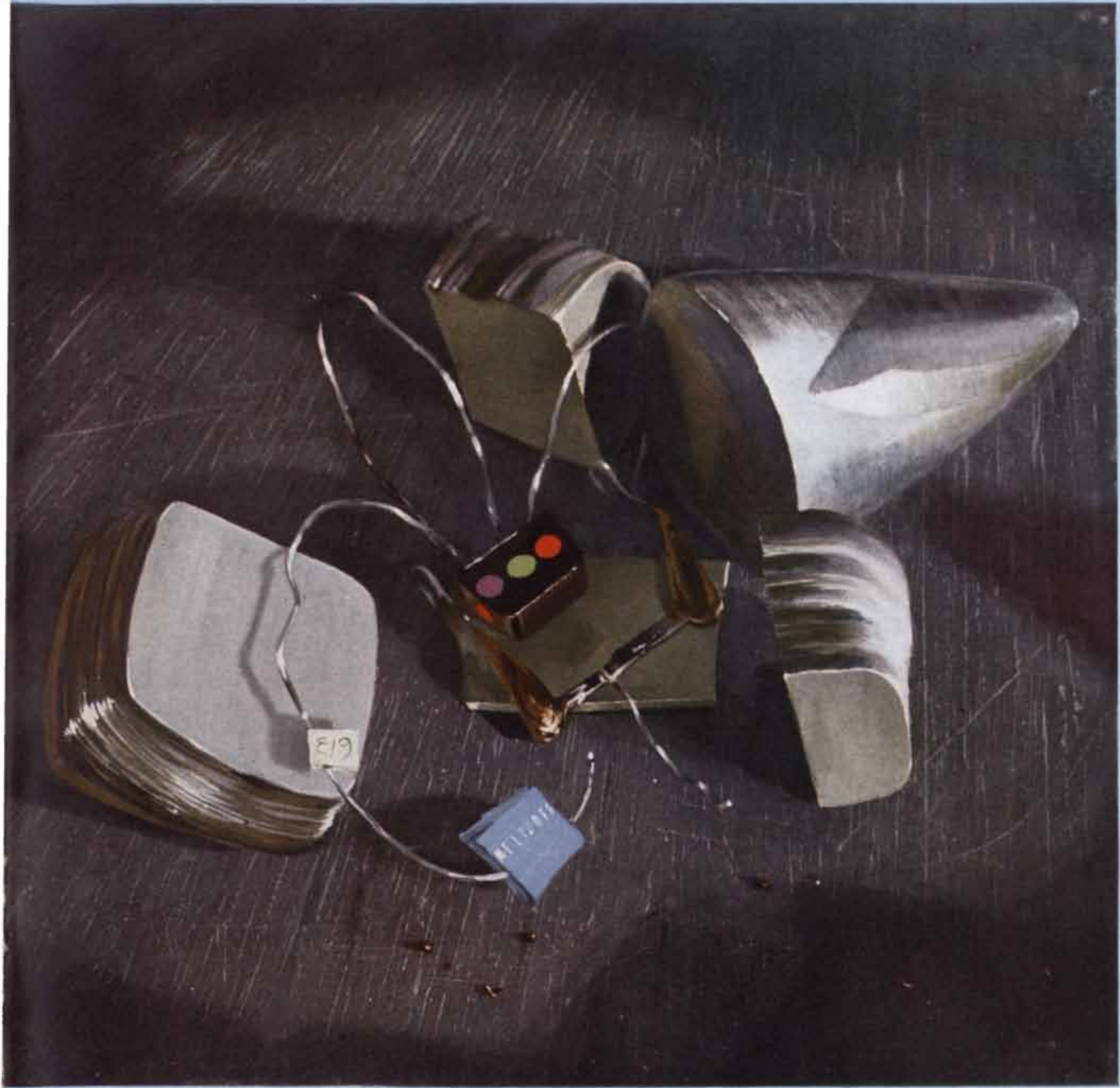
SCIENTIFIC AMERICAN

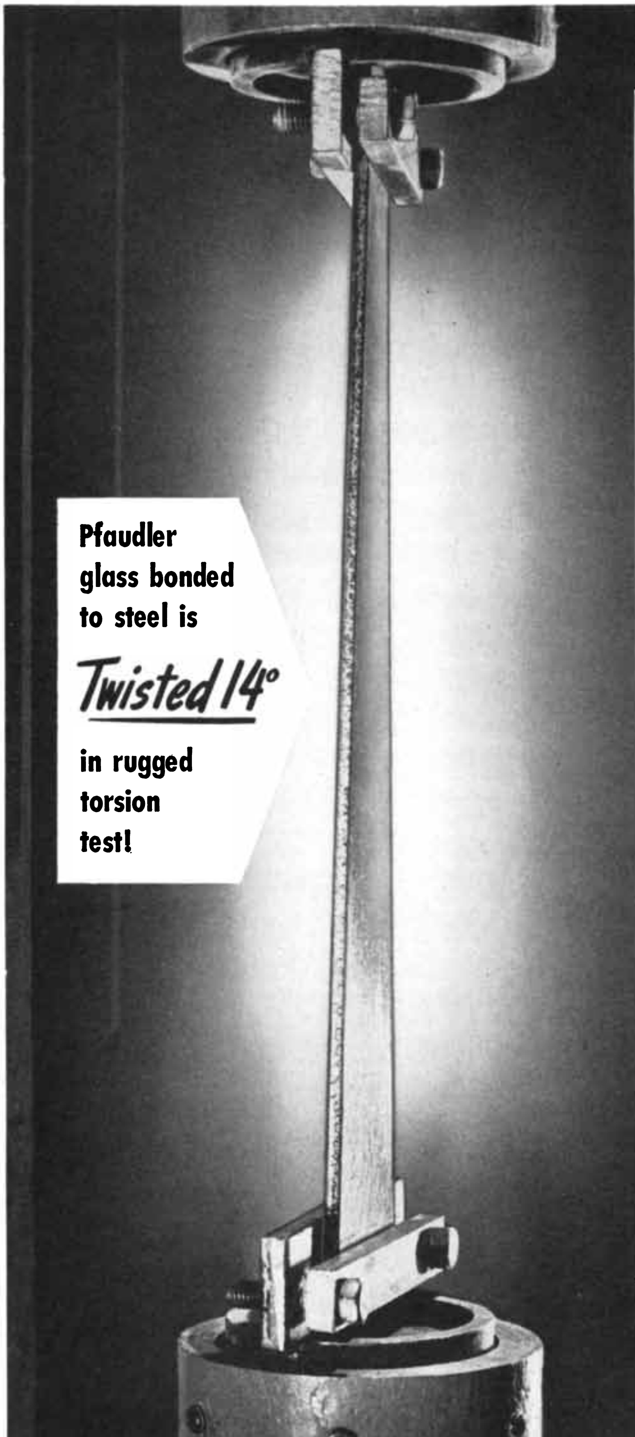


GERMANIUM AND TRANSISTORS

FIFTY CENTS

July 1952

The corrosion resistance of glass *plus* the working strength of steel



Torsion test reveals high durability of glassed steel

This glassed steel plate, twisted 14°, has been stressed beyond the elastic limits of the steel, yet the glass-to-steel bond and the glass itself remain 100% intact. This remarkable structural strength is due, in part, to the fact that Pfaudler glass and steel are *locked together by chemical action* during firing at temperatures as high as 2100° F. It also results from the toughening stresses which are built up within the glass as the vessel cools after firing.

Because it can be so durably bonded to steel, glass, with its *almost universal corrosion resistance*, is not limited to use in the laboratory alone. Today, glassed steel reactors in capacities up to 3500 gallons are commonplace in the chemical process industries and custom units as large as 8300 gallons have been constructed. These units are equipped with agitation, can be jacketed for heating and cooling, and are supplemented by a complete line of glassed steel accessories—valves, pipe and fittings, condensors, and the like.

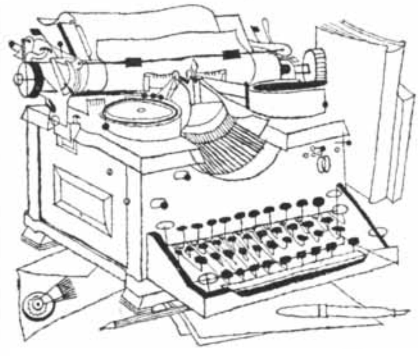
Even at elevated temperatures and pressures, Pfaudler glassed steel is *resistant to all acids except hydrofluoric*. And now, with a new Pfaudler glass, it is possible to handle *alkaline* solutions up to pH 12 and up to 212° F.—with no reduction in acid resistance. Thus it is possible to perform a wide variety of chemical reactions in a single glassed steel vessel.

Whenever you have an equipment problem requiring *corrosion resistance, durability, and versatility*, as well as the economy which these features make possible, look to Pfaudler glassed steel for the solution. Write for our general catalog today.

PFAUDLER

Engineers and fabricators of process equipment since 1884

THE PFAUDLER CO., ROCHESTER 3, N. Y.



LETTERS

Sirs:

I earnestly hope that the broadening of the scope of the section of *Scientific American* devoted to amateurs, as indicated by including articles about amateur scientific activities other than astronomy, will be a permanent policy. I think the choice of bird-banding for the discussion in your May issue is excellent. There are undoubtedly many other such amateur activities about which your readers would like to hear.

As one who has used bird-banding as a means of studying the blood parasites of birds, I should like to correct one possible misconception in your article. The statement "thus providing information on how malaria may be spread by bird carriers" might lead one to believe that human malaria can be spread by birds. The fact is that birds have many kinds of malarial parasites of their own and are not susceptible to attack by the parasites of human malaria. Many contributions to malariology have come about through the experimental study of malaria in birds. Not only have we been able to secure information on the distribution and incidence of malarial parasites of birds through the cooperation of bird banders, but in several instances strains of parasites—some of them representing new species—have been isolated by this method. Such strains in the hands of experimental malariologists have provided valuable additions to our general knowledge of malarial diseases.

CLAY G. HUFF

Naval Medical Research Institute
National Naval Medical Center
Bethesda, Md.

Sirs:

While reading the article in your April issue entitled "The Pacific Floor," I wondered if the origin of the "guyots," or flat-top mountains, in the Gulf of Alaska had definitely been established. The origin given in the article is water erosion during some prehistoric era, when the tops of the volcanic cones protruded above the surface of the water.

It is entirely possible that this origin is proven beyond any reasonable doubt. Being a layman in this subject I permit myself the liberty of suggesting another hypothesis of the origin of these flat tops.

It seems possible to me that the forces which sheared the tops of the mountains were the glaciers of the Ice Age. Thick as it was, the blanket of ice which covered the polar regions undoubtedly did not extend to the bottom of the polar seas, but rather floated on the water down to a certain depth. In its southward movement it would be natural for this ice sheet to grind off any protrusions from the sea bottom which were met on its way. The presence of rounded boulders around these flat tops, mentioned in the article, seems to give support to the above explanation.

PAUL NARBUT

Westinghouse Electric Corporation
Sharon, Pa.

Sirs:

The concept expressed in my article "The Pacific Floor" that the flat-topped sea mounts (guyots) were formerly islands which were truncated by surf action and subsequently deeply drowned is certainly not completely demonstrated.

Narbut's suggestion of truncation by floating ice is attractive in that it does not require any drowning of the guyots, but it seems to me that there are several objections to the hypothesis. First, I believe that we must rule out sea ice because in the present Arctic Ocean

Scientific American, July, 1952, Vol. 187, No. 1. Published monthly by Scientific American, Inc., 2 West 45th Street, New York 36, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer. Entered at the New York, N. Y., Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn.

Editorial correspondence should be addressed to The Editors, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

Advertising correspondence should be addressed to Charles E. Kane, Advertising Manager, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y.

Subscription correspondence should be addressed to Circulation Manager, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y.

Change of address: Please notify us four weeks in advance of change. If available, kindly furnish an address imprint from a recent issue. Be sure to give both old and new addresses, including postal zone numbers, if any.

Subscription rates for U.S.A. and possessions: 1 year, $5; 2 years, $9; 3 years, $12.50. Canada and Latin America: 1 year, $6; 2 years, $10; 3 years, $14. All other countries: 1 year, $8; 2 years, $12; 3 years, $16.

X-ray diffraction . . . the GE way . . .
takes the guesswork out of chemical analysis

X-ray diffraction is industry's most versatile method of analyzing materials. To make your investigations easier, faster, more exact — General Electric offers two x-ray diffraction units in its XRD line, with four standard combinations of components to meet all diffraction requirements. For complete information, see your GE x-ray representative, or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Rm. TT-7.

You can put your confidence in —

GENERAL ELECTRIC

For direct measurement of diffracted intensities. XRD-3D provides quantitative analysis of solid crystalline materials. As in all XRD units, appropriate accessories can readily be added for other technics.

For direct measurement of fluorescent x-ray spectra. The XRD-3S permits rapid quantitative analysis for chemical elements whose atomic number is greater than 22.

For diffraction with film technics. The XRD-4 has vertical x-ray tube axis that provides three ports for all common diffraction cameras.

For diffraction with film technics. The XRD-3F is intended for laboratories anticipating the inclusion of components for direct measurement of diffraction effects.

such ice has an average thickness of only about 12 feet. It is unlikely that sea ice could have grown much thicker than this even during the Ice Age. However, icebergs, which, of course, are formed from land ice, could easily have a draft of 1,500 feet or more. Allowing 400 feet for lowered Pleistocene sea level, it is probable that icebergs would strand and cause some erosion on sea mounts which rise to within about 2,000 feet of sea level. The platform depths of the Gulf of Alaska guyots lie between 2,400 and 6,900 feet so that they are probably too deep to have had icebergs stranded on them. Also I doubt that such erosion would produce a smoothly truncated surface eight miles across. In addition, one would expect the iceberg-cut guyots to have concordant summit levels, but the flat tops are present at a variety of depths. Finally, one would have to make the unlikely assumption that all the shallow but non-truncated sea mounts in the region are postglacial.

The presence of similar guyots in tropical parts of the Pacific where icebergs never reached (as indicated by the absence of ice-rafted debris in the bottom sediments) suggests that a more general theory is required. We have dredged mid-Cretaceous fossil coral from three of these, showing that the guyots were within a few fathoms of sea level in the Cretaceous. By fossil foraminifera we have dated another guyot in the northeastern Pacific as Miocene or earlier. Thus the truncation of the guyots appears to have taken place much earlier than the Ice Age.

The reason for the deeply drowned position of the guyots is certainly a knotty problem. My colleagues, Drs. E. L. Hamilton and H. W. Menard, and I are inclined to ascribe this dominantly to local subsidence of the sea mount by yielding of the crust to the great superposed load rather than to such causes as sea-level rise, great sea-level fluctuations, or to general sea-floor subsidence.

