. It uses a distorted room in which the floor slopes up to the right of the observer, the rear wall recedes from right to left and the windows are of different sizes and trapezoidal in shape. When an observer looks at this room with one eye from a certain point, the room appears completely normal, as if the floor were level, the rear wall at right angles to the line of sight and the windows rectangular and of the same size. Presumably the observer chooses this particular appearance instead of some other because of the assumptions he brings to the occasion. If he now takes a long stick and tries to touch the various parts of the room, he will be unsuccessful, even though he has gone into the situation knowing the true shape of the room. With practice, however, he becomes more and more successful in touching what he wants to touch with the stick. More important, he sees the room more and more in its true shape, even though the stimulus pattern on his retina has remained unchanged.

By means of a piece of apparatus called the "rotating trapezoidal window" it has been possible to extend the investigation to complex perceptual situations involving movement. This device consists of a trapezoidal surface with panes cut in it and shadows painted on it to give the appearance of a window. It is mounted on a rod connected to a motor so that it rotates at a slow constant speed in an upright position about its own axis. When an observer views the rotating surface with one eye from about 10 feet or more or with both eyes from about 25 feet or more, he sees not a rotating trapezoid but an oscillating rectangle. Its speed of movement and its shape appear to vary markedly as it turns. If a small cube is attached by a short rod to the upper part of the short side of the trapezoid, it seems to become detached, sail freely around the front of the trapezoid and attach itself again as the apparatus rotates.

ALL these experiments, and many more that have been made, suggest strongly that perception is never a sure thing, never an absolute revelation of "what is." Rather, what we see is a prediction—our own personal construction designed to give us the best possible bet for carrying out our purposes in action. We make these bets on the basis of our past experience. When we have a great deal of relevant and consistent experience to relate to stimulus patterns, the probability of success of our prediction (perception) as a guide to action is extremely high, and we tend to have a feeling of surety. When our experience is limited or inconsistent, the reverse holds true. According to the new theory of perception developed from the demonstrations we have described, perception is a functional affair based on action, experience and probability. The thing perceived is an inseparable part of the function of perceiving, which in turn includes all aspects of the total process of living. This view differs from the old rival theories: the thing perceived is neither just a figment of the mind nor an innately determined absolute revelation of a reality postulated to exist apart from the perceiving organism. Object and percept are part and parcel of the same thing.

This conclusion of course has far-reaching implications for many areas of study, for some assumption as to what perception is must underly any philosophy or comprehensive theory of psychology, of science or of knowledge in general. Although the particular investigations involved here are restricted to visual perception, this is only a vehicle which carries us into a basic inquiry of much wider significance.

W. H. Ittelson and F. P. Kilpatrick are instructors in the department of psychology at Princeton University.

Sickle-Cell Anemia

A hereditary disease in which some of the red blood cells are shaped like crescents instead of disks has been traced to a defect in the molecule of hemoglobin

by George W. Gray

A NUMBER of years ago a West Indian Negro youth who was enrolled in an Illinois professional school came to a Chicago hospital complaining of fever, a cough, dizziness and a headache. He showed the scars of recent ulcers on his ankles. The attending physician, James B. Herrick, put the patient through a comprehensive examination and reviewed his history exhaustively, but was not able to identify the illness.

He observed a peculiarity in the blood, however, and described it as follows: "The shape of the red cells was very irregular, and what especially attracted attention was the large number of thin, elongated, sickle-shaped and crescent-shaped forms."

The odd shapes were found repeatedly in blood taken from the patient. Herrick was unable to find such cells in other persons whose blood he examined. He concluded: "The question of diagnosis must remain an open one unless reports of other similar cases with the same peculiar blood-picture shall clear up this feature."

That was in 1910. Herrick recorded the strange and striking phenomenon he had observed in the *Archives of Internal Medicine*. The following year a Virginia physician reported a similar case. And four years later a mulatto woman came to the Washington University Hospital in St. Louis for treatment of a leg ulcer, and again the blood showed the presence of numerous sickle cells. These three cases put doctors on the alert to watch for the abnormal shapes in blood. It soon appeared that the condition was hereditary and occurred almost exclusively in Negroes.

Statistical studies now show that some eight per cent of the U. S. Negro population, about one million persons, carry sickle-shaped red cells in their blood. Fortunately the great majority of the one million possess less than one per cent of sickle cells, and they suffer no ill effects. Apparently the abnormality of one cell in a hundred is not sufficient to cause noticeable impairment of blood function. These persons, in whom the tendency to produce sickle cells is present but not predominant, are said to have "sicklemia."

But in some carriers of the trait the proportion of sickle cells is very much higher—as much as 30 to 60 per cent of all the red cells. These persons become definitely ill, for the sickle cells have a higher-than-normal tendency to break down, which reduces the number of red cells in circulation and produces anemia, sometimes fatal. About one in 40 of those who have the sickle-cell trait (*i.e.*, some 25,000 persons in the U.S.) possess it in the exaggerated degree which leads to sickle-cell anemia. Because the trait is hereditary, this number may be expected to increase.

STUDIES of sickle-cell anemia have been made at several medical schools since the discovery of the disease in 1910. The hereditary nature of the disease was first pointed out by J. S. Huck of the Johns Hopkins University. He suggested that the tendency to sickle was inherited by the patient according to Mendelian law. It was Victor E. Emmel of the University of Illinois Medical School who first recognized the distinction between the harmless form of the sickle-cell trait and sickle-cell anemia. He also demonstrated that red cells of normal disk shape would assume the sickle form under certain conditions. This suggested that the behavior was a dynamic property of cells. They appeared normal when launched into the bloodstream, but later took on the crescent shape.

At the Indiana University Medical School E. V. Hahn and E. B. Gillespie found that the sickling behavior was reversible, depending on the pressure of oxygen and the degree of acidity or alkalinity of the blood. It was their idea that sickling followed the cell's release of its oxygen, and that when it took on another cargo of oxygen the cell resumed its normal disklike form. This hypothesis was given further weight by the discovery that even when the venous blood of an anemic patient teemed with sickle cells, the oxygen-loaded blood in the arteries rarely contained such cells. But no one was able to explain why some cells assumed the misshapen form and how the absence of oxygen promoted this suicidal behavior.

Everyone knew that the ability of red cells to pick up oxygen from the lungs, transport it through the arterial circulation and release it to the parts that need it is made possible by the presence in the cells of a protein compound, hemoglobin. Indeed, the red cell is essentially a bag full of hemoglobin molecules. It is hemoglobin that gives blood its color, for some 100 million red hemoglobin molecules are packed within a red cell's enclosing membrane. Each hemoglobin molecule can attach to itself only one of oxygen. The normal red cell has a shape that facilitates oxygen's access to the molecules: it is shaped like a doughnut with a thin membrane across the hole. This is nature's invention to ensure a large transport of oxygen. The sickling action twists and distends the membrane into a shape which impairs its efficiency and increases its vulnerability to damage.

The question was, how does it do this? To identify the mechanism of sickling became the basic problem in understanding the disease.

LINUS PAULING, professor of chemistry at the California Institute of Technology, first heard of sickle-cell anemia in 1945. He had been called to serve on a national committee appointed at the request of President Roosevelt to review problems and prospects for the advancement of medicine. One of the other eight members of the committee brought up the subject of sickle-cell anemia and described its symptoms. As soon as Pauling heard that the sickle cells were found in venous blood but not in arterial, it occurred to him that the fault might lie with molecules rather than with the cell as a whole. The only parts of the cell concerned with the attachment of oxygen were the hemoglobin molecules, and inasmuch as the cells sickled only after being relieved of their oxygen, he thought it reasonable

to look to these molecules for the secret of the abnormality.

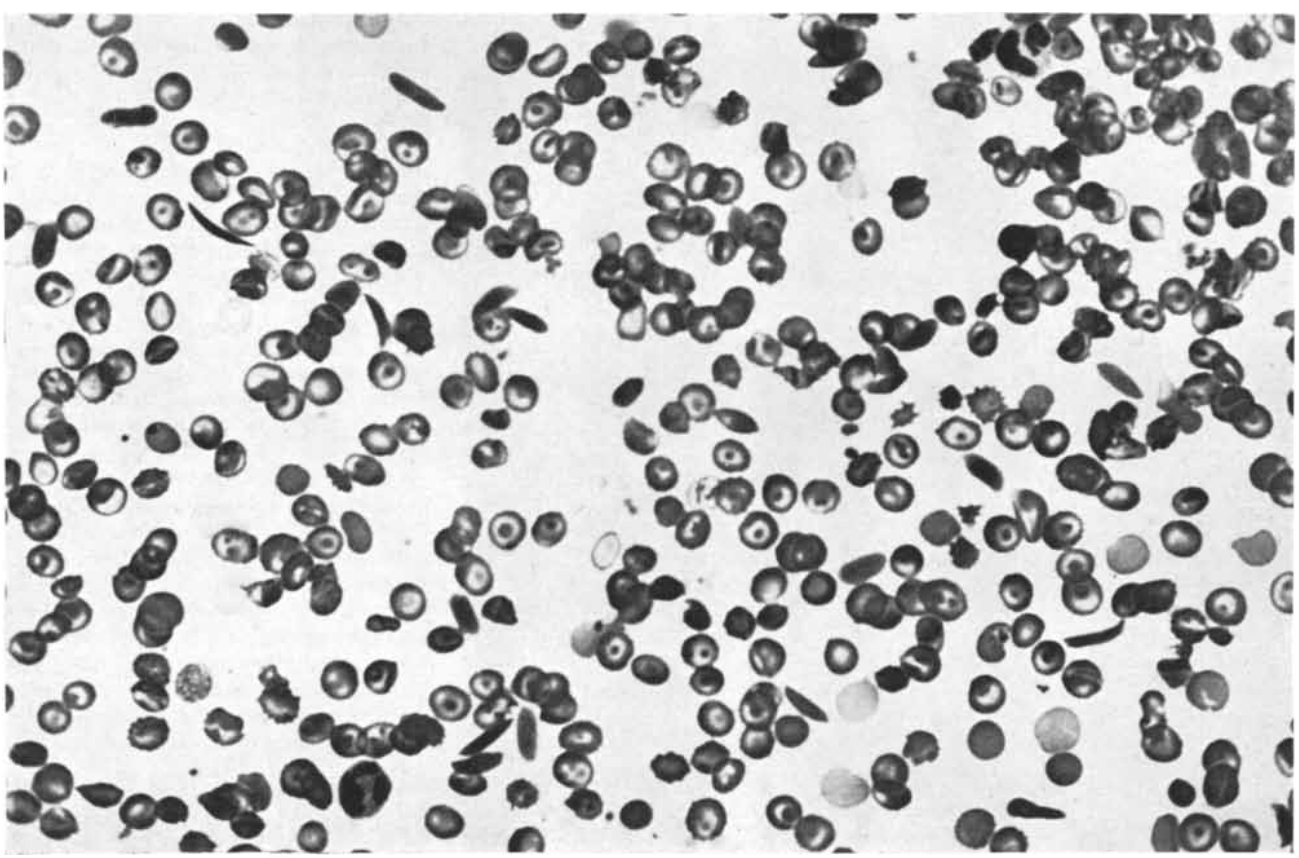
It was perhaps natural that a chemist should think of the behavior as chemical rather than biological—though at the molecular level one wonders where biology begins and chemistry leaves off. At all events, Pauling resolved to explore the subject, and as soon as he got back to Pasadena he started an experiment to test his hypothesis.

He enlisted three younger collaborators: Harvey A. Itano, Samuel J. Singer and Ibert C. Wells. Blood was obtained from 15 patients with sickle-cell anemia, from eight who carried the sickle-cell trait but had no anemia and from seven normal adults. The experimenters extracted hemoglobin from the red cells of each specimen and began a series of physical and chemical tests to see if the molecules from the three sources differed in any particular.

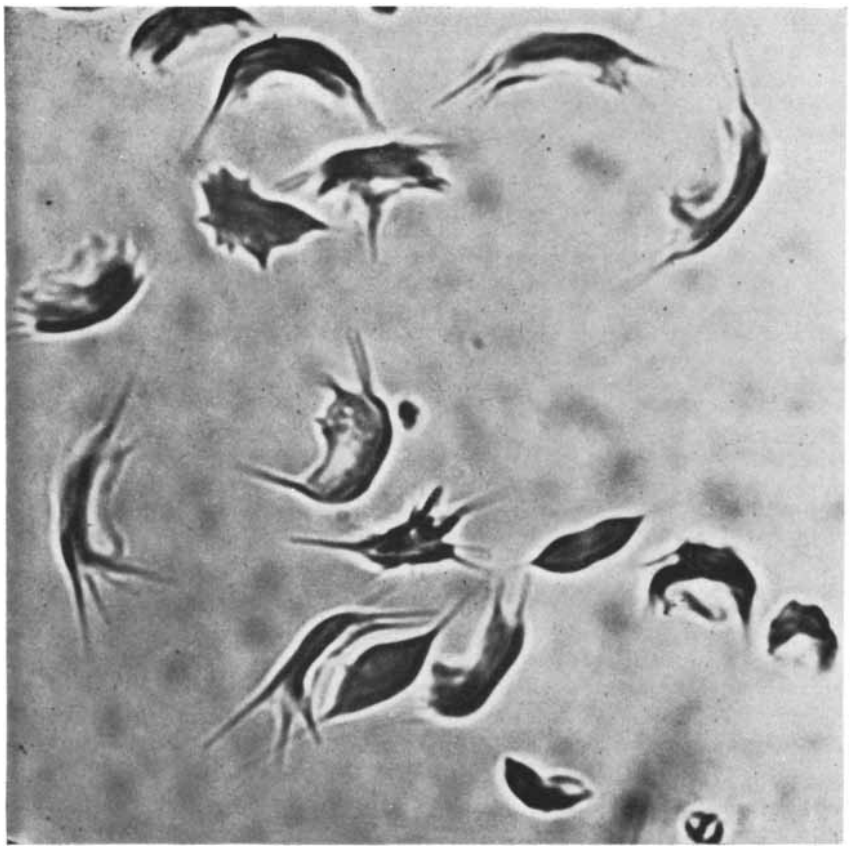
First they tried to find out whether the molecules differed in weight. But tests in the ultracentrifuge and by diffusion in a liquid showed that all three types of molecules were of about the same weight and size. Next the experimenters subjected their hemoglobin specimens to analysis in an electrophoresis apparatus, which measures the surface electrical charges on molecules. Tests were made at various degrees of acidity and alkalinity, and finally a level was reached at which the results were rewarding—and exciting. For when a current of electricity was passed through the solution at this ionic concentration, the normal hemoglobin molecules moved toward the positive electrode while the molecules taken from the sickle cells traveled in the opposite direction. This difference between the electrical responses of the two was spectacular. "We can describe the difference by saying that the anemic molecule carries more positive charges than the normal, or that the normal carries more negative charges than the anemic," says Pauling. "At present we do not know which description is the better."

The number, distribution and nature of the electric charges on a molecule tell the chemist something about its structure and affinity for other molecules. In the case of the anemic hemoglobin, Pauling knew that a molecule charged in the way indicated by the experiment would be endowed with high chemical affinity, and he was led by the evidence to visualize it as a self-complementary structure. "I believe," he explains, "that one end of the molecule is able to form a bond with the opposite end of another hemoglobin molecule. Under these circumstances, the molecules clamp on to one another to undergo a sort of pseudo-crystallization, which then twists the red cell out of shape." Pauling suggests that sickle-shaped cells are absent from arterial blood because the attachment of an oxygen molecule to each hemoglobin molecule in this phase prevents the affinity of hemoglobin for hemoglobin from asserting itself.

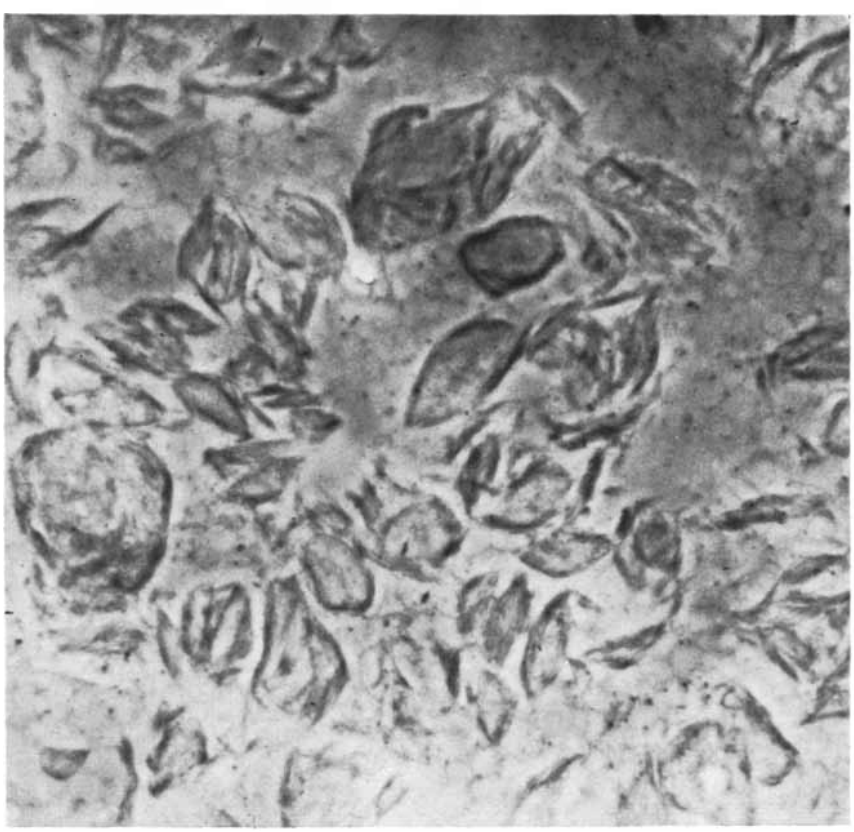
INASMUCH as hemoglobin, like all proteins, is made of chains of amino acids, a group in Pauling's laboratory undertook an analysis to see whether there was any difference in the amino acids of the two kinds of hemoglobin. This work was done by Wells in association with W. A. Schroeder and Lois M. Kay. Seventeen different amino acids are built into normal hemoglobin, and they found that all 17 were also present in sickle-cell hemoglobin. However, there are indications that the sickle-cell molecule contains slightly less of the amino acids leucine and valine and slightly more of serine and threonine than the normal hemoglobin molecule. It is admitted that these differences in themselves cannot contribute directly to differences in the net electric charge on the molecules, but they may affect the folding or coiling of the amino-acid chains of which the molecules are made and in this way either bring charged groups into play or remove them from action. Such influences could affect the electrophoretic behavior of the hemo-



NORMAL AND SICKLED CELLS appear in a photomicrograph of the blood of a person suffering from a mild form of sickle-cell anemia. The disk-shaped normal cells predominate, but the sickle cells appear throughout.



CELLS SICKLED by oxygen lack were photographed by phase microscopy in laboratory of John W. Harris at Thorndike Memorial Hospital in Boston.



LIQUID CRYSTALS FORMED when hemoglobin from sickle cells was allowed to stand. This suggests that defect of molecules allows them to join.

globin and account for the Pauling picture of the molecule.

Additional evidence which seems to support the Pauling picture was turned up by John W. Harris in the course of studies at the Thorndike Memorial Hospital in Boston. Harris took hemoglobin from sickle cells and concentrated it in a 10 per cent solution. He found that after standing awhile, the mass formed liquid crystals. The molecules joined together not merely by twos but apparently in long chains. These chains of hemoglobin molecules assumed a rigidity which could easily distort a red cell into the sickle shape.

The Caltech researchers found that in persons who have only a few sickle cells (sicklemia) only half of the hemoglobin molecules are defective. It is believed that in these cells the normal molecules resist the coupling tendency of the abnormal ones; thus fewer of the long structures are formed.

IN 1950 Dr. Itano of the Pauling group and James V. Neel of the University of Michigan Heredity Clinic turned up a third, in-between form of the trait in which the victims have milder than usual symptoms of sickle-cell anemia. These persons carry in their red cells not only the abnormal hemoglobin that is characteristic of sickle-cell anemia but also an entirely new component. The new component is red and has the chemical characteristics of hemoglobin, but when placed in the electrophoretic stream it migrates as a more positive ion than either normal hemoglobin or sickle-cell hemoglobin.

Cases of the mild anemia have been found in only two families, living in Ann Arbor, Mich. When electrophoretic studies were made of both parents and children, some interesting combinations showed up. In Family A, for example, the father's blood contained about 65 per cent normal hemoglobin and about 35 per cent of the new component, which we may call x-hemoglobin. The mother's blood contained 66½ per cent normal and 33½ per cent sickle-cell hemoglobin. Their child, who had the disease, assayed 13 per cent normal, 39 per cent sickle-cell and 48 per cent x-hemoglobin.

In Family B the father had about 70 per cent normal and 30 per cent x-hemoglobin; the mother had 69 per cent normal and 31 per cent sickle-cell hemoglobin; their diseased daughter had 47 per cent sickle-cell and 53 per cent x-hemoglobin, and their diseased son had 50 per cent sickle-cell and 50 per cent x-hemoglobin.

It appears that the presence of the x-hemoglobin may have a moderating effect on sickle-cell hemoglobin, though it is not able to neutralize the latter molecules to the extent that normal molecules do. Hence when the content

of the red cells is about evenly divided between sickle-cell hemoglobin and x-hemoglobin, the resulting condition is a mild form of the disease involving only a moderate amount of sickling. When it is evenly divided between sickle-cell and normal hemoglobin, the effect is the recessive condition known as sicklemia. But when the great majority of the molecules are sickle-cell, the effect is an out-and-out case of the crippling anemia. These inferences are only tentative, however; more evidence is needed.