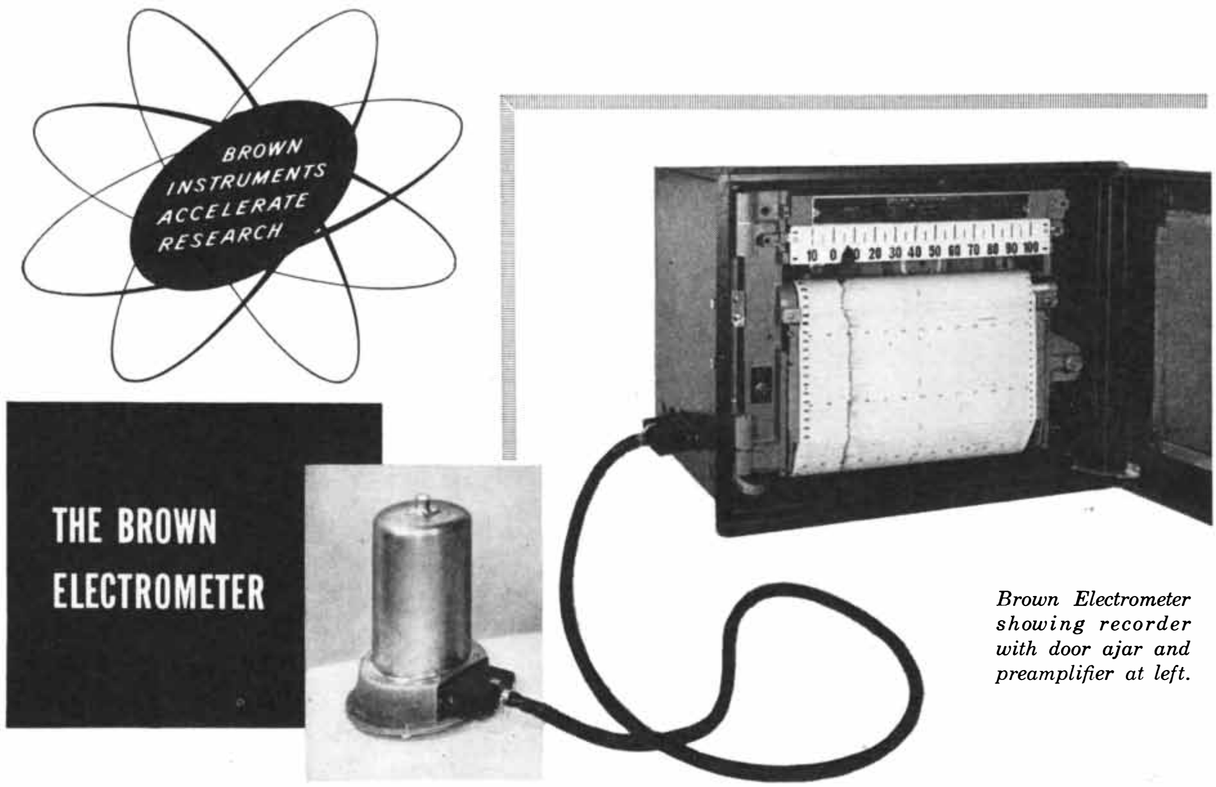
ROBERT S. DIETZ

U. S. Navy Electronics Laboratory
San Diego, Calif.

Sirs:

I enjoyed James E. McDonald's article on the Coriolis effect in your May issue, and I should like to add another interesting effect of Coriolis acceleration to those mentioned in the article.

The effect is a rather disagreeable one: seasickness. Sensitive people are affected by it if they ride in quickly moving vehicles such as elevators, cars, trains, merry-go-rounds, airplanes, ships, etc. If the person himself moves, he is subject to violent Coriolis forces which are said to be responsible for the feeling of seasickness. These are especially strong forces at sudden unexpected



Brown Electrometer showing recorder with door ajar and preamplifier at left.

for measuring and recording currents as low as 10^{-15} amperes

Electrical Characteristics

- Full Scale Current Ranges Available: 10^{-13} amperes with 10^{11} ohm resistor, and selector switch adjustment for full scale of 10^{-12} or 10^{-11} amperes. Using other resistors, full scale current ranges up to 10^{-7} amperes can be supplied with selector switch adjustment up to 10^{-5} amperes.
- Input Resistor: 10^{11} ohms for most sensitive current measurement. (Also supplied in values down to 10^{5} ohms.)
- System Accuracy: Approximately 1 per cent of scale.
- Zero Drift: Should not exceed 0.3 millivolt per day.
- System Noise: Approximately 5 microvolts.
- Instrument Speed of Response: Available for either 24, 12, or 4½ seconds full scale.
- Maximum Speed of Response Using 4½ Second Instrument Speed: 5 seconds for 90 per cent of change, with preamplifier located at source.
- Power Supply: 115 volts, 60 cycles. Also dry cell supplied in instrument.
- Power Requirements: 65 watts.

ACCURATE measurement of extremely small currents is accomplished in this instrument through the use of a null balance servo system and a-c amplifiers that prevent drift and consequent instability. It is the only such system that incorporates a recorder as an integral part of the circuit. Designed to measure and record minute currents in ionization chambers, the Brown Electrometer may be used in any application where currents as low as a billionth of a microampere are encountered.

Features of the instrument include a special power supply to prevent false measurements from stray signals which might originate in an a-c power source . . . vibration frequency carefully selected to prevent phase shift . . . and automatic standardization of voltage across the slide-wire.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4580 Wayne Ave., Philadelphia 44, Pa.

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

H HONEYWELL

First in Controls

● *Important Reference Data*

Write for Data Sheet No. 10.0-4 . . . and for Bulletin No. 15-14. For valuable information on analytical and research instrumentation.

accelerations, as in sudden stops or starts, turns, sudden lifts or drops, the uncontrollable movements of a rolling or pitching ship. Lying perfectly still minimizes the effect; even the movement of a hand causes individual Coriolis acceleration.

HUGO MANDELBAUM

Department of Geology
Wayne University
Detroit, Mich.

Sirs:

Regarding the article about the aerodynamics of birds in your April issue, I have myself looked into some of the dynamics of animal flight, and some very interesting questions arise. For example: what *power* is developed by a running animal or by a bird in flight, or by a jumping frog or flea, or by a swimming marine animal, say a whale? Also how do birds in long, uninterrupted migratory flights obtain the energy they need?

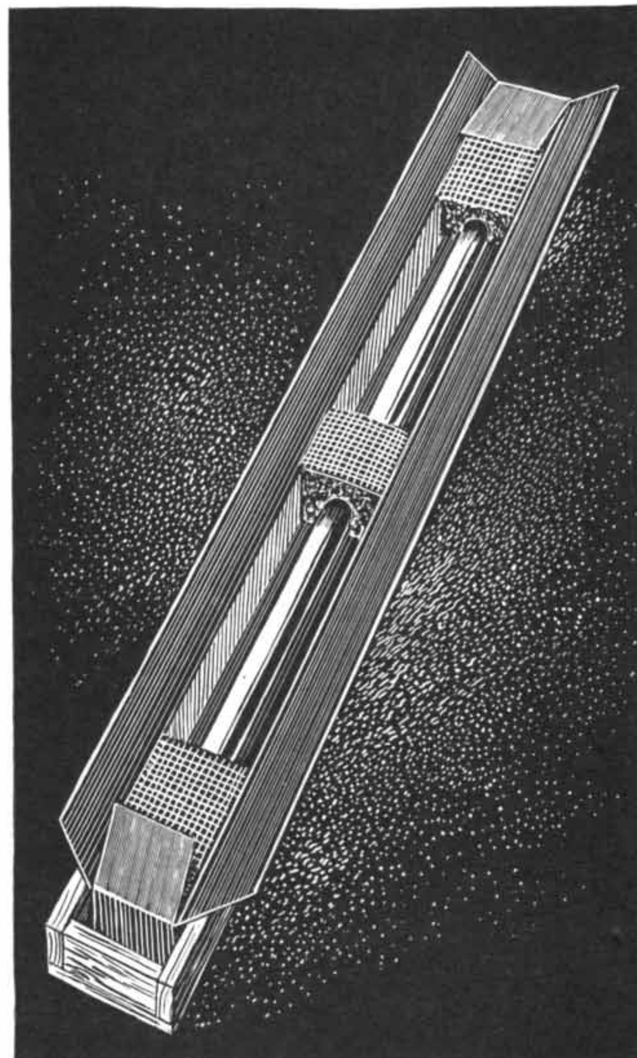
The hummingbird, flying, say, at 60 miles per hour, moves its wings about 100 times per second. The horsepower developed, reckoned per unit of body weight, is staggering. The hummingbird weighs only about two grams. The stork, on the other hand, moves its wings about two or three times per second. These frequencies turn out to be roughly the inverse of the cube root of the weight.

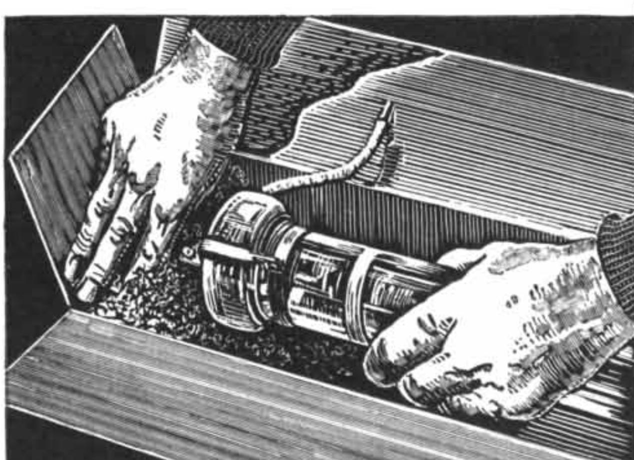
Fundamentally it is muscle behavior that governs animal motion, and this in turn is regulated by oxygen consumption. When this line of inquiry is pursued another astonishing notion creeps in. Oxygen consumption governs energy availability; the proportion is nearly linear. In turn, oxygen consumption is proportional to blood flow. An animal, then, whose linear dimensions are 10 times that of another has 1,000 times the blood-volume flow, and the velocity of the blood is 10 times as great. Here Bernoulli's principle enters my thinking, and it seems that the pressure difference between heart and artery in the large animal must be 100 times as much as in the small one. This is quite impossible.

Lastly, the kinetic energy of a limb of an animal (a wing, say) is governed by the mass and the square of its velocity. The mass of the limb varies as the cube of the linear dimension. If two similar animals performed similar movements of similar limbs in the *same* time, the kinetic energy developed would go up as the fifth power of the limb dimension. This would be a flagrant waste of energy and hazardous to the animal!

JULIUS SUMNER MILLER

Division of the Natural Sciences
Dillard University
New Orleans, La.





50 AND 100 YEARS AGO

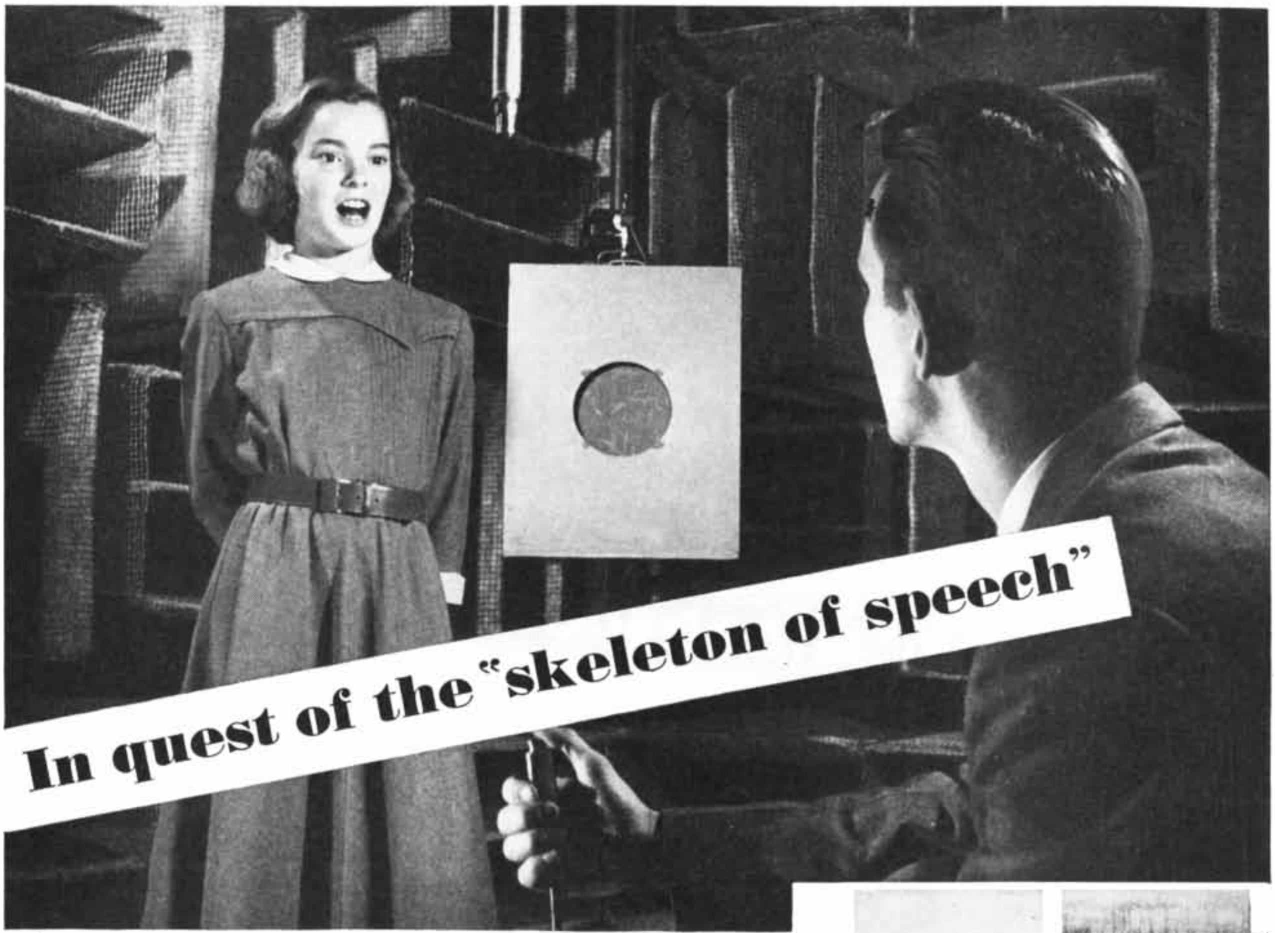
JULY, 1902. "Much satisfaction was expressed at the Great Barrington meeting of the American Institute of Electrical Engineers that the government has now established a Bureau of Standards which is conducted in harmony with electricians. One important matter which the Institute leads off in establishing without awaiting governmental or other sanction, but confident that its action will meet general approval and command universal acquiescence, is the fixing of a standard for candle power. After full discussion the recommendation of the committee was approved; and the standard, as far as the Institute can fix it, makes the Hefner equal 0.88 British candle, as the ratio of horizontal intensities. The Hefner-Alteneck amyl-acetate lamp is—says the report—in spite of its unsuitable color the standard luminous source generally used in accurate photometric measurements."

"Now that the submarine boat has fully justified its existence as a potential fighting factor which will exert a far-reaching influence upon naval battles of the future, efficacious destroyers are being sought for the purpose of nullifying its power and operations. A destructive machine for this purpose has been contrived by an English inventor, Mr. Gardner of London. The basis of his apparatus is an application of the transmission of ether waves. Mr. Gardner has contrived a small submarine whose movements are controlled by wireless telegraphy from a fixed point, such as the deck of a battleship. When the key of the transmitter is set in action, the ether waves are arrested by a receiver upon the weapon, and conveyed to a small electric motor, which is thus set in motion. It must be explained, however, that the energy for propelling the motor is not transmitted through the air, but the etheric waves control the action of the energy upon the little craft. The motor in turn drives a centrifugal governor. As the speed of the governors is increased, the force so generated is communicated to a series of switches, each of which represents an action to be controlled. By means of a chart the operator is guided in his manipulations of the transmitting key, in order to deviate his weapon from the straight course either to the right or left. Directly the pursuing boat comes within sufficiently close range, the operator opens a switch, and the 200 pounds of guncotton which the small crewless submarine carries is detonated."

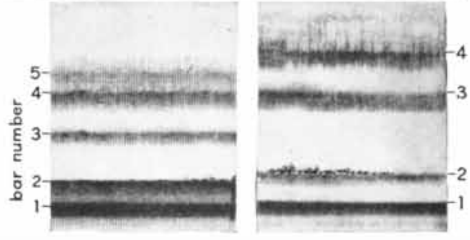
"M. Charles Nordmann, in a paper read before the Académie des Sciences, gives an account of some experiments which he made at the Mont Blanc observatory in order to determine whether waves of an electro-magnetic nature are given off by the sun. It seemed possible that a source of luminous and calorific energy should emit electro-magnetic waves, as these are now recognized to be of the same nature. But all the results were negative. This seems to prove that the sun does not emit such electro-magnetic waves as can be propagated along a wire and act upon a coherer; or in the contrary case such waves must be absorbed by the sun's atmosphere or the upper atmosphere of the earth."

"One of the most trenchant opinions which has been delivered in some time on the subject of pure science in America, comes from the pen of Prof. Carl Barus of Brown University. Among other things, our self-distrust is sharply criticized. We are not quite certain that we have among us a great savant until we are told so by foreign scientists. For Americans the aristocracy of science resides in England, although it cannot be denied that the Continent too has its attractions. Prof. Barus tells us that our scientific men are apt to outgrow first the American Association, then the National Academy, and finally even their own country. The question arises: Can we ever hope to reach intellectual maturity in the eyes of the world if we belittle the dignity of our own institutions? Self-confessed incompetency, says Prof. Barus, may be a virtue, but one should at least first be sure that the incompetency really exists."

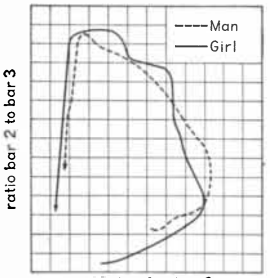
JULY, 1852. "The time will come when the earth will be belted by the electric wire, and New York will yet be able to send the throb of her electric pulse through our whole continent, Asia, Africa, and Europe, in a second of time. Telegraphing is but in its infancy: it is only eight years since the first telegraph line was erected in our country. Since that time the telegraph has made many triumphs, and at the present moment there are no less than 15,000 miles of telegraph lines. Mr. Alexander Jones believes that it will yet supersede the Post



In the famous Quiet Room at Bell Laboratories, this young volunteer records speech for analysis. Scientists seek to isolate the frequencies and intensities which give meaning to words . . . stripping away non-essential parts of word sounds to get the basic "skeleton" of speech.



Spectrograms of young girl's voice (right) and man's voice making "uh" sound as in "up." Horizontal bars reveal frequencies in the vocal cavities at which energy is concentrated. The top of the picture is 6000 cycles per second. Pictures show how child's resonance bars are pitched higher than man's.



The word "five." Graph shows ratio of frequency of spectrogram bars. The solid line is for a girl and the dotted line is for a man. Note the similar patterns despite pitch differences. Human hearing extracts the speech sounds from this sort of pattern in the identification of words. Scientists aim at machines that can do the same.

A child or an adult . . . a man or a woman . . . an American or an Englishman—all speak a certain word. Their voices differ greatly. Yet listeners understand the word at once. What are the common factors in speech which convey this information to the hearer's brain?

Bell scientists are searching for the key. Once discovered, it could lead to new electrical systems obedient in new ways to the spoken word, saving time and money in telephony.

Chief tool in the research is the sound spectrograph which Bell Telephone Laboratories developed to make speech visible. Many kinds of persons record their voices, each trying to duplicate an electrically produced "model" sound. While their voice patterns are studied, a parallel investigation is made of the way human vocal cords, mouth, nose and throat produce speech.

Thus, scientists at Bell Laboratories dig deeply into the fundamentals of the way people talk, so that tomorrow's telephone system may carry your voice still more efficiently—offering more value, keeping the cost low.

BELL TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields.

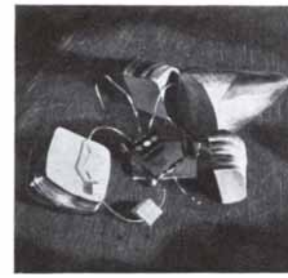
Office, and although we are not so enthusiastic, we will not pretend to deride the idea, for it has, in a measure, done so already. While Daniel Webster a few weeks ago was speaking in Faneuil Hall, those who sat listening to his voice had only that advantage over others in distant cities, for as the words were falling from his lips in Boston, the electric telegraph was recording them for the printer at the same instant in New York."

"Although a great deal has been said upon the subject of ventilating railroad cars, and although a number of patents have been taken out, for the purpose of effecting this object, the evil, so far as the cars and their owners are concerned, is just as ugly and glaring as ever. There is not a single railroad connected with this city that is fit to travel on so far as cleanliness and ventilation are embraced as objects of comfort. It is really afflicting to ride on the Hudson River Railroad at present. The passengers, when they land in Chambers Street, look as if they had been working all day in a plaster mill; their clothes are spoiled, and in every sense of the word they look as if they had been doing some dreadful penance."

"Two or three years ago, experiments were made by members of the London Faculty Physicians, in different hospitals, for the cure of diseases of the lungs, by breathing in warm medicated vapors. The success of the experiments was so gratifying that an institution, the Brompton Hospital, for the cure of bronchitis and consumption, was immediately established, and so favorable has been the result of the treatment that the number of patients admitted during the past year is between two and three thousand, and the Hospital Report shows that full seventy-five in every hundred have been completely cured."

"What do we know of flame, excepting this: 'It is the exhibition of a certain action of certain substances, such as carbon, hydrogen, and oxygen.' We are in the dark, yet, respecting one of the most common and simple chemical phenomena. Actinism, and the recent discoveries of the properties of different colored solar rays, are enough to incite philosophers to investigate this subject with great diligence. We are still ignorant of solar light—that is, how it is produced."

"The public press records the appearance and prevalence of epidemic cholera at various places in the southern and western portions of our country, and a recent outbreak on board the steamship *Philadelphia,* on her passage from the Isthmus to Havana, has increased public anxiety lest another visitation of the dreaded and fatal pestilence should reach our Atlantic cities."



THE COVER

The painting on the cover is a still life of germanium and the transistor, the new electronic device that is made from it (*see page 28*). The silvery metal objects are parts of a single germanium crystal that has been cut apart to make transistors. Lying on the flat section of the crystal from which these devices are cut are two transistors. The lower of the two is an experimental transistor mounted between two wires. The upper is sealed in a block of plastic.

THE ILLUSTRATIONS

Cover painting by Stanley Meltzoff

Page	Source
17-18	Courtesy Victor W. von Hagen
19	John Tremblay
20-21	Courtesy Victor W. von Hagen
23-25	Fogg Art Museum, Harvard University
26	Fogg Art Museum, Harvard University (*top left, top right, bottom left*); Daniel Cushing (*bottom right*)
27	Fogg Art Museum, Harvard University
28-31	Irving Geis
32	Keturah Blakely
34	Brookhaven National Laboratory
46	Boyden Station, Harvard College Observatory
47	Copyright *The Friend*, Bloemfontein, Union of South Africa
48-49	James Egleson
50-57	Boyden Station, Harvard College Observatory
59-61	Eric Mose
62	Atomic Energy Commission
63-66	Sara Love
68-69	Copyright H. G. Vevers and the Marine Biological Association of the United Kingdom
70-74	Courtesy Samuel R. M. Reynolds, Carnegie Institution of Washington
82-87	Roger Hayward

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR JULY, 1952 VOL. 187, NO. 1

ARTICLES

DEPARTMENTS

What's Happening at CRUCIBLE

about REXWELD hard-surfacing rod

The general use of hard surfacing consists of overlaying the work piece with a different alloy. This is done to improve the properties of a specific area of the work piece from the standpoint of resistance to abrasion, heat, corrosion, or a combination of these properties. Hard surfacing rods of the Rexweld type are ordinarily never recommended for joining, but only for overlay on such products as valves, oil pump parts, mixer shafts.

here's how REXWELD is made

Rexweld, a very high alloy material, is melted in small furnaces. It is tapped into small ladles and poured into molds in sizes of ⅛″ diameter and larger. Prior to processing the rod further, each heat is thoroughly tested for weldability. After test, the rod is cut off with an abrasive wheel and ground. It may be shipped flash ground or centerless ground for gas welding. If long lengths are required for automatic or semi-automatic gas welding, the rod is butt welded to the desired length. For arc welding, the rods are coated and tested for arc weldability. After finishing,the rod is marked to identify grade and is ready to ship.

here are some REXWELD features

Cut welding time: Rexweld builds up and holds an edge better, reducing the amount of welding time.

Increase production: Rexweld flows more readily on flat surfaces. In machine gas welding operations valve companies have reported an increase in production per shift using Rexweld.

Less porosity tendency: Because of its smoother flowing and better wetting properties Rexweld has less tendency for porosity.

Better wearing quality: Tests have shown that Rexweld has better wearing qualities.

REXWELD ups die production 10 times

A well-known Chicago forging concern employs a hot-working upsetting operation that consists of upsetting a 2″ piece of round stock 4″ long to a 1¾″ thickness with a 4″ OD. This blank is then hot formed and trimmed; made ready for machining into an automotive transmission gear. Before hardfacing with Rexweld, the company averaged 4,000 to 5,000 pieces per set of upsetter plates. With Rexweld the upsetter plates turned out 45,000 pieces. Then, the plates were removed, re-hard surfaced and used again!

This concern is also using Rexweld for building up cutting edges for intricate hot-work blanking dies, such as the male and female cutting edges of a seven-fingered star-shaped die set. Due to the intricacy of the dies, it is very difficult to build up cutting edges eliminating check cracking which would cause spalling deposits, but Rexweld is doing it every day at this plant.

engineering service available

If you are looking for ways to increase the life of your tools and production equipment, or you have a problem that hardsurfacing can solve, feel free to call in Crucible. Our hardsurfacing and welding specialists can help you. Crucible Steel Company of America, General Sales and Operating Offices, Pittsburgh, Penna.

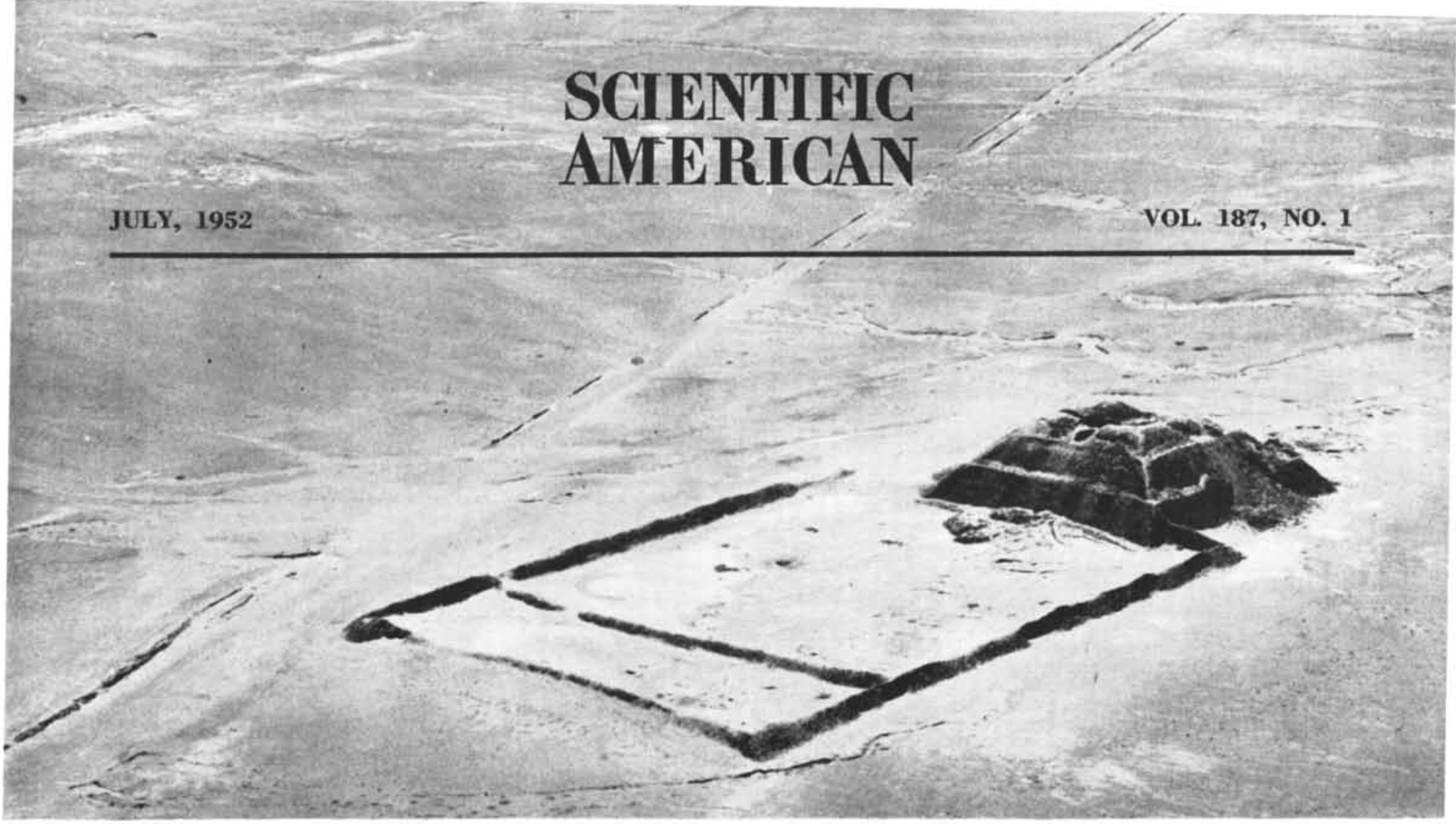
CRUCIBLE first name in special purpose steels

52 *years of Fine steelmaking*

Midland Works, Midland, Pa. • Spaulding Works, Harrison, N. J. • Park Works, Pittsburgh, Pa. • Spring Works, Pittsburgh, Pa. National Drawn Works, East Liverpool, Ohio • Sanderson-Halcomb Works, Syracuse, N. Y. • Trent Tube Company, East Troy, Wisconsin

SCIENTIFIC AMERICAN

JULY, 1952 VOL. 187, NO. 1



SEACOAST HIGHWAY of the Incas runs past a pyramid in the Peruvian desert of Chicama. Here the road is 30 feet wide. On either side of it are adobe walls that were built to keep the sand from blowing over the road.