Apparently the anemia victim inherits the sickle-cell trait from both parents. He therefore has two genes which call for sickling, and the only hemoglobin he is able to produce is the defective kind. In the case of the sicklemia individual, the sickling trait is inherited from only one parent. The child has one gene for normal hemoglobin and one for sickle-cell hemoglobin; as a result his system produces red cells which are packed with about a 50-50 distribution of normals and abnormals. In the case of victims of the mild form of the anemia, it would seem that the patient inherits a gene for sickle-cell hemoglobin from one parent and a gene for x-hemoglobin from the other; his body therefore synthesizes both kinds of abnormal hemoglobin and packs them into his red cells.

The great mass of human beings, having neither gene defective, naturally produce only normal hemoglobin. Incidentally, the study at Caltech showed that the hemoglobins of normal adult white and Negro individuals were indistinguishable.

THIS tracing of human disease back to its source in a diseased molecule may carry far-reaching implications for medicine—both in sharpening man's knowledge of pathological processes and in suggesting methods of treatment. It is conceivable, for example, that chemists may be able to devise a small, innocuous molecule which will lock permanently on to the defective hemoglobin and prevent the abnormal molecule from misbehaving, without interfering with its transport of oxygen. This would involve making use of a chemical mechanism similar to the antibody reaction.

An even more important outcome of these studies, however, is the remarkably clear evidence it has given that life is basically an affair of molecules. It is significant that the detective who tracked sickle-cell anemia down to its lair was a physical chemist, and the chief instrument of his research was that versatile tool of physical chemistry—the electrophoresis apparatus.

George W. Gray, a member of the staff of the Rockefeller Foundation, is a writer who has contributed many articles to this magazine.

A Machine That Learns

Concerning Machina docilis, descendant of Machina speculatrix, the small imitation of life that was described in the May, 1950, issue of this magazine

by W. Grey Walter

THIS ARTICLE is a sequel to one published here last year which described experiments with a simple little machine designed to mimic certain elementary features of animal behavior ("An Imitation of Life," SCIENTIFIC AMERICAN, May, 1950). Consisting only of two vacuum tubes, two motors, a photoelectric cell and a touch contact, all enclosed in a tortoise-shaped shell, the model was a species of artificial creature which could explore its surroundings and seek out favorable conditions. It was named *Machina speculatrix*. Although it possessed just three simple characteristics—the properties of being attracted to moderate light and repelled by bright light or by material obstacles—*M. speculatrix* displayed complex and unpredictable habits of behavior, resembling in some ways the random variability, or "free will," of an animal's responses to stimuli. But its responses were in no way modified by experience; in other words, it lacked the power to learn.

We have gone on from that early model to the design of a more advanced mechanical creature which does possess the ability to learn. The present report will describe this new creature, named *M. docilis* from the Latin word meaning teachable.

The mechanism of learning is of course one of the most enthralling and baffling mysteries in the field of biology. In its simplest experimental form modification of behavior by experience is often called "conditioning," a term suggested by the Russian physiologist I. P. Pavlov, whose original experiments on "conditioned reflexes" brought the study of higher nervous function into the realm of brain physiology. The basic event in this form of learning is that an unrelated stimulus, when repeatedly coupled with one that evokes a certain response, comes to acquire the meaning of the original stimulus. In the classical experiments on animals the activity used as the basis for conditioning was a simple reflex—the flow of saliva when food enters the mouth, or the withdrawal of a leg when a painful stimulus is given to the foot. The food or the pain is called the unconditioned, or specific, stimulus. The conditioned, or neutral, stimulus to which the animal is trained to respond with the same behavior can be any event to which the animal is sensitive: a light, a sound, a touch—anything at all. If, for example, a bell is rung on 10 or 20 occasions just as food is offered, the flow of saliva, which originally occurred only at the sight of the food, eventually is conditioned to begin as soon as the bell is rung. After about 20 more repetitions the bell alone, without the presence of food, evokes almost as copious a flow of saliva as does the food itself. One may say that the bell comes to "mean" food.

SUCH learning is of course perfectly familiar in ourselves and is the basis of all animal training. Indeed it has been argued that all learning is based on conditioning, for any bodily function can be made the basis of a conditioned reflex, and one conditioned reflex can be built on another. Even quite unconscious changes, such as quickening of the pulse, dilation of the pupils, a rise in blood sugar or a fall in temperature, can be "conditioned" to some previously neutral stimulus by mere repetition. In this way it is possible to obtain control over functions originally quite involuntary. A man can "learn" to slow his pulse, flush, go pale, secrete sugar in his urine and so forth by a process of simple conditioning. This process may be conscious and deliberate, and such training accounts for the feats of Yogi fakirs. It may also be unconscious and even undesired by the subject, sometimes producing "psychosomatic" disorders, in which symptoms of bodily disease are attributable to nervous strain or conflict.

In spite of the vast mass of empirical information collected by Pavlov and his pupils, we still do not understand the process whereby the neutral stimulus acquires the meaning of the original one. But it is clear that one of the principal requirements for this associative learning is a complex mechanism of memory, capable not only of storing the traces of the two series of events but also of providing the information that the coincidence between the two is greater than would be expected by chance. The creation of such a memory mechanism was the problem to which we addressed ourselves in designing *M. docilis*.

Our earlier model, *M. speculatrix*, had a very elementary form of memory. In order to get around an obstacle it encountered, the model had to remember it long enough to get well away from the hindrance before resuming its journey to the attracting light. Even among living creatures such a memory is not universal; the absence or brevity of this memory accounts for the tireless and ineffective buzzing of a fly on a windowpane. *M. speculatrix's* elementary memory works as follows: When the model touches an obstacle, the contact closes a circuit which converts its two-stage amplifier into an oscillator of the type known as a "multivibrator." The oscillations thus generated make the model stop, turn, withdraw, and go forward, and these maneuvers are repeated until the contact is opened by clearance of the obstacle. It is a characteristic of this simple circuit that while it is oscillating it cannot amplify, so the model is blind to the attracting light while circumventing a material difficulty. Furthermore, even after the touch contact is opened, one more oscillatory discharge takes place, and this ensures that the model moves well away from the obstacle before regaining its vision. The after-discharge in the oscillatory circuit is an example of the most elementary form of memory trace, in which the internal effect of a stimulus outlasts its external duration. Such an after-discharge is common in the reflex activity of the spinal cord of animals, and the more complex the reflex, the longer the after-discharge is likely to last. When you step on a tack, your leg is withdrawn by reflex action, but the withdrawal continues after your foot has left the tack, so that when you straighten your leg again it does not come down on the same place.

ON first analysis the problem of transforming *M. speculatrix* into an educable species seemed quite simple.

Its essentials are illustrated by the upper of the two diagrams at the lower left-hand side of the next page. In *M. speculatrix* we had a reflex mechanism with three elements: a specific stimulus Ss (a light or touch), which produced a specific effect Es (the operation of the motor relays) by way of a transmission system T_1 (the two-stage amplifier). To introduce the factor of conditioning, this mechanism must be linked with a second activated by a neutral stimulus which does not initially produce the effect Es. The second arrangement would consist of the neutral stimulus Sn and a transmission system T_2. (It might produce a specific effect of its own, Es_2, but with this we are not at the moment concerned.) T_1 must be linked with T_2 in such a way that the former comes to respond to the neutral stimulus with its normal effect Es, as if Sn were in fact Ss. This means that there must be a "learning box" of some kind between T_1 and T_2. The question is: What are we to put into the learning box (L)?

Obviously it must contain an apparatus which will receive signals from both T_1 and T_2 and combine them in such a manner that after Ss and Sn have occurred together more often than they would by chance, Sn can find its way through the learning box and have the effect Es. We experimented with some simple electronic circuits suggested by these requirements, but the first trials were disappointing. We soon realized that a more detailed analysis of the learning process would be necessary. It was clear that the statistical relation between Ss and Sn would have to be assessed before we could determine how to establish an association between them. That is, circuits must be provided to deal with any particular Ss and Sn in such a way that only a significant degree of coincidence between them would be registered. For example, an animal being trained to expect food when a bell is rung must first decide whether the ringing of the bell is really worth noticing. If bells are rung and food is offered entirely at random, there is no basis for supposing the two to be in any way related.

It took some time to appreciate the number and complexity of the operations involved in establishing a connection between different stimuli to achieve a conditioned response. Eventually it was found that no fewer than seven distinct operations must be performed. They are:

1. The beginning of the specific stimulus must be sharply differentiated from the absence of the stimulus. That is, it is the change that is important, *e.g.*, the transition from no food to food in the case of an animal, rather than the duration of the stimulus.

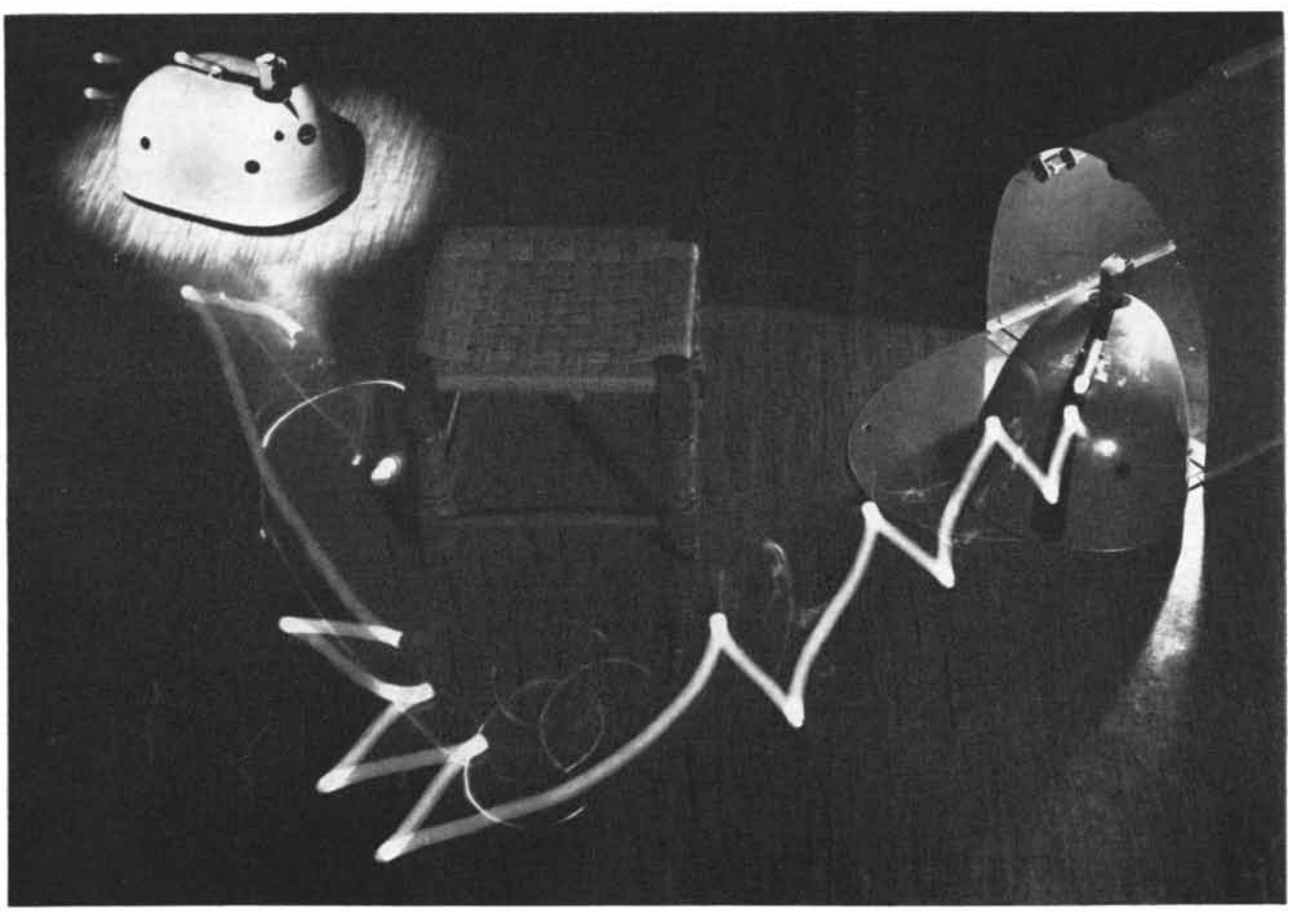
2. On the other hand, the impact of the neutral stimulus must be extended in time. This is because it may occur some while before the specific stimulus and must therefore be "remembered" long enough for its significance to be noticed.