America's Oldest Roads

The highways of the Incas, which are in many respects more impressive than those of the Romans, are now to be explored for the light they shed on the life of the Peruvian empire

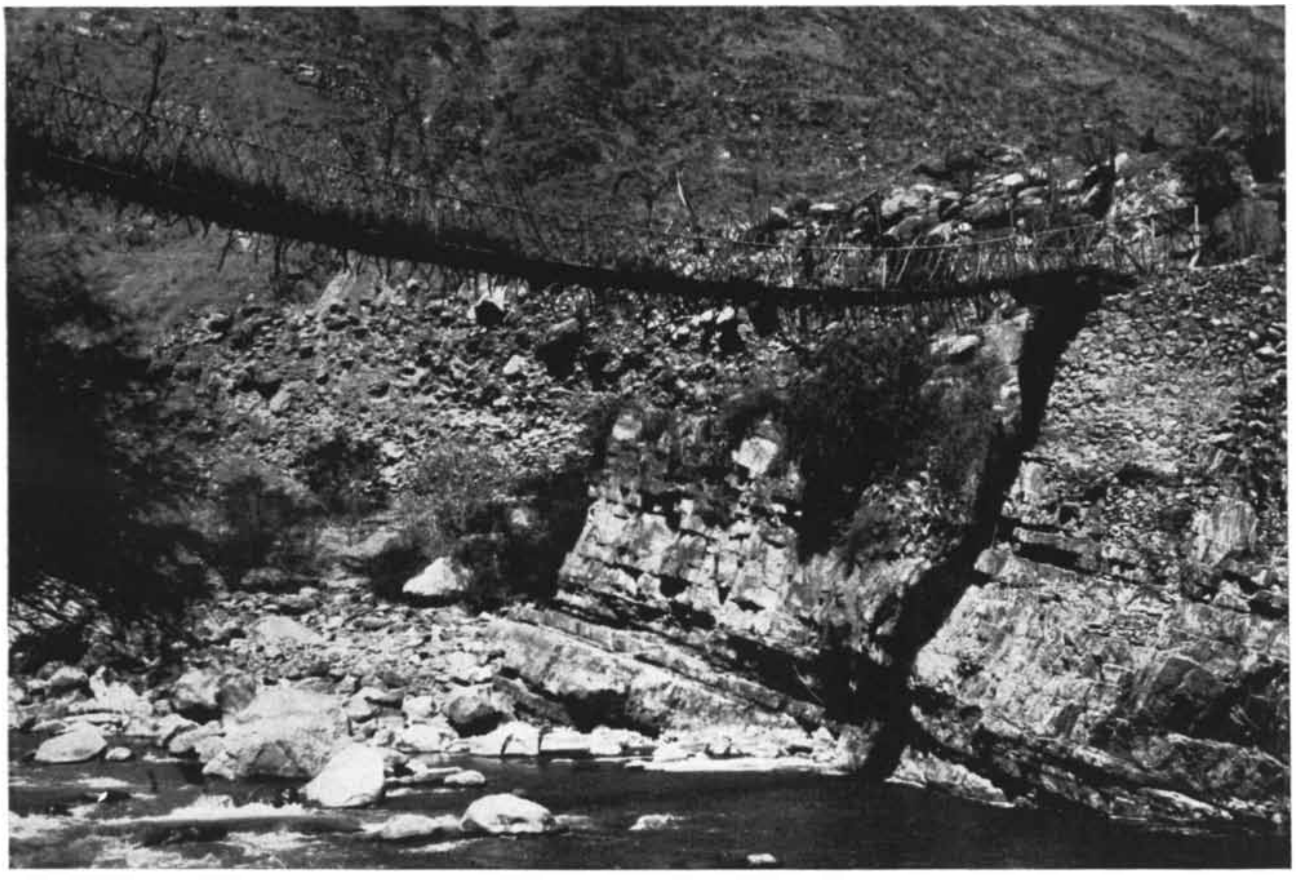
by Victor W. von Hagen

THE BRIDGE of San Luis Rey, which snapped its cables on the morning of July 20, 1714, and hurled a company of travelers into the gorge of the Apurímac River below, was part of a road system that is one of the wonders of human history. This 200-foot suspension bridge and hundreds of others like it had been built by the ancient Incas of Peru to carry their fabulous roads over the abysses of their mountainous empire. The Incas had a network of 10,000 miles of paved highways, stretching from Chile to Colombia and from the Pacific across the Andes to the jungle headwaters of the Amazon, that ranks with the road systems of Rome, Persia and other ancient empires. Though far less celebrated than the famous roads of Rome, the Inca highways are in many respects even more remarkable. A century and a half ago the explorer Alexander von Humboldt, retracing the remnants of the Inca roads, rapturously pronounced them "the most stupendous and useful works ever executed by man."

All great conquerors have perforce been great road builders, and when an empire dies, its roads may be its most durable and revealing monument. Much that we know of the political and social structure of the Roman empire we learned from the Roman roads. The Inca highway system, which so far has been little studied, may similarly hold answers to many of the still unanswered questions about the Inca civilization: its engineering and commerce, its geographical and political organization, its relations with the tribes conquered by the Inca rulers. Within a few months an expedition under the author's direction will begin a two-year exploration of the ancient Peruvian roads to seek light on these questions.

There was a period of some 400 years (before Napoleon reconstructed the Roman roads in Europe) when the royal road of the Incas was, so far as we know, the only decent highway system in the world. For centuries the culture of Europe was literally bogged down in mud, and it was said that a traveler needed

INCA CAPITAL of Cusco was the focus of the roads. Shown here in the center of the city is the Square of Huakypata that has survived since the time of the Incas. From it roads ran to the north, south, east and west.



SUSPENSION BRIDGE across a stream in the Andes is typical of the larger structures that were built by the Incas. The bridges were suspended from heavy cables of vegetable fiber that were anchored to stone piers.

"a falcon's eye, an ass's ears, a monkey's face, a merchant's words, a camel's back, a hog's mouth, a deer's feet" to survive his journey. By contrast, in South America during that period Inca couriers were carrying messages from Quito to Cusco, a distance of 1,500 miles along the ridges of the Andes, in five days. What makes the ancient Peruvian road unique, however, is not its extent nor its excellence but the fact that it was built by a people who had never heard of the wheel. The Incas built the greatest footpath in history.

It is not to be supposed from this that the Peruvian system was an affair of mountain tracks and jungle trails. It was built broad, straight and solid, and it carried a heavy traffic: llama trains laden with produce and tribute and gold, soldiers on their way out to guard or extend the boundaries of the realm, relays of messengers trotting from one center to another on a schedule not unlike the pony express of the American West.

IN MAIN PLAN the Peruvian road system took the form of two parallel turnpikes—one along the ocean, the other high in the mountains. The two roads, running the length of the empire, were connected at intervals by laterals that knifed through the hills at terrifying grades. The coastal road, 30 feet wide, ran 800 level miles through a desert so dry that rain falls there only once in 25 years; it was bordered on either side by a waist-high wall of sun-baked adobe to hold back the drift of sand. The mountain road, about 15 feet wide, traversed territory of such overpowering difficulty that its engineering feats were not duplicated until the railroad builders of the 19th century opened up much of the same region.

The Inca construction engineers followed a simple rule in laying out their roads: they ignored all obstacles and ran their lines over the shortest route, straight across the face of the land. Over marshes the road became a causeway, so well built that parts of it are still in use. When the road came to a lake, it was securely floated on balsa pontoons. When it came to a chasm, the engineers flung a bridge across it. They made no concession to steep rock walls; when they encountered one, they either tunneled right through it or cut steps and went over the top. And all this was built in a clime as inhospitable as the moon—at an average altitude of about 13,000 feet, where the thinness of the air exhausts men and the glare of the sun on the snowcaps blinds them. The labor gangs that built the road were drafted from the villages along its route, and the state levied a special tax (in produce; the Incas had no money) for the road's maintenance.

Perhaps the greatest achievements of the Inca engineers were their suspension bridges. These spans look gossamer-frail, but they were strongly made of six-inch fiber cables anchored in solid masonry and laid with a floor of wooden laths lashed together and covered with coarse matting. Marvelously well wrought also were the paved sections of the roads near cities; the paving blocks, laid without mortar, fitted so perfectly that a knife blade could not be forced between them.

At intervals of 4 to 12 miles along the entire 2,000 miles of the system, the engineers put up wayside houses—like the refreshment stations along today's turnpikes. These large, single-roomed caravanserais were always stocked with food and kept in repair against the weather. There was also a separate chain of posthouses, maintained for the royal messengers, who were specially selected and trained to travel at high speed in the thin atmosphere.

In 1545 a young Spanish soldier named Pedro Cieza de Léon rode the whole length of the main road. He kept a travel diary on the journey, and it is from his notes that we know so much of what the system was like at the time of the Incas. Cieza de Léon began his journey at Quito, near the northern terminal, and traveled south 2,000 miles over the mountain route, stopping nights at the roadhouses. He describes these houses as being "the width of 21 feet and the length as much as a horse's gallop, all made of stone, embellished with huge wooden beams, over which a straw-thatch is laid with much skill." He found that where the "mountains were rocky, the road was made in steps, having great resting places and paved ways which are so strong that they will endure for many ages." Approaching the bridge of San Luis Rey over the Apurímac, the road was "much broken by mountains and declivities so that those Indians who constructed it must have given much labor in breaking up the rocks and leveling the ground, especially where it descends to the river. Here the road is so precipitous that some of the horses, over-

PRINCIPAL ROADS (*solid red lines*) ran along the seacoast and through the Andes. At several places the systems were connected (*dotted lines*).

laden with gold and silver, have fallen in without the possibility of their being saved. There are two enormous stone pillars to which the bridge of the Apurímac is secured." Throughout the whole extraordinarily hostile terrain, the young traveler noted that the road was "level and paved, along mountain slopes well excavated, by the mountain's edge well terraced, through the living rock cut, along the rivers supported by walls, in the snowy heights with steps and resting places, in all parts clean, swept clear of debris, with stone storehouses and temples of the sun set at intervals."

THE BUILDERS of this road, the Inca rulers, came from a tribe that had lived on the shores of Lake Titicaca. They were large-lunged, short, stocky Indians with coarse jet-black hair and jet-black eyes set at a Mongolian slant. They cultivated the bean, the potato and other tubers, and built their houses of adobe and their temples of well-cut stone. The Incas were originally only one small tribe among many spread up and down the range of the Andes. Then in the 11th century, about the time of the Battle of Hastings, this tribe began to expand. By the year 1200 they had moved into a large fertile valley north of their birthplace and had built their first city, which they called Cusco. There the dynasty of the divine Incas was established, and from their capital the Peruvians spread out steadily for a period of 300 years. One after another the smaller Andean tribes tumbled into the empire, until by 1500 the Incas controlled a vast region, now occupied by Peru, Ecuador, Bolivia and substantial parts of Chile, Argentina and Brazil.

The Peruvians built their cities mostly of stone. They perched fortresses on the mountaintops, and from the profits of empire they raised sun temples whose exteriors were faced with beaten gold. They greatly extended the fertile terraces on the slopes of the Andes, inherited from an earlier culture, and built large, complicated irrigation systems to water them. Granaries against famine were spotted throughout the realm. And wherever the Inca extended his empire, his road followed the conquest. It became at last a gigantic network weaving the disparate regions of South America —the desert coast, the high Andes and the humid jungle—into a unity of empire.

All the great roads of antiquity are somewhat akin: they were all royal roads, built at the command of the ruler, dedicated to the service of the ruler and traveled upon only by permission of the ruler. Roads began to appear in Asia Minor soon after the wheel was invented around 3500 B.C. By 1200 B.C. road engineers were attached to the army of the Assyrians and built a road "made shining like the light of day" for military and ceremonial purposes. The royal road to Jehovah in the Talmud had bordering trees pruned to the height of a camel's head; Herodotus knew from old documents that Darius in the fifth century B.C. built a stone-paved road from Susa to Babylon and that on it the journey was marked by milestones and broken by posthouses. Egypt began her formal roadbeds—as did the Incas—by building them to the stone quarries. By the 12th century B.C. Ramses II had run them throughout Egypt. In Karnak there was a stone avenue lined by sphinxes and lotus-crowned columns and "glistening with marigolds at its sides."

It was the Romans, however, who wrote the great epic of road building in the ancient world. As early as 500 B.C. Roman tracks and gravel beds were common, and by 100 B.C. the double pressure of conquest and commerce had developed the system to the point where highways spread throughout Italy, Asia Minor and into the kingdom of the Franks. The Roman roads and the Inca roads were much alike: both systems had night stations at approximately the same intervals, both were kept up by public levies and both were so well constructed that extensive sections of them today provide the beds for modern highways. However, unlike the Romans, who allowed everyone to travel freely over their highways, the Incas reserved theirs for royalty's purposes; common people traveled on them only at the monarch's pleasure and had to use separate bridges, paying a toll each time for the privilege.

LIKE THE ROMANS, the Incas built their roads primarily for conquest, then for tribute and finally for commerce and communication. In the end their superb highway system became the avenue for easy conquest of the Incas themselves. The Spanish invader found the Incas' excellent roads an open route to the heart of the country. After the coming of the *conquistadores* in 1537, the main Inca road fell rapidly into disrepair. Its destruction was begun by heavy Spanish oxcarts (for which the road was not intended), was continued by the beat of horses' hoofs, and was made permanent by lack of upkeep. The Spaniards, intent on funneling out the riches of the country, were interested primarily in the laterals that would take them quickly out of the mountains and down to the rivers and the sea.

When Cieza de Léon traveled over the road eight years after the conquest, Cusco was still the center of Inca culture and the main source of wealth for the Spaniard. It was also the hub from which the road's branches spread out through the empire. The land, Cieza de Léon noted, "was called *Tahua-ntin suyu*—literally, the-land-of-the-four-directions." Toward the end of his journey, this conscientious soldier burst out: "I believe that since the history of man has been recorded, there has been no account of such grandeur as is to be seen in this road which passes over deep valleys and lofty mountains by snowy heights and over falls of water, through living rock and along the edges of furious torrents. . . . Oh, what greater things can be said of Alexander or of any of the powerful kings who had ruled in the world, than that they have made such a road as this and conceived the works which were required for it!"

CULVERT in Cusco shows how the Incas built these structures. Although the Incas did not possess the wheel, their highways were paved with fitted stones.

Victor W. von Hagen is the author of The Four Seasons of Manuela *and numerous other books about the history and archaeology of South America.*

GREAT WALL runs up into the Peruvian highlands near the Veru River. The wall marked the boundary between the Inca empire and Chimu kingdom. In the 15th century the Incas attacked and absorbed the Chimus.

SCIENCE IN THE ART MUSEUM

The modern scholar uses some ingenious physical and chemical methods to explore old paintings and other works of art, tell how they were made and protect them from the erosion of time

by Rutherford J. Gettens

WHAT a visitor sees at a museum of art is paintings on the walls, statues on pedestals, small, precious or fragile objects in glass cases and a few solid-looking men in uniform loitering about to see that no one tampers with the attractions. Except for refinements of lighting or display, art galleries still look much as they always have. But behind the scenes great changes have been taking place in the last 50 years. The old atmosphere—part curiosity shop and part ivory tower—has been swept away, and the working area of almost any large museum today is a complex laboratory manned by a varied group of scientists, researchers and technicians. Since many of the important modern collections were established after 1900 and have thus grown up in an age of science, it is not surprising that scientific method should have found its way into the art gallery.

Science is applied to art with most spectacular results when it is used to authenticate a disputed masterpiece or to expose an ingenious forgery. Detective work of that kind is as entertaining to the layman as it is satisfying to the expert. But sleuthing is neither a frequent nor the most important aspect of the art scientist's role. He is concerned primarily with investigating the methods and materials of early schools and masters, with repairing and restoring the objects that come into his care and with protecting them from their own internal weaknesses and the slow erosion of time.

Chemical analysis was first associated with art toward the end of the 18th century, when investigators in England, France and Germany published studies on the composition of Greek and Roman coins and other ancient artifacts. These pioneer researches were the foundation of a science now known as archaeological chemistry. In 1890 the English chemist A. H. Church, who had made a specialty of the subject, published a classic work called *Chemistry of Paint and Painting*, and at about the same time E. Raehlman in Germany and A. P. Laurie in England began the scientific study of paintings by microscopic and microchemical methods.

At about the turn of the century the administrators of large museums began to realize that the care of their growing collections involved technical problems which could be handled only by trained experts. Just before World War I a chemical laboratory was established in the Berlin Museum, and shortly thereafter a similar department was set up in the British Museum. These early laboratories were concerned mainly with the preservation of antiquities of stone, iron, bronze, ceramics, wood and fabric; paintings were still entrusted for the most part to "restorers."

One of the first American institutions to undertake the systematic analysis and preservation of paintings was the Fogg Museum at Harvard University. In the 1920s the Fogg's director, Edward W. Forbes, was founding what has become the finest university art collection in the U. S., and along with the paintings he brought together a technical staff to study and care for them. This group, headed by George L. Stout, formed a Department of Conservation which developed a system for scientific examination of works of art, especially painting. Similar departments have since been established at the Museum of Fine Arts in Boston, the Metropolitan Museum in New York, the Brooklyn Museum and elsewhere.

BROADLY SPEAKING, there are two main ways of examining a picture—visually and by analysis. The first uses X-rays, ultraviolet light and several types of microscopes, spectroscopes and other optical instruments to study the painting itself. The second subjects small samples taken from it to chemical and physical tests. By using the two methods in proper combination the technician determines a painting's "condition"—a term which, in this field, includes a description of the materials used, their distribution within the subject and the changes that have befallen them from wear, environment and time. From a painting's "condition" one can frequently identify its age, style and authorship, diagnose its structural weaknesses and recommend preservative treatment. From "condition" also students learn the materials and methods of the past, and historians often pick up significant new data on the society in which the work was produced.