3. The series of clipped Ss and stretched Sn must be mixed in such a way that their areas of coincidence are appreciated.

4. The coincident areas must all be summated, or integrated, to form a consolidated stimulus.

5. When the sum of all the areas of coincidence reaches a value greater than would ever be obtained by chance, the memory process is activated. This activation is in the nature of a trigger process—a single event, analogous to a flash of insight into a contingency previously ignored.

6. Once the existence of a significant degree of coincidence between Ss and Sn has been registered, it is preserved in the memory for some time and fades away gradually. In the *M. docilis* model the memory takes the form of a damped oscillation, but it could well be any mechanical, chemical or electrical process in which stored energy is slowly released, as in the escapement of a watch. It is



MACHINA SPECULATRIX, photographed by time exposure, is attracted by light in hutch at right. It begins at left, encounters obstacle, backs away, encounters obstacle again, backs away again and enters the hutch.

essential only that the energy should be in such a form that it can be readily available for the final operation.

7. This final phase is the combination of the preserved trace with a fresh Sn to give Es as the new conditioned response. The operation is analogous to the testing by experiment of a hypothesis, the hypothesis here being the likelihood of a correlation between Ss and Sn.

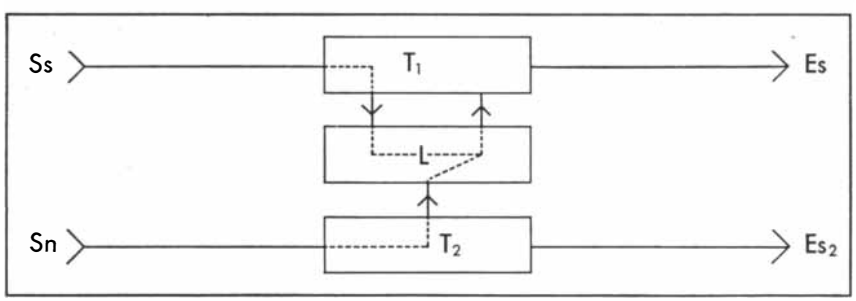
In terms of conditioned reflexes, the acquired response must be reinforced, otherwise it will vanish without trace. Consequently when the fresh Sn is presented in the seventh operation, it must be followed by the confirming Ss. Eventually, after a number of such events, the new response Sn → Es is permanently established and requires no further corroboration.

ALL THIS can be represented in a diagram of a simple nervous system (*see the lower of the two diagrams at the lower left-hand side of this page*). In this drawing there are two series of nerve cells—two reflex arcs—which correspond to the transmission systems T_1 and T_2. Between the two is a network of nerve cells which serve to perform the seven operations detailed above. Branching off from the first reflex arc is a synapse (1) with the property of discharging only at the beginning of the stimulus; this corresponds to the perception of food. In the second reflex arc is a synapse (2) with a long afterdischarge: the prolongation of the neutral stimulus. The signals from the two stimuli both reach a neurone at (3), are mixed there and added together at (4). When the summated inputs reach a certain level, they discharge a trigger neurone (5). This introduces a pulse into the quiescent closed circuit at (6) which, by reason of positive feedback, continues to oscillate for a long while. An output from this leads to a mixing neurone at (7), which is also connected directly with the second reflex arc. This neurone can only discharge when it is activated simultaneously by signals from the storage circuit at (6) and a signal from the second reflex arc. When it does receive signals from both, its discharge is conducted to the output of the first reflex and has the specific effect Es. It thus acts as a gate to Es—normally shut to Sn but opened by the memory that Sn has often been followed by Ss.

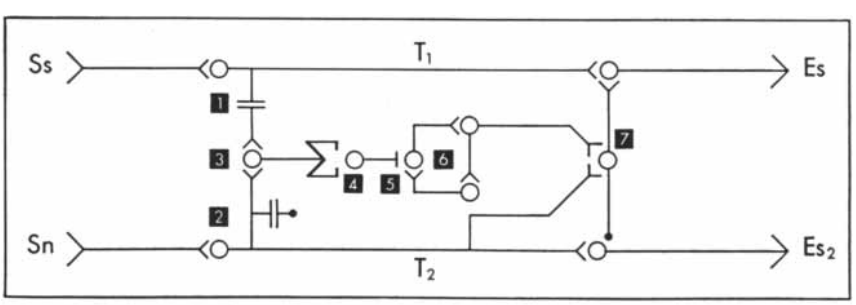
Once this scheme had been worked out, it became possible to create an electronic circuit to perform the necessary operations (*see diagram at the lower right-hand side of these two pages*). The details are perhaps of interest only to an electrical engineer; the system involves a number of electronic tubes coupled with capacitors, resistors and so on in such a way that the signals are properly amplified, timed and mixed, and the resulting pulses are combined to produce the desired results.

In one arrangement of the working model of *M. docilis* the specific stimulus is a moderate light and the neutral one is the sound of a whistle. The whistle is blown just before the light is seen; after this has been repeated 10 or 20 times the model has "learned" that the sound means light and will come to the whistle as though it were a light. If it is teased by withholding of the light, it soon forgets the lesson and disregards the sound. In another arrangement the specific stimulus is touch, that is, an encounter with an obstacle. In that case the whistle is blown just as the model comes into contact with the obstacle, so that after a while the warning whistle triggers a withdrawal and avoidance reaction. This process may of course be accelerated by formal education: instead of waiting for the creature to hit a natural obstacle the experimenter can blow the whistle and kick the model. After a dozen kicks the model will know that a whistle means trouble, and it can thus be guided away from danger by its master. This last is an example of a negative or defensive conditioned reflex; as in an animal, responses of this type are more easily established and retained than any other. Because the mechanism sets up very large oscillating pulses which keep feeding into the learning circuit, the conditioned reflex, once established, lasts as long as the decay time of the memory and requires little or no reinforcement.

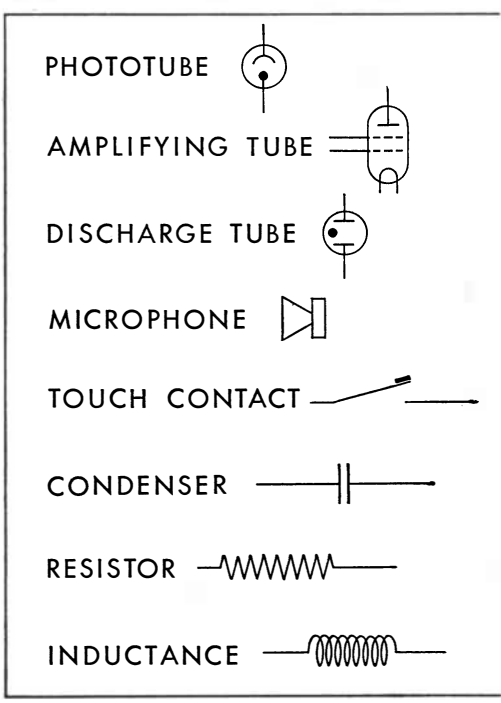
SEVERAL interesting problems arose in the working out of these experiments. For example, the use of sound as a conditioned stimulus was convenient, but the internal noise of the motors and gears was so loud compared with an external sound that the model could not "hear" the signal. It was found necessary to provide a special amplifier with a resistance-capacitance feedback circuit sharply tuned to the note of a whistle—about 3,000 cycles per second. As an alternative we tried arranging a muting



LEARNING links two systems. Ss and Sn are specific and neutral stimuli; Es and Es_2, effects; T_1 and T_2, transmission systems; L, learning box.



CONDITIONED REFLEX requires this arrangement of nerve cells. Numbers correspond to operations described in text and to diagram at right.



CIRCUIT for Cora, which stands for conditioned reflex analogue, is out-

mechanism whereby the motors were turned off periodically and the microphone was simultaneously switched on for a moment to pick up any extraneous sound. This type of gating mechanism emphasizes the importance of the stretching operation applied to the sound signal, for the information the latter conveys is used after the brief listening period, which may occur only once a second for a tenth of a second. The muting-pulse device was not adopted because it seemed more complicated than the sharply tuned amplifier, but the former may be more akin to the physiological mechanisms in living creatures.

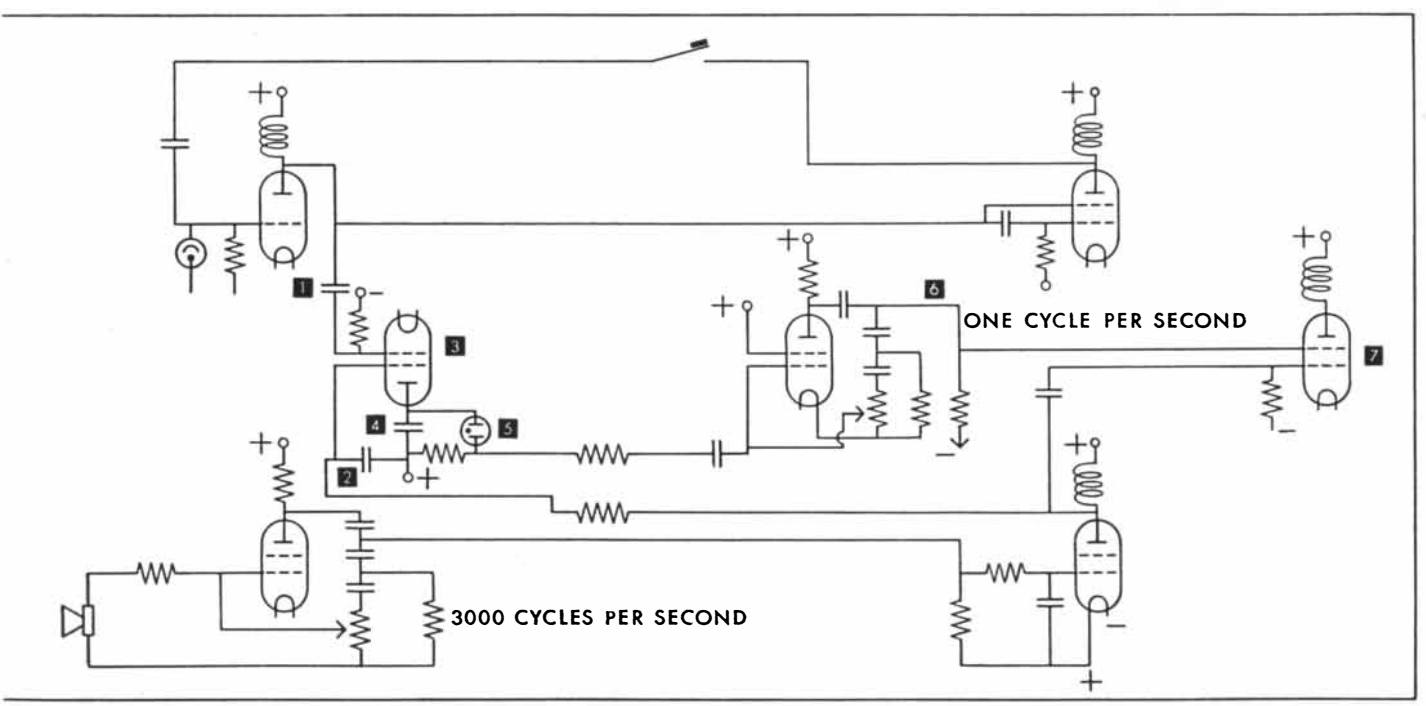
Further complications in *M. docilis* arise when the sound amplifier (neutral stimulus) is arranged to produce its own specific effect. For example, it can easily be arranged to make the sound switch off all motors, so that the model "freezes" when it hears the whistle. Such a reaction is very common in animals; many marsupials and rodents "play 'possum" when they hear a strange noise. If now it is intended to teach the model that sound means light, which may mean food, the freezing reaction must be inhibited to permit conditioning of the new response. A separate branch must therefore be taken from the output of the mixing tube at (7) to the output of the sound amplifier, whereby the "instinctive" effect of the latter is suppressed as soon as the positive conditioning has been established.

WE have described so far the simplest possible mechanism, consisting only of a single learning circuit connected to two signal amplifiers. With this arrangement the model is reasonably docile. But if we introduce a second learning circuit, or build in two neutral or specific signals instead of one, it becomes only too easy to establish an experimental neurosis. Thus if the arrangement is such that the sound becomes positively associated both with the attracting light and with the withdrawal from an obstacle, it is possible for both a light and a sound to set up a paradoxical withdrawal. The "instinctive" attraction to a light is abolished and the model can no longer approach its source of nourishment. This state seems remarkably similar to the neurotic behavior produced in human beings by exposure to conflicting influences or inconsistent education. In the model such ineffective and even destructive conditions can be terminated by rest, by switching off or by disconnecting one of the circuits. These treatments seem analogous to the therapeutic devices of the psychiatrist—sleep, shock and psychosurgery.

In *M. docilis* the memory of association is formed by electric oscillations in a feedback circuit. The decay of these oscillations is analogous to forgetting; their evocation, to recall. If several learning pathways are introduced, the creature's oscillatory memory becomes endowed with a very valuable feature: the frequency of each oscillation, or memory, is its identity tag. A latent memory can be detected and identified among others by a process of frequency analysis, and a complex of memories can be represented as a synthesis of oscillations which yields a characteristic wave pattern. Furthermore a "memory" can be evoked by an internal signal at the correct frequency, which resonates with the desired oscillation. The implications of these effects are of considerable interest to those who study the brain, for rhythmic electrical oscillation is the prime feature of brain activity. We may gain new respect for the speculations of the English physician-philosopher David Hartley, who 200 years ago suggested that ideas were represented in the brain as vibrations and "vibratiuncles."

THESE models are of course so simple that any more detailed comparison between them and living creatures would be purely conjectural. Experiments with larger numbers of circuits are perfectly feasible and will certainly be instructive. One weakness of more elaborate systems can be predicted with confidence: extreme plasticity cannot be gained without some loss of stability. In the real world an animal must be prepared to associate almost any event with almost any other; this means that if a nervous system contains N specific receptor-effector pathways, it should also include something of the order of N^2-N learning circuits. In such a system the chances of stability decline rapidly as N increases. It is therefore no wonder that the incidence of neuropsychiatric complaints marches with intellectual attainment and social complexity.

W. Grey Walter is director of the physiological department at the Burden Neurological Institute in Bristol, England.



lined by simplified diagram. The circuit element labeled "3,000 cycles per second" is tuned so that Cora responds only to sound of that frequency. The element labeled "one cycle per second" provides machine with memory.

What GENERAL ELECTRIC People Are Saying

C. H. LANG

Vice President

GIRDING FOR PEACE: America is trying something new and daring in this old game of power politics. Where the normal historic reaction is simply to build a bigger army than the potential aggressor, America has undertaken a much more imaginative task: *She will deliberately grow.*

She will swiftly and systematically increase her entire, basic productive strength, to the point where she can be adequately armed and still live as a healthy, prosperous, and peaceful nation.

I must emphasize that this is a new approach in international affairs. It is not girding up for war; it is girding up for peace. As far as I know, no nation has ever tried it. . . .

After all, what is the key to survival? How shall we stand up to the armed millions of Communism? How shall we bring them to their senses?

We can't outnumber them. We can't outslave them. *But we can outproduce them.*

America, with 6 per cent of the world's population, now turns out 40 per cent of the world's goods. This means that Americans are roughly ten times as productive as other people.

Russia has been working hard on industrialization—but with 25 per cent more people than America, she produces only one-third as much. And her new ally, China, is much less productive.

Hotel Astor
New York City
March 4, 1951

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F. M. CLARK

General Engineering Laboratory

INSULATION: The history of electric power is a story of repeated demands for higher and higher blocks of power generation and transmission. Increasing power loads lead to increasing voltages of transmission for technical and economic reasons. Insulating air was soon replaced by silk or cotton wire coverings, sometimes coated or impregnated with varnish or waxes. Later, natural rubber jackets were applied.

Perhaps the first real contribution of chemistry to the science of electrical insulation was the application of vulcanized rubber as insulation for the conductor. But with continued demands for the transfer of larger and larger blocks of power, the inadequacy of available insulation soon became apparent.

To provide the engineer with means for adequately meeting the growing demands for electric power has been the opportunity for chemistry. It has met this opportunity and responsibility with a myriad of new products and processes, and with the modification and improvement of older materials and processes.

General Electric Review
February, 1951

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E. J. LAWTON

Research Laboratory

CATHODE RAYS: An experimental cathode-ray unit is in operation at the General Electric Research Laboratory that is capable of delivering an ionization dose of one million equivalent roentgen units in seven seconds at a distance of 10 cm from the tube window and at 800 kv (peak) energy . . . A dose of one million roentgen units has been found to be lethal to most moulds and bacteria . . . Although it is possible to sterilize foodstuffs so that they can be stored without refrigeration, the sterilization dose in some cases is sufficient to produce undesirable changes in odor, taste, and color.

Enzyme systems, both in the natural and isolated states, are deactivated by cathode rays. Chemical changes are produced in other materials irradiated with cathode rays.

Plants from seeds irradiated with electrons produce flowers that show color mutations. The maximum survival dose was found to vary with the different varieties of seeds and over a range of approximately 5000 to 100,000 roentgen.

National Academy of Sciences
Schenectady, New York
October 10, 1950

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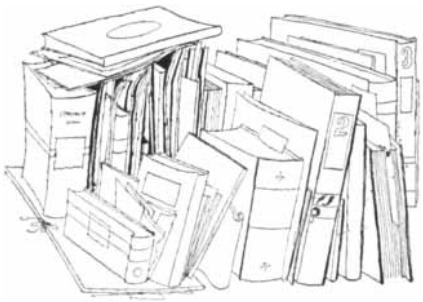
C. E. THEALL, JR.

Electronics Department

COMPUTERS: The one basic difference between the calculating machine and the man is that the machine has no creative intelligence of its own. It cannot stop halfway through a problem and suddenly discover a new method for solving the problem. Nor can it solve any problems that the mathematician instructing it cannot solve. The mathematician must make all the decisions and list all the conditions before the problem is fed into the machine.

This might raise the question: "Why have computers, if we already know how to solve the problems before we start?" The answer is that high-speed calculators work thousands of times faster than men and, through the use of them, the abilities of a few skilled mathematicians are magnified greatly. While mathematicians know the methods used in computation, some problems are so vast that it would take hundreds of men working for years to solve them. The computer, programmed by a few experts, can save all this manpower and still give back the answers in less time.

Railway Mail Clerks
Syracuse, New York
April 18, 1951



BOOKS

Human fertility: a big subject with some journalistic pitfalls

by L. S. Penrose

HUMAN FERTILITY: THE MODERN DILEMMA, by Robert C. Cook. William Sloane Associates ($4.50).

THE human race presently numbers more than 2,500 million people. Its rate of increase is believed to be on the order of one per cent per year. Almost everyone agrees that some parts of the world are overpopulated. In his book *Human Fertility: The Modern Dilemma* Robert C. Cook describes, among other things, the effects of limited resources and cramped surroundings upon the rapidly increasing population of Puerto Rico. As an object lesson of what might happen very easily in Japan and possibly in the British Isles, this problem has great significance for demographers; Mr. Cook is right in bringing it into public view.

There are nonetheless two serious defects in his presentation. The first of these is that although Mr. Cook touches upon changes in population structure with respect to age groups and sex, and uses a few statistical diagrams for purposes of illustration, there is a complete absence of data on the detailed effects of birth and death rates upon total population numbers. Mr. Cook is very much concerned to emphasize the seriousness and the magnitude of world population problems; there is no doubt that he succeeds in making the reader's flesh creep. But the problems he discusses are so extremely difficult and complex that it is unlikely that they can be solved by dramatic and superficial gestures such as providing everyone with automobiles and the cinema. As in other fields of medical and social science, advances toward the control of populations at their optimum numbers and age structures will only be achieved by applying the results of painstaking observations. A much fuller understanding of the causes of variation in human fertility is required, and Mr. Cook's oratorical approach seems incompatible with the true scientific spirit.

The second point is that Mr. Cook has confused the issue by emphasizing the eugenic aspect of population problems, thereby weakening the strong case which can be made out for planned population numbers. He believes that "misplaced and badly distributed human fertility is leaching away the inborn qualities of tomorrow's children" and that "each succeeding generation will be less well equipped with the biological foundation for those qualities we call good: health in mind and body, intelligence and personality." This genic erosion is supposedly the inevitable consequence of differential fertility, engendered by conditions of civilized life because they encourage the multiplication of weaklings. How things differ now, since the discoveries of Pasteur and Lister, from what they were in the days of the Pilgrim Fathers! Writes Mr. Cook: "Persecution in England for two generations had eliminated the weak-willed, the faint-hearted and weak-minded," and half the immigrants died during their first winter in Massachusetts. One might mention that most persecutions discriminate against the strong-minded, but the point need not be pressed. The main question is whether genic erosion—the cream of a nation's gene pool going down the drain—is a reality.