Wilhelm Roentgen, the discoverer of X-rays, was himself the first to apply this tool to the study of works of art. It has been used to examine thousands of paintings. An X-ray picture shows a pattern of the relative density of pigments and the relative thickness of paint layers. White lead, which until recently was used liberally in almost all painting, is comparatively opaque to X-rays, and a shadowgraph of a painting exposes the "skeleton of white lead." X-ray examination also reveals the painter's corrections and alterations of his picture, thus telling much about his temperament and working methods, and it may bring to light instances in which a second hand has painted over the original author's work. Occasionally it discloses that the work being studied covers an entirely different painting underneath. This may mean only that an impoverished artist was forced to use second-hand canvas, but forgers often buy old paintings to supply themselves with canvas of convincing age and texture. Not long ago X-rays exposed the Dutch counterfeiter Han van Meegeren, who had painted a "Vermeer" on top of a Hondius hunting scene.

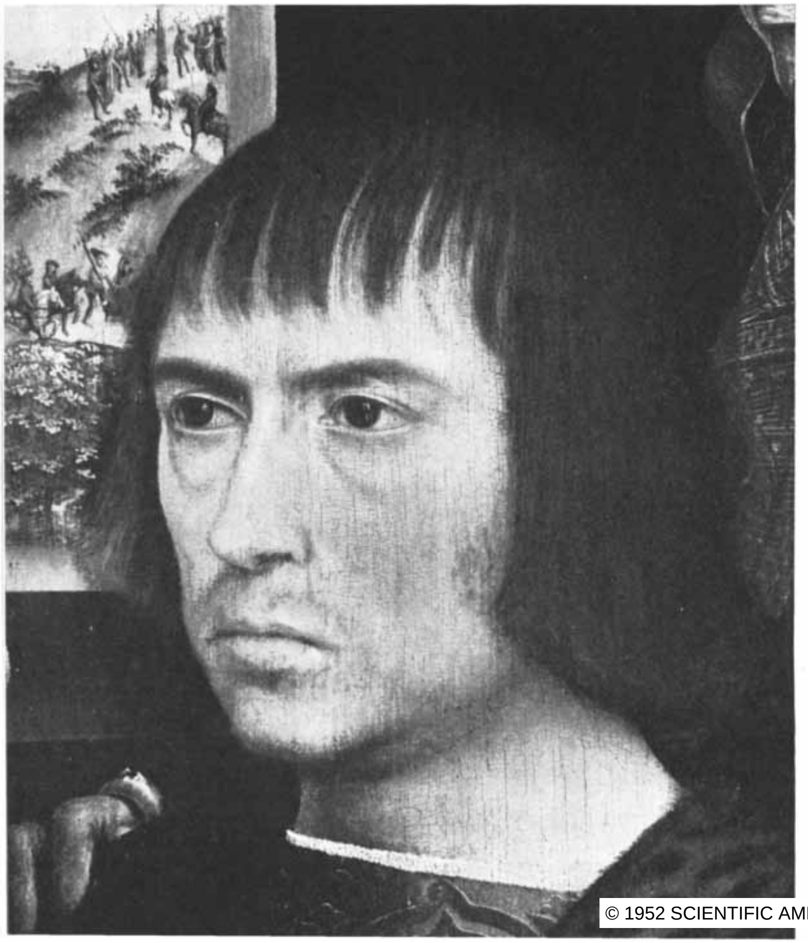
Today ultraviolet light is often used instead of X-rays, because it is simpler and quicker. Ultraviolet radiation shows alterations by variations in the fluorescence of the paints. Infrared photography is especially useful for penetrating a thick veil of varnish to reveal the detail hidden beneath.

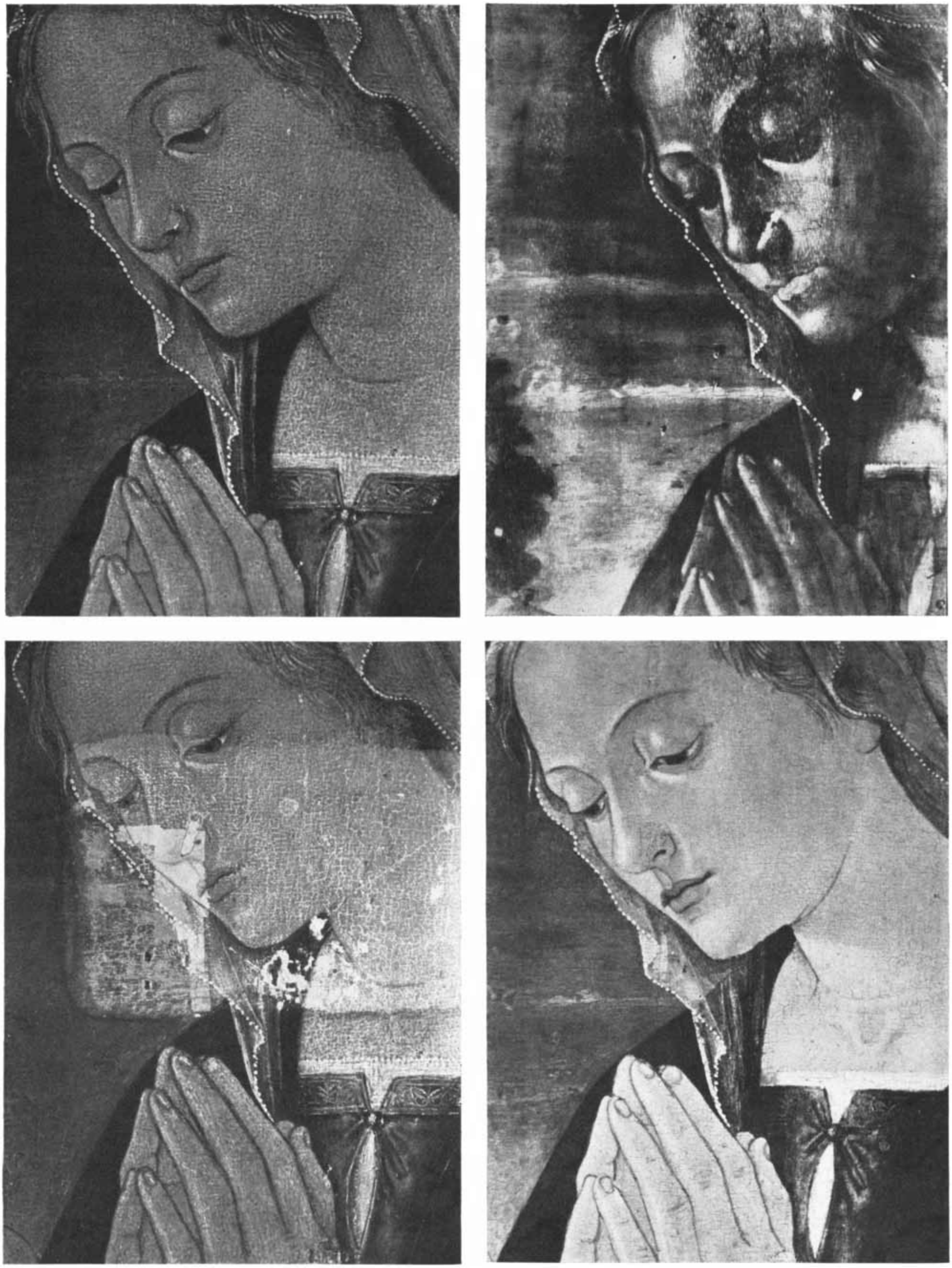
Alan Burroughs, while at the Fogg, assembled a collection of some 4,000 X-ray plates of paintings from all over the world, and used them both to untangle vexing problems of authorship and to study individual techniques. Some painters work slowly and meticulously; others paint in bold and broad strokes. Some lay on their paint in flat and even layers; others model it almost like sculptor's clay. Many of these stylistic points can be seen with the naked eye, but there are times when only X-rays will bring them out. Critics who have examined by X-ray the paintings of the 15th-century Flemish painter Jan van Eyck, for instance, have reported that he used very little white or build-up of paint: he was what is known today as a flat painter.

WHEN the materials of a painting are to be analyzed, the first step usually is to work over the subject carefully with a binocular microscope of from 5 to 30 power. Such examination brings out details of paint contours and exposes crackle, paint loss and repair work. The second step may be to take samples from the painting for microchemical analysis. With a sharp, harpoon-shaped needle the technician stabs the painting and takes out cores so minute that their removal does no damage to the picture. The cores are then analyzed by tests with water, acids, alkalis and organic solvents to show what kind of medium—oil, protein or carbohydrate—the artist has used to hold his pigments, and to identify the pigments themselves, most of which have characteristic color, crystalline structure or optical properties. The refractive index, birefringence, shape and size of the pigment particles are all clues. For example, the irregular particles of ultramarine blue derived from the mineral lapis lazuli and much used by medieval painters can readily be distinguished from the smaller and more uniform particles of artificial ultramarine, which came into use after 1828. Prussian blue, another common pigment, can be identified by its stainlike character and tendency to bleach in the presence of alkalis. It was first produced in 1704, and therefore no picture that contains it can be earlier than that date. The mineral azurite served widely as a blue pigment in the Middle Ages, but its source in Hungary eventually gave out. You will find little of it in work done after 1750. The presence of this mineral in a fragment taken from the sky of a Ruisdael landscape recently confirmed the director of an American museum in his opinion that the painting was authentic. Chromium, cobalt, zinc and cadmium pigments were not added to the artist's palette until after 1800. Cobalt was one of the traps that caught the forger van Meegeren. For his *Woman Taken in Adultery,* painted in imitation of Vermeer, van Meegeren bought some expensive and supposedly genuine lapis lazuli in a London supply shop. Ironically, the mineral had been adulterated with cobalt blue; this anachronism was an important link in the evidence that jailed the careful craftsman.

Useful information can often be obtained by going beneath the pigment layers and studying the white priming coats with which an artist prepares his canvas or panels. The wood panels of Italy and other Mediterranean countries were usually prepared with a coat of burned gypsum in glue called "gesso." If the painting comes from Tuscany, the gypsum will probably be an anhydrous variety readily distinguished from the normal gypsum to be found, say, in the ground of a Venetian work. The Dutch

X-RAY PHOTOGRAPH of a 15th-century Flemish painting in the Fogg Museum revealed some interesting details. At the left is a panchromatic photograph showing the head of a man in a painting entitled *Portrait of Bishop and Donor*. At the right is an X-ray photograph of the same area. The X-ray photograph dimly discloses the features of a younger man with full lips and a curved nose. The present head was apparently painted on top of another. The light rectangle at the lower right of the X-ray photograph proved to be the corner of an important coat of arms on the back of the painting. This had been covered up by a subsequent backing.





CLEANING AND RESTORATION of a 15th-century Italian painting is shown in these photographs. At the upper left is a detail of a Romano *Madonna and Child.* At the upper right is an X-ray photograph of the same detail indicating hidden blemishes and highlights in the original painting. At the lower left is a panchromatic photograph showing removal of two layers of varnish and grime. At the lower right is the restored painting.

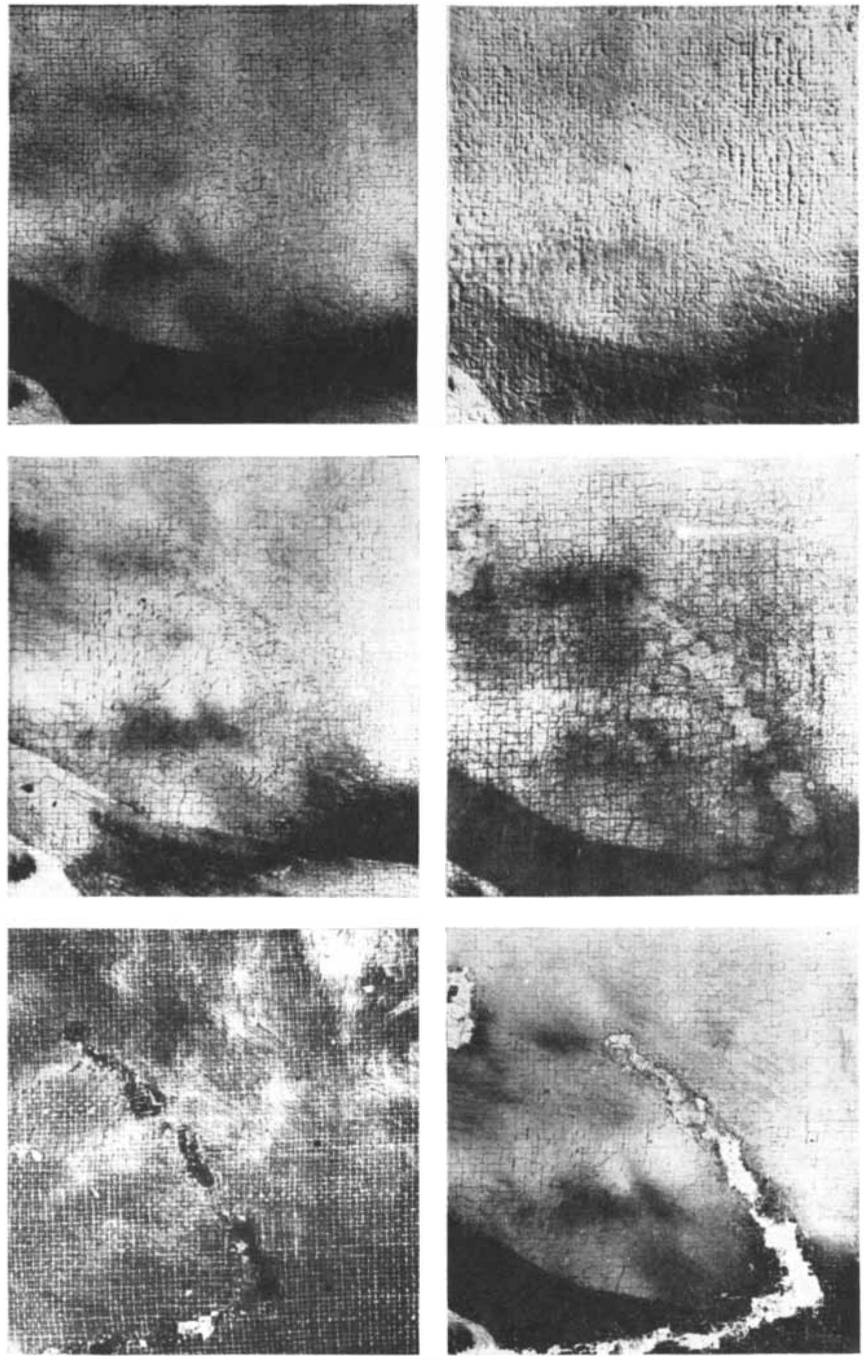
and Flemish masters used chalk in their grounds, and a microscopic sample from their priming coats will show tiny marine fossils.

An extremely delicate technique recently developed is the cross-sectioning of paint films. Chips smaller than the head of a pin are mounted in wax at a precise orientation and then sliced with a microtome knife to expose the layers running through the body of the paint. Cross-sectioning will, among other things, locate the boundaries of a layer of paint which is partly on the surface, partly hidden by other layers. In a *Baptism of Christ* attributed to Tintoretto, which was being cleaned at the Fogg not long ago, borings were made to determine which layers had been repainted. Cross sections from these samples showed that in certain places a coat of Prussian blue overlay the original azurite. This later blue, an unnecessary restoration, was cleaned off the picture. Cross sections can be photographed at a magnification of 300 times or more and are thus invaluable for teaching and for permanent reference.

THE MICROSCOPE is the key analytical tool in all these studies, but other instruments, notably the spectrograph and the X-ray diffraction camera, are important adjuncts. The spectrograph is always the best instrument for detecting elements present only in minute traces. Recently it served to identify the arsenic of Paris green in the imitation patina of an ancient Chinese bronze.

To identify the materials in paintings the technician needs a wide assortment of substances for comparison. At the Fogg Museum Dr. Forbes built a large collection, gathered in a series of world trips. It includes various pigments, oils, resins, scraps of old paintings, fragments of Aegean, Egyptian, Mesopotamian and Roman wall paintings, bits of plaster, inks, brushes, papers, and so forth. The collection is in constant use for teaching the history of painting, besides providing the control materials for microscopic comparison.