Little is known about the differential fertility of more than a century ago, but it may be reasonably assumed that there has always been a fertility gradient with respect to intellectual stature. In his survey of genius Francis Galton noted how commonly the ablest men left no descendants. Evidently the highest category of intellect must rely for replenishment upon the more fertile groups in lower categories. The infertility of imbeciles and idiots also escapes Mr. Cook's notice. In a natural population, to which the human race approximates more closely than to a laboratory stock of animals, extreme variations at both ends of the scale are infertile; this tends to produce equilibrium. It is also possible to have a stable genic structure when maximal fertility is associated with subaverage intellect. These points are entirely neglected.

A large portion of the book is devoted to interestingly written but often irrelevant extracts from the history of medical and biological science. After being told that unbalanced and unchecked fertility, due to the control of deaths by medical techniques, is "ravaging many lands like a hurricane or a tidal wave," the reader is confronted with Pasteur, Lister, Koch and Roentgen. The work of these men, Mr. Cook feels, may have been a curse to mankind rather than a blessing. On the other hand, Abbot Mendel obtains unqualified approbation: his laws, "which ought to be understood as widely as the multiplication table," should guide the eugenist in determining how to breed the next generation to the greatest advantage. But the reader can find no hint as to how these laws could be applied in population control. It is also difficult to see the precise significance of the space given to the details of the Tennessee monkey trial and the Lysenko controversy.

Any work that attempts to cover so large an amount of ground is bound to contain many mistakes of fact. For example, Huntington's chorea does not account for 5 per cent of the patients in U. S. mental hospitals; it accounts for only about 1 per cent. Again, the metabolic disease phenylketonuria is probably commoner in the U. S. than in Scandinavia, not rarer; and amaurotic babies are not eyeless.

Mr. Cook's ability to write dramatically and arrestingly is such that had he confined himself to his original theme of overpopulation the book might have been good. As it is, by attempting too much and yet actually presenting only one side of the case, he has not brought the problems he raises any nearer to solution. The result is that at the end the reader is horrified, confused and frustrated instead of encouraged to settle down to the kind of scientific evaluation of the facts that is necessary if progress is to be made.

L. S. Penrose, an outstanding student of human genetics, is professor at the University of London and author of The Biology of Mental Defect.

GREEK CIVILIZATION AND CHARACTER, edited by Arnold J. Toynbee; GREEK HISTORICAL THOUGHT, edited by Arnold J. Toynbee; GREEK RELIGIOUS THOUGHT, edited by Francis Macdonald Cornford; LATER GREEK RELIGION, edited by Edwyn Robert Bevan; GREEK ETHICAL THOUGHT, edited by Hilda Diana Oakeley. The Beacon Press ($3.00 each). Each of these small books consists of a rather long introduction by a noted scholar and selections appropriate to the title. Together they present an extraordinary tapestry of ideas—ideas which in the more than 20 centuries since they were first expressed have lost none of their grandeur and humanity. In this notable array may be

found the reflections of a great people on the nature of man, "the place of reason and knowledge in the good life," the significance of human life, the gods and their relation to man, the varieties and limits of philosophy, the mainsprings of character, the trend of history. "In essence," writes Toynbee in the preface to the volume on historical thought, "the historical experiences which wrung these thoughts out of Greek souls are akin to the experiences through which we ourselves have been passing. The Greek thoughts here reproduced in English are reflexions, in human minds, of world wars and class wars, cultural encounters at close quarters between peoples with sharply different social heritages, atrocities and acts of heroism, and all the other enigmatic patterns, woven in the particolored web of Good and Evil, that stimulate human minds to wrestle with the paradoxes of Human Nature."

THE HEAVENS ABOVE, by J. B. Sidgwick. Oxford University Press ($4.00). A soundly planned, intelligent introduction to astronomy. It begins auspiciously by describing the sky in terms that can be comprehended by those not possessed of the higher faculty of detecting animals in the various constellations; it explains, with a minimum of mathematics, the problem of the real motions of the stars and planets; it discusses clearly, with the aid of historical sequences, the increase of knowledge won by the telescope and spectroscope; it outlines the more complex facts and theories about the constitution of the stars, the nature of the solar system and the nebulae, the distances and dimensions of the universe, the relation between astronomy and atomic physics. This is an uncommonly attractive primer, equally suited for school use or as a supplement to back-yard stargazing.

GEOGRAPHY IN THE TWENTIETH CENTURY, edited by Griffith Taylor. Philosophical Library ($8.75). In this interesting and unusual volume 20 American, British and European geographers discuss the salient features—techniques, aims and trends—of modern geography; its changes in emphasis during the last 50 years; the characteristics of the French, German and West Slav geographic schools; the progress of geomorphology; the sociological aspects of geography; its relation to aviation, racial geography, geopolitics and geopacifics; and a considerable number of related topics of philosophical or practical scope. Mr. Taylor, head of the Department of Geography at Toronto University, has himself contributed six chapters and a glossary of geographical terms.

THE BEGINNINGS OF DIPLOMACY: A SOCIOLOGICAL STUDY OF INTERTRIBAL AND INTERNATIONAL RELATIONS, by Ragnar J. Numelin. Philosophical Library ($12.00). This detailed and thoroughly documented study shows that in pre-literate societies many of the trappings of modern diplomacy and international relations were present in vestigial form—envoys with special privileges, treaties, alliances, declarations of war and the like. And among such societies, the author believes, peace was more the rule than the exception, suggesting that perhaps "savage" diplomacy was more effective than that practiced by moderns. Although the volume contains much interesting material, the awkward style and the innumerable footnotes and references will make it heavy going for the nontechnical reader.

JANE'S FIGHTING SHIPS, 1950-1951; edited by Raymond V. B. Blackman. McGraw-Hill Book Company, Inc. ($20.00). The 52nd edition of this standard work, with a new and more effective layout of the pages, 500 fresh illustrations, considerable revision of the textual material, and the usual encyclopedic, up-to-date and authoritative array of information on everything from giant aircraft carriers and "Hunter-Killer-Destroyers" (U.S.) through Zanzibar mine sweepers and Thailand frigates. There are 41 pages alone on the Russian Navy which, it is "persistently reported," is building three new powerful battleships (36,000 tons), and is now believed to have between 350 and 370 submarines, many of the latest type. Soviet Navy estimates for the year 1950-51 are almost as large as U. S. appropriations ($3,750,000,000 as against $4,168,000,000), yet despite this and other evidence of a tremendous spurt in naval construction, the Russians are not known to have any aircraft carriers and even the report that three carriers of 25,000 tons are to be built is described as "unconfirmed."

JANE'S ALL THE WORLD'S AIRCRAFT, 1950-1951; compiled and edited by Leonard Bridgman. McGraw-Hill Book Company, Inc. ($20.00). For the 41st edition of this companion to *Jane's Fighting Ships*, the comprehensive revision has been supplemented by a resetting of the entire text, more than 400 new illustrations and other features. Every year the compilation of this meticulous record becomes more difficult, not only because the tempo of civil and military aviation activities continues to increase, but because security restrictions constrict the channels of information as to technical advances, production and the like. Mr. Bridgman is exceptionally conscientious in sifting reliable data about Russian aviation from the hodgepodge of propaganda and rumor.

MEASUREMENT AND PREDICTION: VOLUME IV, STUDIES IN SOCIAL PSYCHOLOGY IN WORLD WAR II, by Samuel A. Stouffer, Louis Guttman, Edward A. Suchman, Paul F. Lazars-

feld, Shirley A. Star and John A. Clausen. Princeton University Press ($10.00). A highly technical account of the methods used by the Research Branch, Information and Education Division, War Department, in attitude and prediction studies, the results of which were reported in the first three volumes of the series. Volume IV is required reading for the social scientist who is concerned with the difficult problems of attitude measurement.

MATHEMATICS, QUEEN AND SERVANT OF SCIENCE, by Eric Temple Bell. McGraw-Hill Book Company ($5.00). Two older books have here been consolidated and considerably amplified: *The Queen of the Sciences,* a little survey written by Dr. Bell in connection with Chicago's Century of Progress Exposition in 1933, and *The Handmaiden of the Sciences,* which appeared in 1937. Dr. Bell is most adept as a popularizer. His learning is immense; his opinions are pleasantly cantankerous and often original; he moves through a large field with an ease which should comfort the reader.

REALITY AND DREAM: PSYCHOTHERAPY OF A PLAINS INDIAN, by George Devereux. International Universities Press, Inc. ($7.50). The chief contribution of this volume is the presentation of verbatim notes made during 30 counseling interviews with an Indian mental patient. These notes, together with the author's interpretations, provide valuable insights into the ways in which cultural factors affect the growth and development of personality.

ANIMAL NUTRITION, by Cyril Tyler ($2.40); VISION AND THE EYE, by M. H. Pirenne ($1.92); PROTEINS AND LIFE, by M. V. Tracey ($1.60); ATOMIC ENERGY, by R. R. Nimmo ($1.44); COSMIC RAYS, by L. Jánossy ($1.44); The Pilot Press Limited, London. The Frontiers of Science series, to which these volumes belong, occupies a place in the range of scientific literature about midway between the simplest of popular expositions and works designed exclusively for specialists. As is to be expected, the studies differ in readability and general interest. A competent level is nonetheless maintained throughout by the experts selected for the various topics. The modest price at which these volumes are offered adds to the usefulness and attractiveness of the entire undertaking.

NATIVE ARTS OF THE PACIFIC NORTHWEST, by Robert Tyler Davis. Stanford University Press ($7.50). The late Axel Rasmussen, an Alaskan school superintendent, collected the practical and ceremonial articles shown in this volume. They are presented with an introductory text by Mr. Davis. A beautiful book.

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AUGUST

1951

Conducted by Albert G. Ingalls

PROBABLY half of the telescopes built by amateurs are of necessity made portable because their owners lack a suitable place to erect them permanently. And of these more than half are designed for limited portability within only 100 feet or so of the house. The means for moving such instruments need not be elaborate; the simpler the better. All manner of contrivances have been devised for this purpose, and one more example is shown in the illustration on the opposite page. The carrier and the telescope base and mounting were built by C. W. Flohr of Denver, Col. The telescope proper, that is, the tube and the optics, was built by C. S. Walton of Wheatridge, a Denver suburb.

The base of this telescope is a light, hollow plywood structure open at the bottom. "It seems to squat down solidly almost anywhere you put it," Walton writes. When the telescope is set up for use, the light wheelbarrow on which it has been trundled is detached like a sulky from a race horse and temporarily pushed into a corner. Roger Hayward's drawing shows the wheelbarrow and the manner in which it is temporarily attached to the telescope.

"The telescope is restrained from flip-flops by the handles and by a hinged latch," Walton says. A pushed conveyance such as a wheelbarrow in which the weight hangs from the arms of the pusher is inherently under better control and less accident-prone than the pulled four-wheel truck that is sometimes used, the stability of which is wholly dependent on the bumpiness of the ground.

Flohr's telescope is neither rough nor uncommonly elegant, but it is a type that many could build as, perhaps, their second instrument. It embodies a few relatively inexpensive machining and welding jobs that most amateurs are not equipped to perform at home, but there is plenty of evidence that in the average case the expenditure of about $10 for outside work is not a consideration that blocks the construction of an instrument.

The polar axis is a length of two-inch

THE AMATEUR ASTRONOMER

pipe that has been turned smooth in a lathe and rotates on simple bearings of wood, an excellent material for bearing-boxes. The declination axis is also a piece of two-inch pipe turned smooth. It rotates within an open-topped box of bent sheet-metal welded at the ends and without special bearings. "We didn't think such bearings would get hot," Walton comments.

The counterweight is a large, heavy, solid rubber ball.

The tube is free to rotate to place the eyepiece at the most comfortable observing position. "I wouldn't have anything else," Walton writes, after much experience with telescopes, including a 17-inch reflector that he made. This feature is being included in telescopes more and more often, by providing for either rotation of the whole tube by loosening its clamping bands or for rotation of the head alone.

IN the May issue of SCIENTIFIC AMERICAN Edwin Emil Webb of New York, N. Y., proposed in this department a method of abolishing the diffraction effect caused by the secondary mirrors of compound telescopes. A practical method of doing this would improve all optical instruments and would be a basic invention of economic importance. Webb's idea is to apply a nonreflecting ring of particles, too small to diffract light, to the primary mirror adjacent to the geometrical shadow of the secondary and tapering outward to full reflectivity within a quarter or an eighth of an inch. Such a ring would have no edge.

A number of interesting comments on this proposal have been received. There is also evidence that the optical manufacturers have been at work on the problem.

James E. Lipp of Santa Monica, Calif., comments: "If we substitute the word 'uncoated' in place of Webb's word 'blackened' most of the result he desires could be obtained, since an uncoated area of glass reflects but a small percentage of the light that falls upon it. The method is to use a specially arranged set of masks and source of material to be deposited during the aluminization of the primary mirror by the evaporation method.

"The drawing [*at the upper left in the illustration on the next page*] shows an arrangement to take care of the central and edge zones. The molten aluminum is in a small round crucible. A disk-shaped central mask is placed between the crucible and mirror and is supported from the center of the mirror. An annular mask with an opening larger than the disk is supported from the bell jar or another structure. Because of the finite size of the crucible each mask will cast a shadow on the mirror having an umbra (completely uncoated) and a penumbra with a smoothly tapered density of coating. With a given size of crucible the sizes of these two zones can be governed by the diameters of the masks and their distances from the mirror.

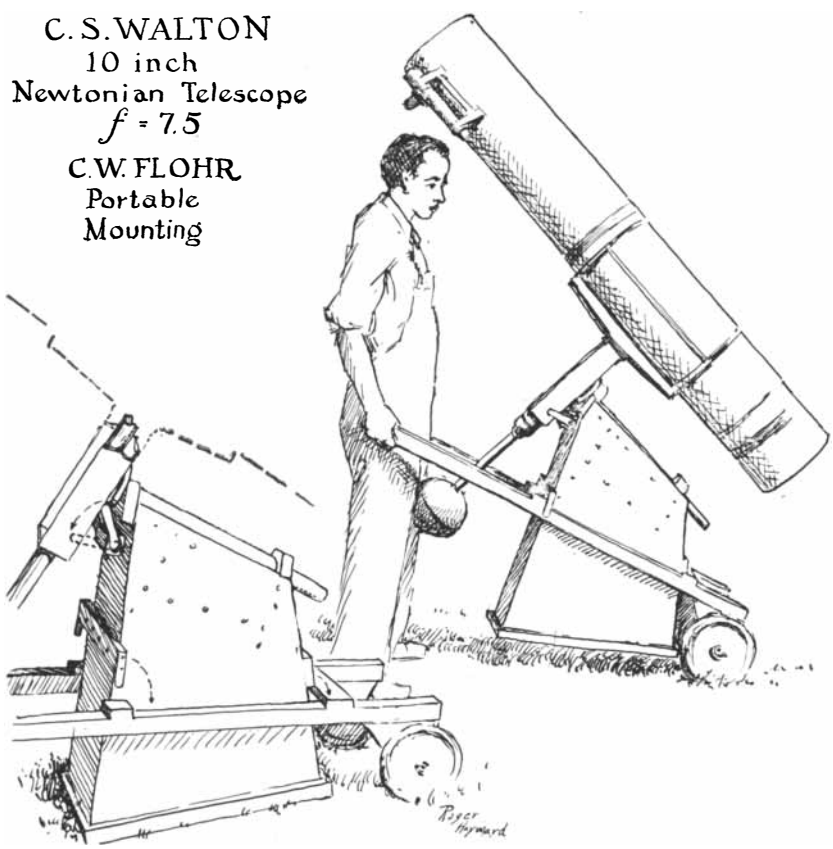
"Strips connecting the disk and annulus can be used as masks to offset spider diffraction. A better idea," Lipp continues, "contributed by James S. Thompson of Santa Monica, would seem to be to support the diagonal by means of a plane-parallel glass plate covering the entire aperture of the telescope, thus getting rid of the spider itself. The pane should have a nonreflective coating. It may be possible to apply a nonreflective coat just prior to aluminizing. This would further decrease the returned light from the unaluminized area without (I hope) affecting the reflectivity of the useful area."

Lyle T. Johnson of La Plata, Md., makes a proposal that is similar but different in detail. "Webb's anti-diffraction idea," he writes, "is very interesting. The result could be accomplished by aluminizing. The equipment could be set up as in John Strong's method for figuring mirrors by aluminization, described in his *Procedures in Experimental Physics,* pages 180-185; that is, by adding 'non-uniform films with the thickness of the film varying in just the manner required to parabolize a spherical mirror.' A diaphragm something like the one shown in the drawing [*at the upper right in the illustration on the next page*] could be used. Instead of building up the thickness for figuring purposes, it would be reduced to allow light to pass through without being reflected.

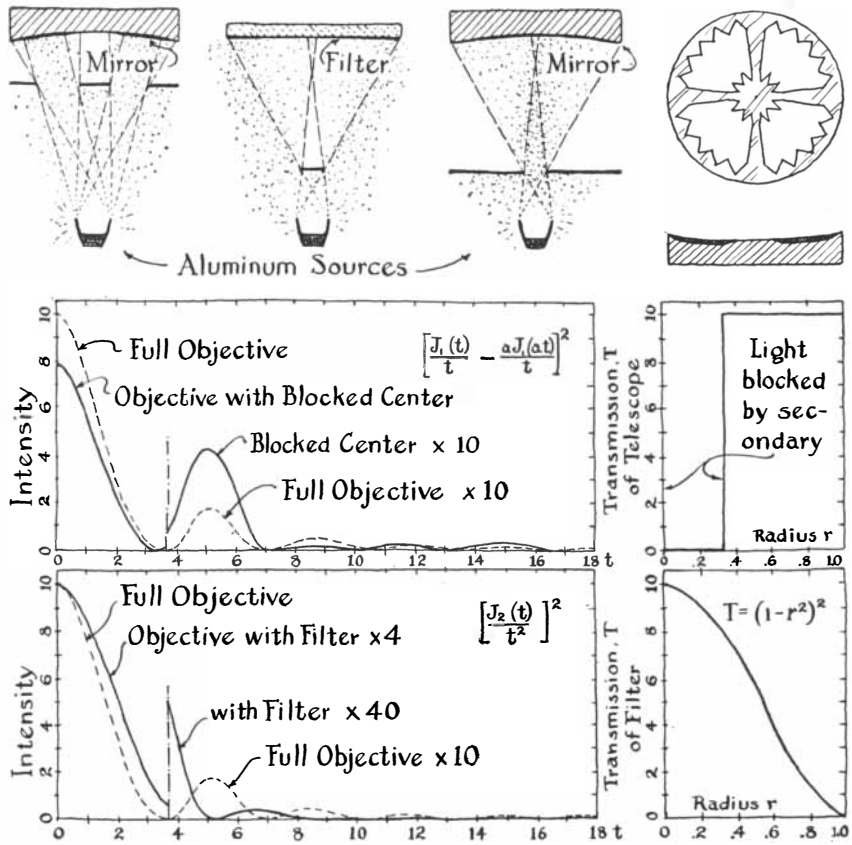
"The aluminum coating would have the usual thickness over most of the mirror, but it would taper off to nothing at the edge and at a spot at the center. This tapering of the coating would have the same effect as a zone, so the mirror would have to be figured with a turned-up edge and a high zone around the center to compensate."

William Sinton, a graduate student in the department of physics at the Johns Hopkins University, read Webb's proposal and pointed it out to the experimental physicist John Strong, for whom he is a research assistant. Sinton has made a six-inch telescope mirror and has devised a new stellar interferometer for measuring double stars that gives achromatic fringes. Strong asked him to prepare an analysis of Webb's proposal which, Sinton believes, contains merit but needs modification. He writes:

"It seems to be an idea of Webb's and probably of many amateur astronomers that it is the *sharp* edges that cause dif-



The Flohr portable telescope with detachable wheelbarrow



Toward the abolition of edge diffraction effects

fraction or diffraction effects. This, however, is not the case. You correctly stated the situation when in introducing the proposal in the May issue you wrote that 'diffraction is a process that goes on continuously in all wave fronts.'

"There is a set mathematical procedure for finding the diffraction pattern formed by an object that blocks off part of a wave front. Simply stated it is this: The diffraction pattern in terms of amplitude of light is the Fourier integral transform of the object. Actually this is not strictly true in all cases, but it is quite applicable to telescopes. To get the diffraction pattern in terms of intensity we square the amplitude pattern. In most cases the integrals that are involved are too difficult to evaluate in simple terms. Problems dealing with circular apertures usually involve Bessel functions, which most people abhor. But I have worked out a couple which will throw light on Webb's suggestion.

"The diffraction pattern of a circular opening such as the lens in a refractor is proportional to $(J_1(t)/t)^2$, where $J_1(t)$ is the Bessel function of first order, and t is a coordinate in the image plane of the objective and is proportional to the radius from the center of the pattern. This function is plotted in the two graphs [*at the lower left in the illustration on this page*]. The normal diffraction pattern of a refractor is obtained by rotating the diagram about the ordinate axis. The height of the resulting figure at any point is the intensity of the diffraction ring or Airy disk at this point. (After their first minimum all the diagrams are blown up by a factor of 10 to emphasize the rings.)

"The diffraction pattern of a reflector with a secondary mirror one-third the diameter of the primary is also shown in the first graph, as is its mathematical expression where a is the ratio of the diameter of the secondary to that of the primary. One-third is admittedly rather large, but it was desired to find the effect in an extreme case. From the first graph we see that the first dark ring has moved in [*full line*] toward the center. In other words, the Airy disk is now smaller and the telescope will actually show *higher* resolving power than without the obstructions. This is because most of the light comes from near the edges of the mirror. The increase in resolving power is entirely similar to that obtained with the Michelson interferometer where the whole objective is replaced by two parallel slits at opposite edges of the objective. Notice also that in general the rings have become stronger, but the first ring is only about twice as strong.