Art scientists often make special studies of the materials and methods of a well-defined epoch or locality. Such investigations may produce information of interest outside the realm of art. They sometimes give evidence of trade between different regions of the old world. The natural ultramarine used by European painters in the Middle Ages, for example, came from mines in Afghanistan. It was carried by caravan across the mountains and deserts of central Asia to ports in the Levant, shipped to Venice, where it was refined, and then distributed all over Europe. The indigo found in the early *santos* of New Mexico proves that the painters of that region relied on supplies from old Mexico; the vermilion of Italy came from the cinnabar mines



SIX VIEWS show a small damaged section of *Saint Jerome*, by the 17th-century Spanish painter José Ribera. At the upper left is a panchromatic photograph; at the upper right is a photograph made by "raking" or slanting light; at left center is one made by infrared radiation; at right center, one made by ultraviolet; at lower left, one made by X-rays. At the lower right is a panchromatic photograph of the area after cleaning.

of Almadén in Spain. The presence of an artificial pigment (and Egyptian blue goes back to the second millennium B.C.) is evidence of contemporary industries and of some experience in applied chemistry. In fact, the development of chemistry can be traced all through the history of painting.

The scientific examination of paintings has had a revolutionary effect on methods of restoration and preservation. The early restorer was usually an amateur painter—or an unsuccessful one—who felt it was his job to present the public with a finished picture. He had little regard for the integrity of the work entrusted to him and was prepared to improve on the taste or craftsmanship of the original artist. He was frequently unskilled at matching tones and would

WOOD BACKING IS REMOVED from the surface of an early German painting and replaced. In the first photograph several layers of tissue and adhesive have been affixed to the surface of the painting. In the

therefore repaint large areas to cover a minor blemish.

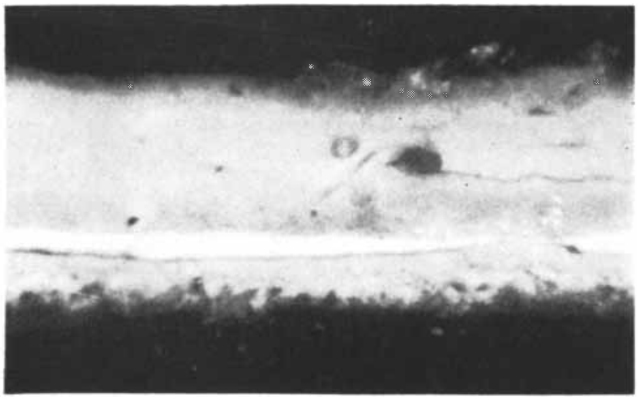
Furthermore, early restorers, like early doctors, treated symptoms as often as they did causes. They would clean off the old yellow varnish on a painting and replace it with a new coat which would soon turn yellow and dull. They braced and flattened wooden panels with heavy cradles which themselves set up new stresses to cause further cleavage and paint loss. The cleaning solvents they used, like the pigments to which they applied them, were little understood, with the result that important detail was often erased by overcleaning. And since they rarely left records of their successes or failures, the craft had little chance to improve by experience.

Today the practice of restoration and preservation is recognized as an exacting profession almost like medicine, with its own specialized training and equipment. It is carried out in laboratories where rigid standards of cleanliness, lighting, heat and humidity can be maintained. Every important job is preceded by a thorough examination whose findings are set down on a chart not unlike the record that is hung at the foot of a patient's bed in a hospital.

Roughly speaking, the clinical work in a modern museum can be divided into the protection or replacement of the support on which the picture is painted and the restoration and preservation of the paint surface itself. With the help of some of the new vinyl plastic adhesives the painting can actually be taken intact off its backing. A cloth or paper cover saturated in one of these adhesives is glued on the face of the painting, and the support is then cut, scraped and rubbed away until the very back of the paint strata is exposed. A new backing is then glued on, and the temporary support that covered the face is removed. This was done some years ago at the Fogg with a group of Chinese tempera paintings on mud walls. The murals were large and their support was both fragile and exceedingly heavy. The mud was entirely cut away and replaced by strong, light fiberboard.

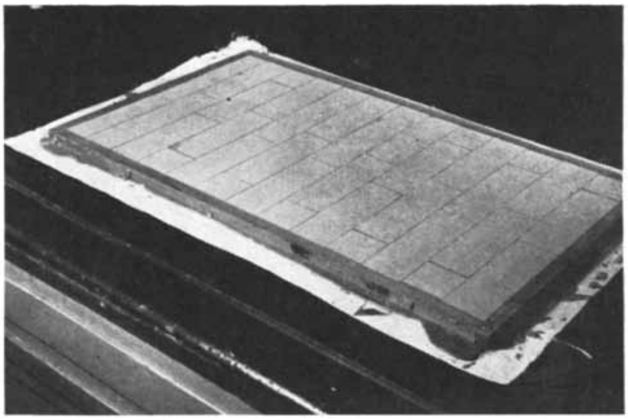
One of the most difficult problems of picture conservation is the treatment of Italian panels on wood. Often the wood has rotted, and even sound wood may crack and warp, especially in the American climate. Warping is sometimes controlled by attaching elaborate wooden cradles to the back of the picture to keep it flat. A more effective treatment, perfected by Richard Buck and his colleagues, is to remove most of the original support and replace it with a panel made from squares of balsa wood cut across the grain and put together like paving blocks. This backing changes little with temperature or humidity. Paintings on canvas are treated in much the same way. Frayed or rotted linen can be replaced with new cloth or, if the damage is not too severe, a painting can be relined with a second canvas affixed to the original. In recent years, stretchers with aluminum corner plates and tension springs have been devised to hold a canvas tight and in plane under fluctuating conditions.

THE DEVELOPMENT of new cleaning solvents by chemists during the last 25 years has been a great help. To the traditional alcohol and turpentine there have now been added the chlorinated hydrocarbons, such as ethylene dichloride, the higher ketones, the "cellosolve" series and amines such as morpholine. They afford the restorer a wide choice of specific solvencies, evaporation rates, boiling points, and so on. But



CROSS SECTION OF PAINTING made by Holbein shows layers of paint. Sample is taken with "harpoon," mounted in wax, sliced and photomicrographed.

CROSS SECTION OF BRONZE from China shows corroded metal in center and cuprite at left. The bright streaks at left and right are redeposited copper.



second photograph the wood backing has been sanded almost down to the back of the paint. In the third photograph balsa blocks are cemented to the back of the painting. The fourth photograph shows the finished support.

he must be an experienced operator to use them successfully. The cleaning of paintings is simple in principle; essentially it is the technique employed by any householder who attacks an old table with paint remover and a pad of wire wool. The difference is that the householder is usually prepared to take his table down to the bare wood, while the restorer must find a solvent or combination of solvents that will loosen old varnish and dirt but not soften the paint underneath.

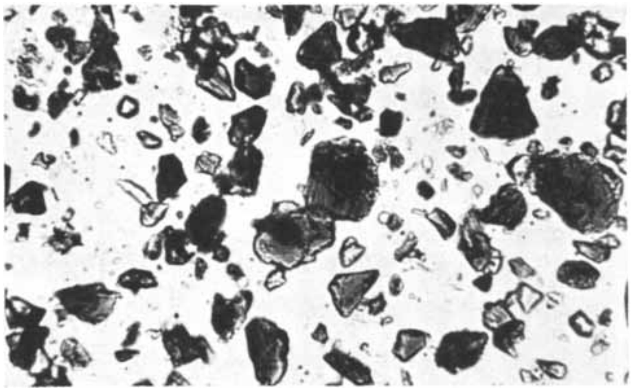
Oil paintings are, of course, only part of a museum's problem. Objects made from such substances as stone, ceramic and metal are also subject to deterioration. There is, for example, "bronze disease." Bronze objects long buried in the saline soil of such desert areas as Egypt or Mesopotamia acquire a thick coating of corrosion with an underlayer of cuprous chloride, an unstable colorless salt. When they are dug up and exposed to moisture, beads of basic cupric chloride form on their surfaces, and these in turn are transformed on drying into a bright green powder identical with the mineral atacamite. Alternate periods of dampness and drying can seriously disfigure and even destroy a bronze figure. This particular corrosion mechanism is not yet entirely understood or completely under control. Museums also have the problem of preserving and restoring water colors, etchings and other types of reproduction; a great deal of work has been done on the chemistry of inks and papers to this end.

Much that the museums have discovered in the course of studying, restoring and preserving their collections is applied by contemporary artists to their own work. Thanks largely to studies made some years ago by the Federal Arts Project, the National Bureau of Standards now maintains a Commercial Standard for Artists' Oil Paints. This standard, widely adopted by the manufacturers of artists' materials, fixes nomenclature and defines minimum requirements of composition and performance. There is no basis for the claim that the old masters had better materials than are available today. Modern painters have at their disposal the best materials of all time.

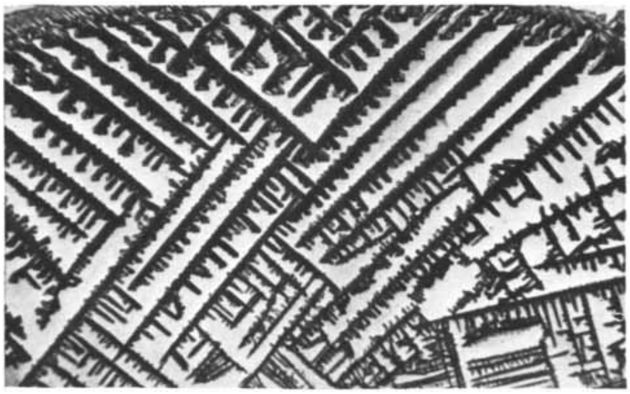
Artists now know that the less organic binder they mix with their pigments, the longer they may expect their work to last. Aside from considerations of permanence, painters can study in detail the ancient techniques and can adapt them to modern uses. That they are doing so is shown by the recent revival of interest in encaustic (wax) painting, egg tempera, fresco and even mosaic.

THE COOPERATION of science and art is now a world-wide phenomenon. Excellent laboratories are functioning in the leading museums of London, Brussels, Paris and Rome; extensive work is being done to preserve the wall paintings of South India. Almost all of this activity abroad is supported by government funds. It may be that similar aid will have to be granted in this country. The Fogg Museum has recently been forced to curtail its research, and other privately endowed institutions find it increasingly difficult to carry on the work of preservation. In England, Belgium and Italy the protection of cultural holdings is recognized as a government responsibility; there is no reason why it should not be so understood in the U. S.

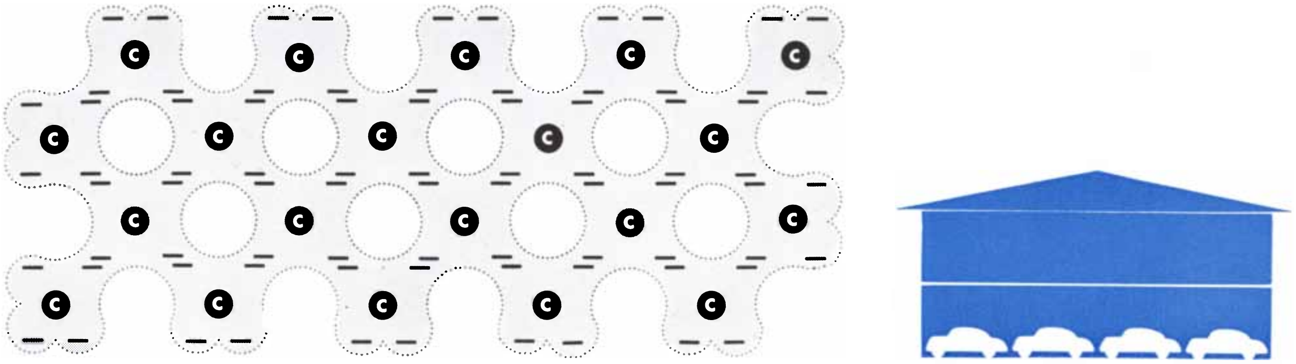
Rutherford J. Gettens was formerly Chief of Technical Research for the Fogg Art Museum of Harvard University.



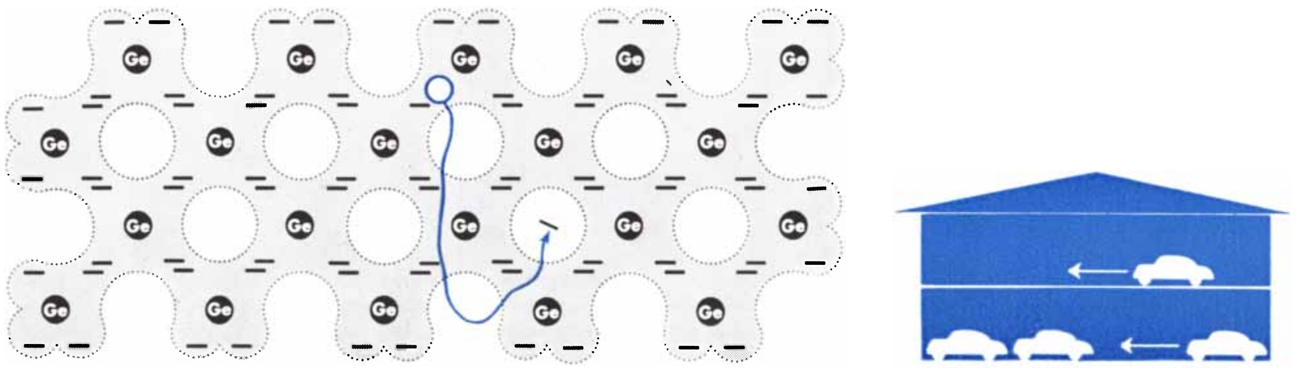
AZURITE PARTICLES from a Simone Martini *Madonna and Child* are magnified some 200 diameters. This mineral pigment was widely used in the Middle Ages.



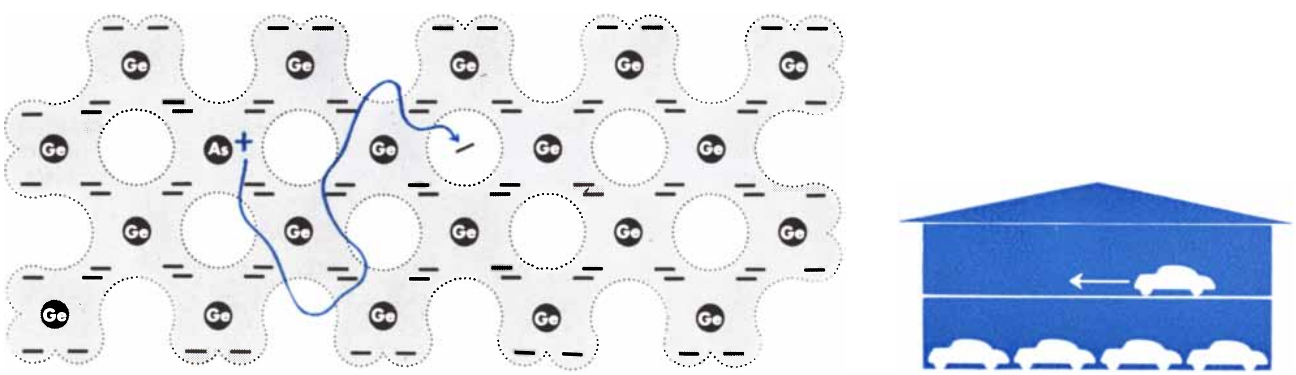
MICROCHEMICAL TEST for the presence of lead in a pigment shows characteristic crystals of lead nitrate. This photomicrograph enlarges crystals 75 diameters.



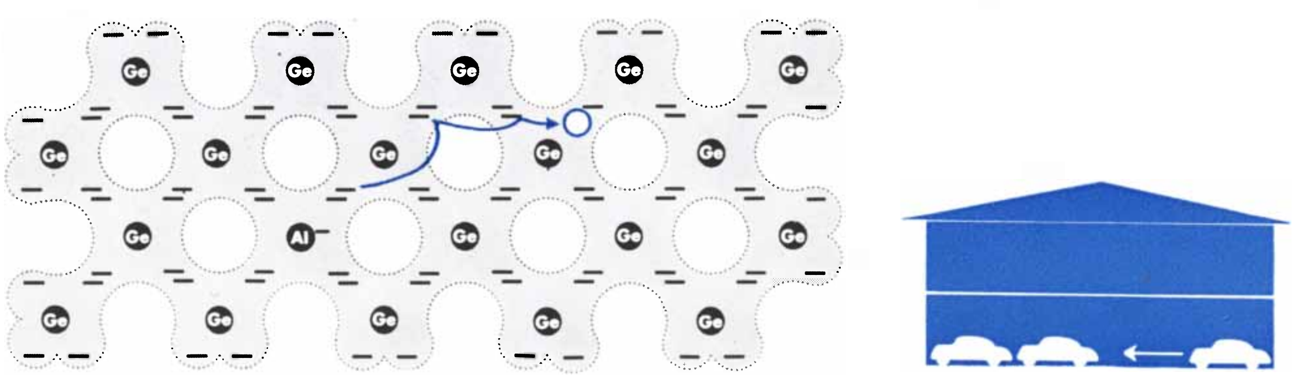
DIAMOND is composed of carbon atoms (C) joined by pairs of electrons (*minus signs*) so tightly bound that the crystal cannot conduct electricity. In garage analogy all cars are on the first floor and no traffic is permitted.



GERMANIUM CRYSTAL electrons are not so tightly bound. When one breaks loose, it is free to conduct electricity. The "hole" it leaves behind can also conduct. In garage analogy traffic is possible on both floors.



ARSENIC IMPURITY has an extra electron which is free to conduct electricity, leaving the arsenic atom positively-charged. This results in n-type conductivity. In garage analogy traffic is permitted on second floor.



ALUMINUM IMPURITY has a "hole" which is free to conduct electricity, leaving the aluminum atom negatively-charged. This is called p-type conductivity. In garage analogy traffic is permitted on the first floor.

The Junction Transistor

It is one of two forms of the remarkable device that amplifies electricity by the flow of electrons in a crystal. An account of its underlying principles and present state of development

by Morgan Sparks

IT WAS just over four years ago that John Bardeen and W. H. Brattain of the Bell Telephone Laboratories announced the invention of the transistor. Within a short time this revolutionary little device, which is destined to usurp the vacuum tube in many of its functions, has emerged from the laboratory to commercial production.

What is a transistor, and how does it work? There are two types, the point-contact transistor and the junction transistor. This article will deal mainly with the latter, which seems to have the bigger future (see "A Revolution in Electronics," by Louis N. Ridenour; SCIENTIFIC AMERICAN, August, 1951).

Bardeen and Brattain were members of a small group of physicists working under the direction of William Shockley at Bell in fundamental research on the solid state of matter. In particular they were studying the surface properties of germanium, a member of the curious class of substances called semiconductors. Their investigation suggested a way to achieve amplification of electric current in a solid—an objective which physicists had vainly been seeking ever since the beginning of the science of electronics. They accomplished this by an unexpectedly simple arrangement. Two thin wire points were placed very close to each other on the surface of a germanium crystal and were connected through batteries to a large-area contact on the opposite face of the crystal. Bardeen and Brattain found that a current through one of the wire points could control the current through the other in such a way as to yield a power gain.

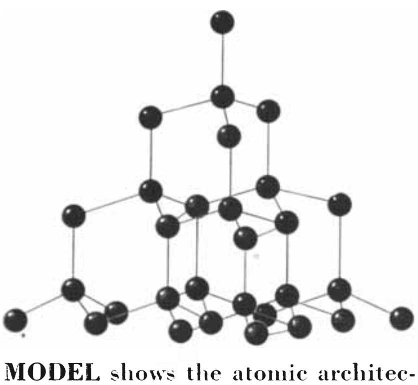
Though the arrangement is almost as simple as the cat's whisker on a crystal radio set, the behavior of the germanium crystal is so subtle and complicated that it defies precise analysis. The essential phenomena take place in an extremely small volume of the crystal—a few millionths of a cubic inch. This volume is near the surface of the germanium, and surfaces are notoriously complex. Furthermore, the current paths in the crystal are three-dimensional, and that complicates the mathematics.

The junction transistor is more amenable to mental dissection, and its history forms a fascinating part of the exciting and swiftly moving story of transistor electronics. Shockley visualized a new structure in which the processes would not be restricted to the surface but would occur inside a single crystal. If his ideas were correct, the performance of the unit would be highly calculable and could be varied by controlling the composition of the crystal.

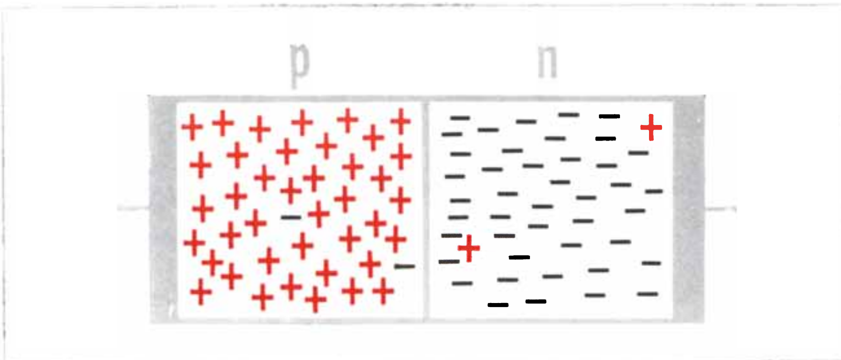
BEFORE DELVING into transistor principles, it is necessary to understand how current is carried in semiconductors. The chemical properties of an atom are determined by the valence electrons: the weakly bound electrons in its outermost incompleted shells. In a good conductor, such as a metal, there are many mobile or "free" valence electrons, perhaps one for every atom. In a nonconductor, or insulator, all the valence electrons are tied up in the chemical bonds which hold the crystal together. Such electrons are immobilized and cannot contribute to electrical conductivity. An example of a good insulator is a diamond crystal, in which all four valence electrons of each carbon atom are tightly bound in covalent bonds. Now the peculiar property of a semiconductor is that its valence electrons can be freed from a crystal lattice rather easily, indeed, merely by the thermal vibrations of the lattice at room temperature. Silicon and germanium, which are tetravalent like carbon, are semiconductors because their valence electrons are less tightly bound and it takes much energy to free them. Shockley has likened valence electrons in such lattices to cars parked in a two-story garage, with the distance between the first and second floors representing the energy needed to free an electron from a valence bond (*see diagrams on the opposite page*). For silicon this distance is only about one-sixth that for a diamond, and for germanium it is smaller still.

At room temperature the conductivity of a pure semiconductor crystal is generally very low: pure germanium, for example, conducts only about one 10-millionth as well as pure copper. But heat or light shining on a germanium crystal increases its conductivity. Absorption of light is a more efficient means than heat for freeing electrons from bonds, because the energy of each photon is dissipated locally rather than throughout the crystal lattice. In fact, for each photon absorbed one of the crystal bonds is altered. The result is that one of the electrons in the electron-pair bond is "excited" to a higher energy level. This excited electron is no longer immobilized. It may move randomly in the crystal, or drift in an electric field and thereby conduct current in much the same way that electrons in metals do. This process of conduction is called n-type conductivity, the n standing for the negatively-charged electrons that carry the current.

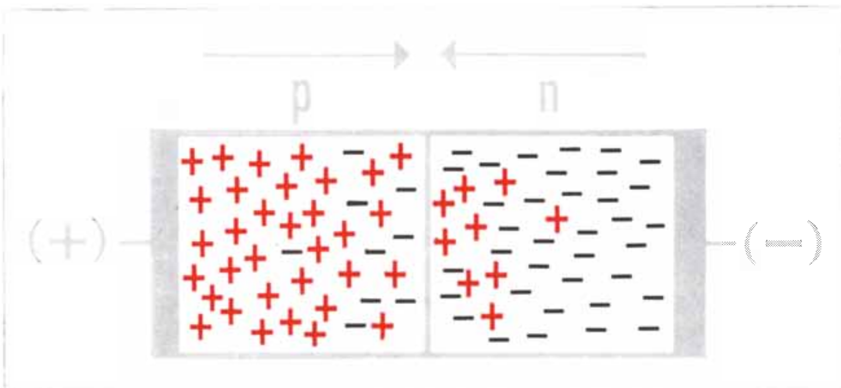
Consider now the region near the origin of the above conducting electron. The broken bond is left with a "hole" where the electron was removed. An unexpected result is that this hole also can conduct electricity. An electron from an adjacent bond may jump into the hole, restoring the original bond structure but creating a new hole in the process. Thus the hole may travel through the crystal; as electrons move



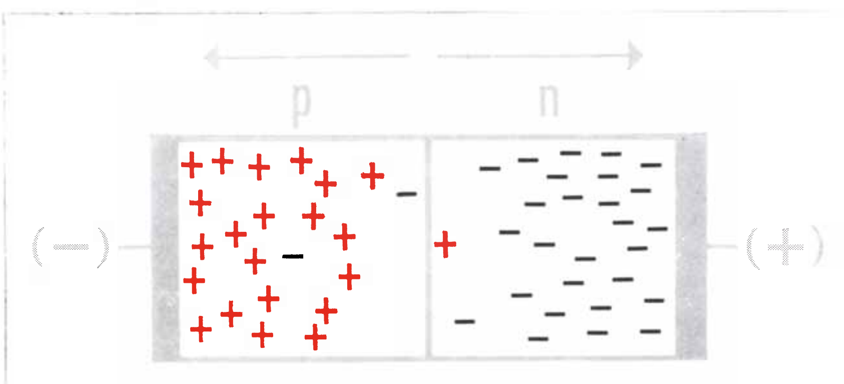
MODEL shows the atomic architecture of diamond and germanium.



IMPURITIES ARE PLACED so that one part of the germanium crystal conducts by means of holes (p) and the other part by means of electrons (n).



VOLTAGE IS IMPRESSED on the crystal so that holes and electrons are pulled across the junction. Current can flow across the junction easily.



VOLTAGE IS REVERSED so that holes and electrons retreat from the junction. Current flows across the junction with considerable difficulty.

to fill a hole, the traveling hole moves in the opposite direction. Conductivity by the movement of holes is called p-type conductivity, because the holes act like positive charges, due to the loss of an electron from a previously neutral region of the crystal. The separation of conductivity in semiconductors into n-type conduction and p-type conduction, moving in opposite directions, is basic to transistor action.

THE MECHANISM by which heat or light produces conductivity always creates holes and electrons in equal numbers. There is a way, however, to make the conductivity of a semiconducting crystal almost entirely n-type or p-type. If an atom such as arsenic, which has five valence electrons, takes the place of a germanium atom in a germanium lattice, it will form electron-pair bonds with the four neighboring germanium atoms. This leaves the arsenic with one unused valence electron. That electron is easily freed; it may be detached by thermal vibration of the crystal at far below room temperature. When the electron escapes, the arsenic atom is left positively-charged, that is, as a positive ion. But it cannot conduct electricity, because it is held tightly in the germanium lattice. Consequently such a crystal will exhibit predominantly n-type conductivity, arising from the movement of the excess electrons.

If the impurity in the germanium crystal is an element such as aluminum, with only three valence electrons, it can form only three two-electron bonds with the neighboring germanium atoms. The remaining bond will be shy one electron—which by definition is a hole. It takes little energy for an electron in an adjacent bond to jump into the hole, thus completing the bond and moving the hole. The negative aluminum ion is immobilized, and the wandering positive hole gives p-type conductivity to the crystal.

Almost all crystals of silicon and germanium contain impurities of the kind described. Whether they will exhibit n-type or p-type conductivity at room temperature depends on the balance of the impurities present; if extra-electron atoms are in the majority, it will be n-type, and *vice versa*. One unneutralized impurity atom in a billion atoms of silicon or germanium is sufficient to tip the balance either way.

Besides this, in any crystal there are always a few electron-pair bonds breaking and reforming due to thermal vibration. This furnishes a small but continuous supply of short-lived holes and electrons in equal number, so there will always be some of each kind of current carrier present everywhere in the crystal. In any region, as well as in the crystal as a whole, one type of carrier may be in the majority. A typical p-type region may have a million times as many holes (majority carriers) as electrons (minority carriers). In another region electrons may be dominant and holes the minority carriers.

Let us now return to the transistor. Much of the information on the electrical behavior of germanium so far described was already known. Most of the available samples of the material were n-type, because the residual impurities after processing were predominantly those with five valence electrons. Occasionally it had been observed, however, that part of the germanium ingot was n-type and part p-type, a result of segregation of the impurities during solidification. It had also been observed that the boundaries between the two conductivity types, called p-n junctions, functioned as rectifying barriers; that is, current passed in one direction more easily than in the other. A metal point on the surface of germanium also exhibits the property of rectification. Shockley developed a theory relating the electrical behavior of p-n junctions to measurable properties of the material on each side of the junction and to some fundamental physical constants such as the charge carried by an electron. The equations contain some seven quantities, but the basic results can be presented qualitatively with an extremely simple model.

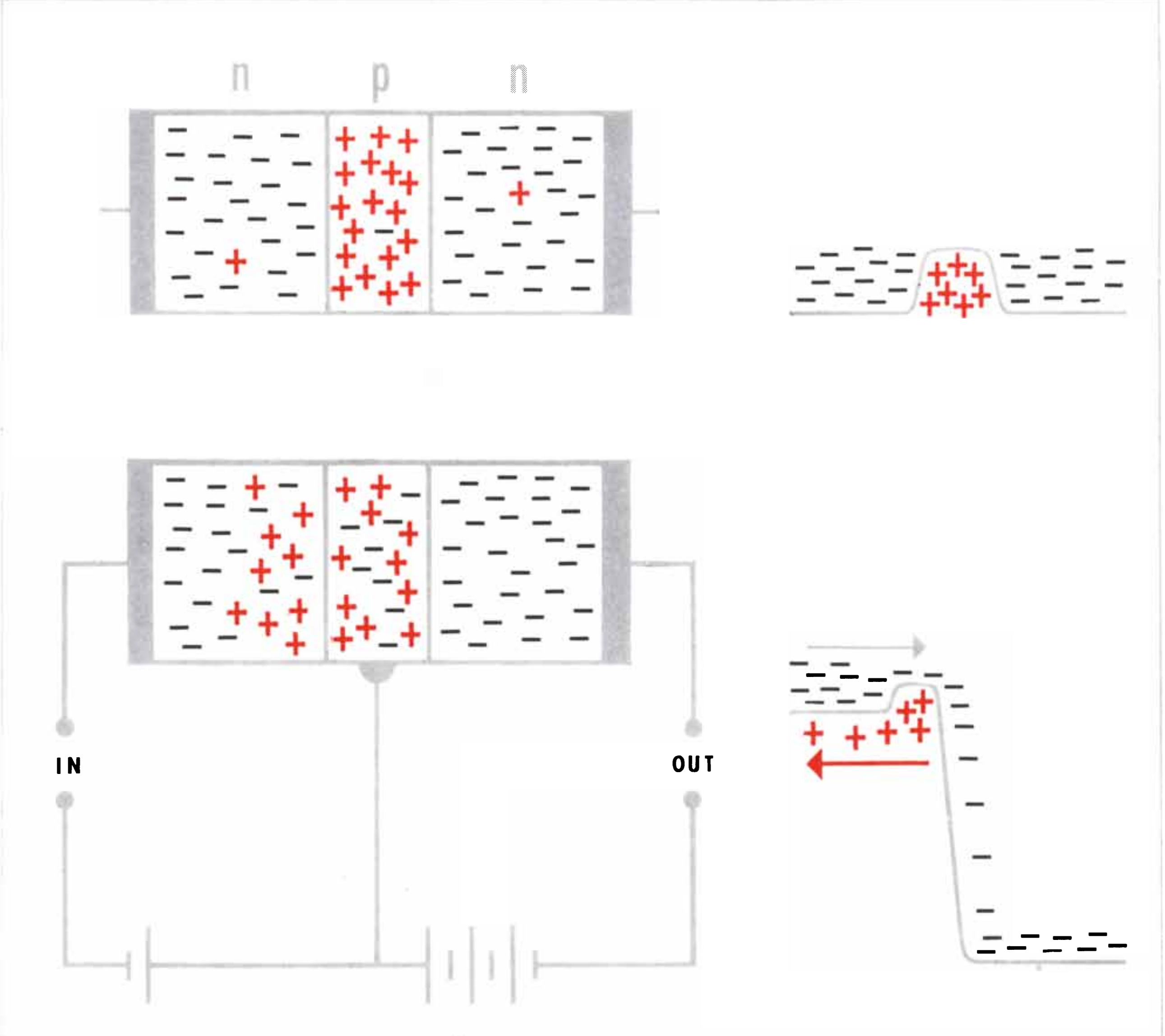
We consider a single crystal of germanium, one-half of which contains impurities producing n-type conductivity, the other half, p-type conductivity (*see diagrams on the opposite page*). The only difference between the two halves of the crystal lies in their content of tiny amounts of impurities, so tiny that the impurities would be difficult for an analytical chemist to detect.