"Now we take up Webb's suggestion. Instead of just tapering the edge for an eighth or a quarter of an inch as he suggested, I went whole hog and tapered as shown in the diagram [*in the lower right-hand corner of the illustration*]. The transmission of the lens or the reflectivity of the mirror decreases from

the center out to the edge as shown. The reason is that this was easy to work out, whereas Webb's tapering would have been much more difficult. The diffraction pattern is shown in the graph [*at the lower left in the illustration*] in comparison to that of the normal objective. The first dark ring has moved farther from the center. The Airy disk is larger and the resolution is somewhat reduced. However, the rings are also reduced. The second ring now just barely shows on the graph, and the rest not at all. The reason is in the formula for the new pattern which is shown on the graph. The intensity in the rings of the normal pattern is approximately proportional to $1/t^3$. For the modified pattern the intensity is proportional to $1/t^5$. This gets smaller much faster than $1/t^3$ as t gets larger.

"A numerical example will help here. Suppose we want to see the companion of Sirius, which is only 1/10,000 as bright as Sirius, with a six-inch telescope. The companion is at present about five seconds from Sirius. With the normal telescope the intensity of the rings at the companion is 1/2,700 the intensity of Sirius; the companion is lost in the glare. But with a filter over the objective which is faded in the manner described and is non-scattering, the intensity of the rings at the companion is only 1/610,000 the intensity of Sirius. The companion should then be all by itself. A few things should be noted. The intensity in the center of the Airy disk is one-fourth that of the unmasked objective, and the total light in the Airy disk is approximately one-third. Thus the limiting magnitude of the telescope becomes one magnitude less.

"It is seen that a tapering over only one fourth or one eighth of an inch will probably not do much good, but a drastic tapering over the whole objective has interesting possibilities. However, the loss in resolving power is something to be considered. The tapering could be useful, though, for seeking dark companions or perhaps for the observation of certain types of planetary detail.

"The general picture is that decreasing the light in the center yields higher resolving power but also increased ring structure, and fading out at the edges lowers the resolution and decreases the ring structure. Indeed, it is quite possible by the method of Fourier transforms to work backward. We can decide what diffraction pattern we want and then calculate how the lens has to be modified to do it. The only trouble is that for the diffraction patterns we might like to have this usually results in infinite-sized lenses. Whether there is some distribution that would result in a better general-purpose compromise than the normal objective, I don't know. It would certainly reduce the available light. In any event, the possibility of modifying the diffraction pattern to suit the needs of a specific problem should be kept in mind.

"I suggest that these filters might be made by evaporation of aluminum to produce partial transmitting or reflecting coats which are graduated during the evaporation by means of a moving diaphragm. Dr. Strong has corrected mirrors in this way. However, since the transmission depends greatly on how much aluminum is deposited, this effect will be difficult to control."

In a second communication Sinton says he has learned that the idea of reducing the diffraction rings by tapering over the whole objective has been worked out by P. Jacquinot and described in French in the *Proceedings of the Physical Society* (London), Series B, Volume 63, page 969 (December, 1950) and in *Comptes rendus,* Institut de France, Volume 223, page 661 (1946). There the method is called "apodization." Sinton has provided, as an alternative to the Bessel function approach to this problem, an approach by the method of vectors. This is available for loan to interested readers.

After seeing Lipp's proposal, Sinton commented further: "Lipp's suggestion seems to me ideal; I wish I had thought of the umbra-penumbra method. Yet his idea is tied to Webb's original distribution. Although I worked out a distribution by a mathematical formula I do not think this has to be adhered to very strictly. The important thing is to have a rather even tapering from the edge to the center. At present I am primarily interested in the problem from the standpoint of refractors, since I have the nine-inch refractor here at my disposal. For such an instrument a filter transmitting 100 per cent, or nearly so, in the center and tapering to zero at the edges can be made by the adaptation of Lipp's method shown in the drawing [*second from the upper left in the illustration on the opposite page*]. For the reflectivity distribution for mirrors I suggest the method shown in the drawing [*third from the upper left*].

"I asked Dr. Strong about the crucible source," Sinton continues. "He suggests that a coil of tungsten bent into a toroid will do as a disk source. With this it might be necessary to rotate the mirror to get an even distribution. With the simplifications, for which I thank Mr. Lipp, I hope to make one of these filters for the nine-inch telescope this summer. I don't plan to make it the same size as the objective, but instead to place it in the cone of light about two feet from the focus where it will have to be only about two inches in diameter. This will avoid the necessity for a nine-inch plate.

"The tapering off of reflection would not go to a black spot as suggested by Webb, since there would still be some reflection from the bare glass, but most of the diffraction effect would be eliminated."

BIBLIOGRAPHY

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

A REVOLUTION IN ELECTRONICS

THE TRANSISTOR. Frank H. Rockett in *Scientific American*, Vol. 179, No. 3, pages 52-55; September, 1948.

ELECTRONS AND HOLES IN SEMICONDUCTORS. William Schockley. D. Van Nostrand Company, Inc., 1950.

THE LOST CITIES OF PERU

THE CALLEJON DE HUAYLAS OF PERU AND ITS MONUMENTS. Richard P. Schaedel in *Archaeology*, Vol. 1, No. 4, pages 198-202; December, 1948.

THE DEEP-SEA LAYER OF LIFE

DEEP SCATTERING LAYER IN THE PACIFIC AND ANTARCTIC OCEANS. Robert S. Dietz in *Journal of Marine Research*, Vol. VII, No. 3, pages 430-442; 1948.

PROGRESS REPORT ON SCATTERING LAYER OBSERVATIONS IN THE ATLANTIC OCEAN. J. B. Hersey and H. B. Moore in *Transactions, American Geophysical Union*, Vol. 29, No. 3, pages 341-354; June, 1948.

HYBRID CORN

INBREEDING AND OUTBREEDING: THEIR GENETIC AND SOCIOLOGICAL SIGNIFICANCE. Edward M. East and Donald F. Jones. J. B. Lippincott Company, 1919.

CORN BREEDING. Frederick D. Richey in *Advances in Genetics*, Vol. III, pages 160-192. Edited by M. Demerec. Academic Press, Inc., 1950.

HEART MUSCLE

ELECTRON MICROSCOPIC HISTOLOGY OF THE HEART. Bruno Kisch. Brooklyn Medical Press, 1951.

EXPERIMENTS IN PERCEPTION

THE "WHY" OF MAN'S EXPERIENCE. Hadley Cantril. The Macmillan Company, 1950.

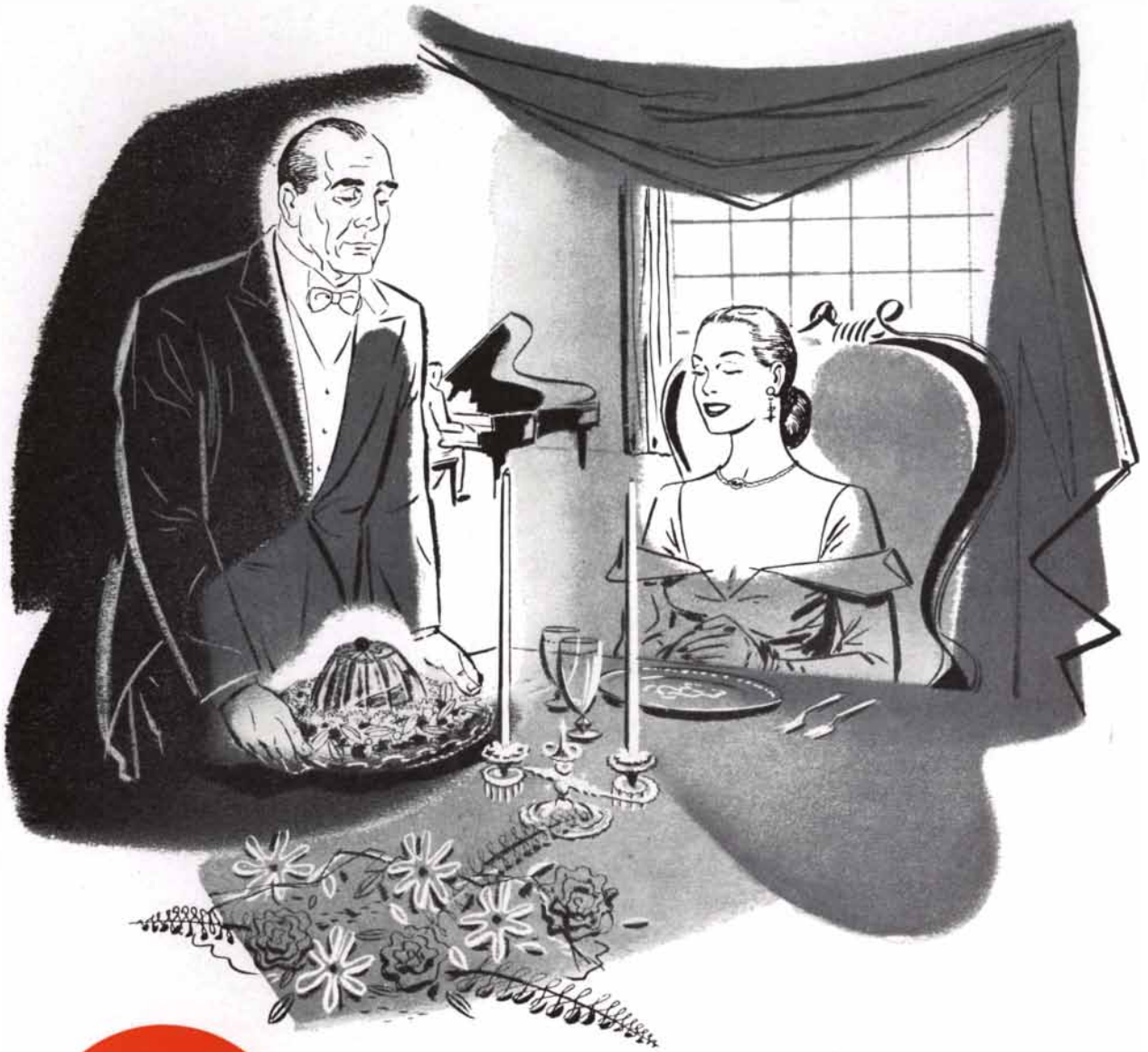
SICKLE-CELL ANEMIA

SICKLE CELL ANEMIA, A MOLECULAR DISEASE. Linus Pauling, Harvey A. Itano, S. J. Singer and Ibert C. Wells in *Science*, Vol. 110, No. 2865, pages 543-548; November 25, 1949.

A NEW INHERITED ABNORMALITY OF HUMAN HEMOGLOBIN. Harvey A. Itano and James V. Neel in *Proceedings of the National Academy of Sciences*, Vol. 36, No. 11, pages 613-617; November, 1950.

A MACHINE THAT LEARNS

AN IMITATION OF LIFE. W. Grey Walter in *Scientific American*, Vol. 182, No. 5, pages 42-45; May, 1950.



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