A large-area metal contact is fixed to each half of the crystal. If a battery voltage is applied to the contacts in the direction such that the holes in the p-type region and the electrons in the n-type region are both attracted toward the junction, there is little resistance to flow of carriers across the junction. This is the direction of easy flow for the p-n junction rectifier. The result of current flow is that the two kinds of carriers rush toward each other and recombine after crossing the junction. For example, a conduction electron in the n-type section near the junction will readily drift across the junction, and as soon as it reaches the p-type side it finds many opportunities to drop into holes. But this process of recombination is not instantaneous, and as a result there is an increase in the concentration of electrons (minority carriers) on the p-type side near the junction. Similarly the current flow produces an increase of holes on the n-type side of the junction.

If the sign of the applied voltage is reversed, the majority carriers on each side are pulled back from the junction. The only current that flows across the junction is carried by the minority carriers present nearby. As we have seen, these carriers arise from thermal generation, and the current is very sensitive to temperature.

The essential fact is that this conduction of electricity is different from ordinary conductivity, in which the current is transmitted as a wave along the conductor; here the current is carried only by the individual minority carriers near the junction.

WE CAN now extend the concept of the p-n junction rectifier to produce a junction transistor. What we need is an arrangement whereby a current in one circuit will produce a proportional current in another circuit at a higher power level, as an electronic vacuum tube does. We have seen that a p-n



TWO JUNCTIONS make a transistor. When no voltage is applied (*upper left*), the p region acts as a barrier (*upper right*). When voltage is applied to one junction (*lower left*), electrons spill across (*lower right*).

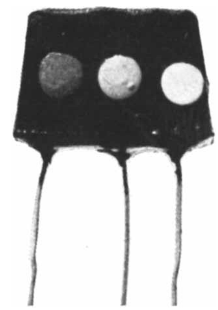
junction has one direction of easy flow. A signal may be transmitted across it at a low power level. In the direction of difficult flow we may impose a high voltage without actually spending much energy, because only a very small current passes. This voltage represents potential energy, however, and if we could induce a signal into the circuit, it would be at a relatively high power level. The situation may be likened to a dam with a reservoir just full enough to allow only a trickle of water to flow over the top. The height of the dam on the downstream side represents potential energy. A ripple (signal) on the surface of the reservoir would be sufficient to increase the flow over the dam, and if the falling water were being used to drive a generator, the ripple would be reproduced as a momentary increase in the output of the generator. For the p-n junction flow in the high-power direction is determined by the nearby concentration of minority carriers.

Let us now consider a germanium crystal with the impurities so situated that there are three sections of conductivity, say n-p-n, which give rise to two parallel junctions (*see diagram on the preceding page*). Suppose that the central p-type section is so thin that the regions of influence of the flow across the two junctions overlap; that is, the region near one junction where the flow increases the concentration of electrons overlaps the similar region near the other junction. Each junction may be used in a separate circuit, and we may supply battery voltages such that one junction is in the direction of easy flow and the other in the direction of difficult flow. This situation fulfills the requirement for an amplifier. If a weak signal, which we wish to amplify, is passed through the low-power junction, it increases the electron concentration in the p-type section, and this in turn increases the current through the high-power junction in exact proportion.

What we have described is a junction transistor. This particular type produces voltage gain only. But by simple changes in the circuits we can achieve current gain as well. Furthermore, we can just as easily make the transistor p-n-p instead of n-p-n, in which case the battery signs would be reversed and the operation of the device would depend on controlling the number of holes instead of the number of electrons in the center section. This illustrates one of the advantages of transistors over vacuum tubes. In effect, one may utilize either positive or negative charges. Simple switching circuits may be designed which employ p-n-p and n-p-n transistors simultaneously.

In both vacuum tubes and transistors all currents ultimately depend on the motion of electrons, and in both cases there are two separable mechanisms for conductivity. But in the vacuum tube we must supply a large amount of energy, in the form of heat, to push the electrons into the vacuum, and this large and inefficient expenditure of energy is one of the greatest restrictions of vacuum tubes. In a transistor we need to provide only enough energy to separate a carrier from an impurity atom, and for that even the heat at North Pole temperatures suffices.

SHOCKLEY'S theories for p-n junctions and junction transistors were published in July, 1949. Efforts toward the realization of the necessary structures had begun before this, and their feasibility had been demonstrated by operating models. The early junction transistors were able to handle larger currents than point contacts could, but



TRANSISTOR embedded in plastic is enlarged four times. The three dots of paint are code for its type.

they did not realize their indicated potentialities. The next step was provided by a group of chemists and metallurgists, and their contributions cannot be overemphasized. They were faced with the task of controlling accurately impurities whose concentrations were below the levels of detection by usual analytical means. To achieve this they purified germanium to a degree far beyond the classification "chemically pure" and learned to grow it in single crystals much larger and more perfect than the largest diamond ever picked up in the Transvaal. A 1,000-carat germanium crystal can be grown from broken chips in about two hours. The small amounts of impurities that remain must be accurately placed in the lattice and properly balanced between n-type and p-type. Chiefly responsible for the achievement of the right kind of crystals was G. K. Teal of the Bell staff.

The junction transistor is not impressive in appearance. In the size chosen by the Bell Laboratories development group for an early model it presents a small lump of opaque plastic with three protruding wires. Embedded in the plastic is the active part of the assembly—a germanium bar only about one-10,000th of a cubic inch in size. Yet this tiny piece of crystal is likely to have profound effects on our technology and society, making possible developments in electronics which could never be achieved with vacuum tubes. In contrast to the relatively short life of most vacuum tubes, transistors should have indefinitely long life. The power needed to operate them is fantastically low: 250,000 oscillators of a type made with an n-p-n junction transistor can be run on no more power than is required to operate a vacuum tube for a subminiature hearing aid. The transistor is rugged, amazingly compact and gives far higher power gains than most tubes. The germanium crystal itself is literally as stable as a rock. Circuit designers foresee the elimination of the socket connections needed by tubes; transistors will be wired permanently, and in fact entire complex circuits may be cast into protective plastic packages.

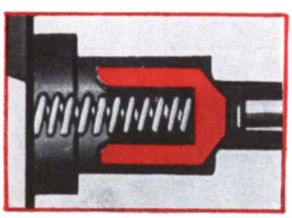
This is not to say that the junction transistor is already a perfected device. There are fabrication problems to be solved, such as protection of the surface from such things as dust and water vapor. The junction transistor is still a little noisier than a good vacuum tube. Transistors have not yet invaded the realm of ultra-high frequencies—though the word "yet" is important here. And full utilization of their possibilities must await further research on circuits. The unsolved problems of transistors are severe and should not be minimized, but we can confidently expect that they will eventually be solved. It has taken about 40 years to bring vacuum tube circuits to their present development, and improvements are still being made in them.

ALTHOUGH this article has stressed the advantages of the junction transistor, it should not be inferred that it will completely supersede the point-contact transistor. The point-contact version, originally variable and unpredictable, has now been developed to a standard of performance comparable with that of vacuum tubes, and even the first units made will apparently have a lifetime of at least 8 to 10 years. For many applications the improved characteristics of the junction type are not needed, and at present the point-contact device is easier and cheaper to make. Further, point-contact units can perform some functions better than present junction models; for example, they produce current gain directly and may be operated at higher frequencies.

The junction form has, however, greatly improved the realizable properties of this remarkable device. It has done more than that: it has placed transistor action on a quantitative basis. Measurement is the heart of science, and the junction transistor has brought the instrument to the stage where its performance can be described in numbers.

Morgan Sparks is a physical chemist at the Bell Telephone Laboratories.

TURNING IDEA-PLASTICS INTO DOLLARS



Check valves of Du Pont nylon plastic seat perfectly without machining...give long, trouble-free service

For fingertip ease in raising and lowering implements such as plows, the newest farm tractors have hydraulic controls. But the first controls designed had a serious "bug." The plow tended to creep up while in use, because hydraulic oil leaked through the check valves as their sealing surfaces wore or became grooved.

So the tractor maker tried a check valve made of Du Pont nylon plastic. Injection-molded in rapid mass production, the nylon check valve needs no machining. Resilient nylon provides a perfect seal . . . even makes up for slight imperfections in the mating surface. Oil can't leak; the plow can't creep. And this nylon part has shown *no signs of wear* after two years of service—withstanding the up to 200°F. temperature of oil in the system, remaining dimensionally stable, chemically inert.

Parts molded or machined of Du Pont nylon have a variety of uses. Nylon is light . . . resists abrasion and moisture . . . runs in many cases without lubrication. In addition, it can be molded in thin sections and around delicate inserts.

There are more than 100 plastics and chemicals made by the Du Pont Polychemicals Department. For information on those products which have possibilities for you, write on your business letterhead.

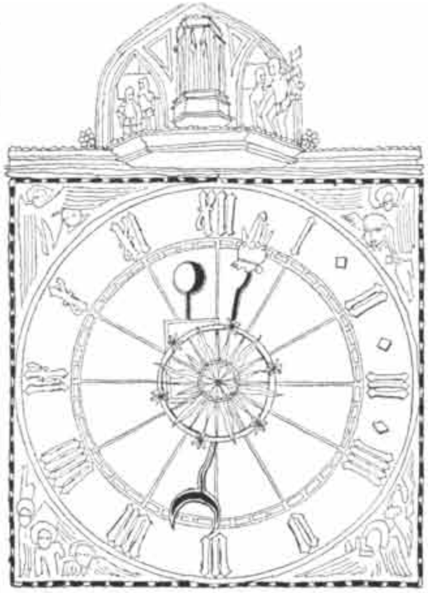
E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, 157S Nemours Bldg., Wilmington 98, Delaware.

District Offices:
818 Olive Street, St. Louis 1, Missouri
350 Fifth Avenue, New York 1, New York
7 S. Dearborn Street, Chicago 3, Illinois
845 E. 60th Street, Los Angeles 1, California

DU PONT
REG. U. S. PAT. OFF.
150th Anniversary
Better Things for Better Living
. . . through Chemistry

Polychemicals
DEPARTMENT
PLASTICS • CHEMICALS

SCIENCE AN



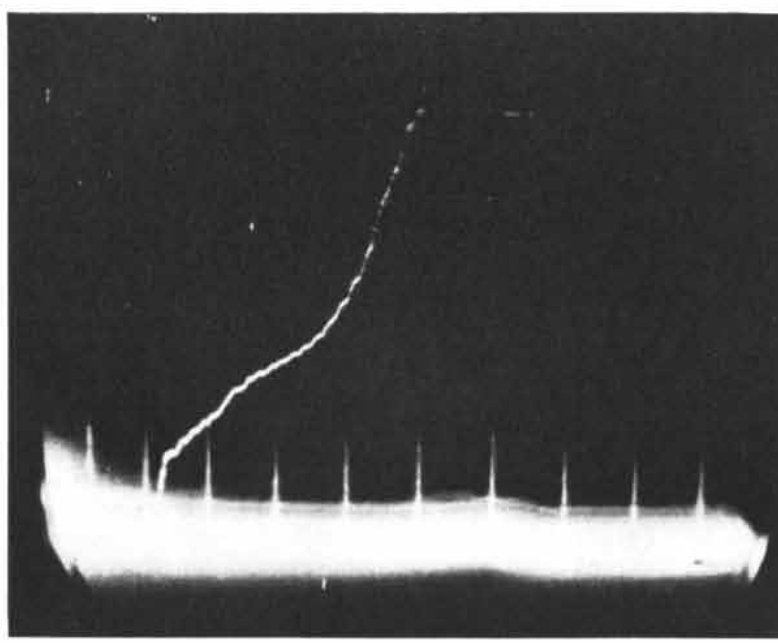
Over a Billion

A NEW chapter in atomic research was opened last month. The Brookhaven National Laboratory's cosmotron whirled a stream of protons to an energy of 1.3 billion electron volts. It thereby won the race to become the first accelerator to pass the billion-volt mark. Soon afterward the cosmotron's output was raised to 2.2 billion volts.

George B. Collins, chairman of the cosmotron project, observed that this newly achieved energy has brought scientists to the third stage of studied dismemberment of the atom: first they stripped off the electrons; then they smashed the nucleus, and now they will proceed to take apart the particles of the nucleus—protons and neutrons.

The cosmotron is the first proton-synchrotron to be completed. Into its hollow magnetic ring, about 60 feet in diameter, are fed 3.6 million-volt protons from a Van de Graaff generator. Held on a circular course through the doughnut by the magnetic field, the protons are boosted to a higher speed on each revolution by a radio frequency generator, the magnet increasing in strength to keep them on the path. In reaching 2.2 bev the particles were kept on the track for about 2,200,000 revolutions, equivalent to four trips around the earth. They achieved a speed of about 178,000 miles per second. During each accelerating period of seven-tenths of a second the current in the magnet coils, supplied by a 40 million-watt generator, rises from zero to 7,000 amperes. Then the magnet is turned off to allow the heat to dissipate, which takes about three seconds.

Liquid hydrogen will be one of the first targets to be bombarded in the cosmotron. Since hydrogen is the only element containing no neutrons, the effects produced will be attributable to the breakup of protons alone. Then other atoms will be attacked to determine the structure of the neutron. Physicists



COSMOTRON passes billion-volt mark, as shown by monitor oscilloscope. Markers along bottom measure energy (*increasing from right to left*); bright line traces decrease in protons with higher speeds.

on the project hope to be able to produce all the known mesons, and would not be surprised to turn up new particles. It is unlikely, however, that the Brookhaven machine will convert energy into mass by creating pairs of positive and negative protons, since present theory indicates this would require a particle energy of some six billion electron volts.

The accelerator was built under the direction of Leland J. Haworth, director of the Brookhaven Laboratory. Other scientists who worked on the design include Collins, George K. Green and John P. Blewett of Brookhaven, M. Stanley Livingston of M. I. T. and M. G. White of Princeton.

Swimming Pool

A LOW-POWER nuclear reactor which operates under water has been developed at Oak Ridge National Laboratory. Submerged in a pool 20 feet deep, 20 feet wide and 40 feet long, the pile is called the "swimming pool" reactor. The use of water as the shield avoids the expense of thick concrete shielding and leaves the core of the reactor visible. It is suspended from a bridge which can roll the unit from one end of the pool to the other. Test instruments can be lowered into the water from the bridge. The reactor can also be confined to a 10-foot section shut off by an aluminum gate while workers go into the drained pool to place instruments or make repairs.

The whole installation, exclusive of fuel costs, was built for less than $250,000; the reactor core itself cost only $58,400. Its designers suggest that it is a model low-cost research reactor for schools and other institutions. It produces a flux of 100 billion neutrons per square centimeter per second, and a focused neutron beam can be obtained from it for neutron diffraction research.

Chemicals by Hydrogenation

COAL is a rich source of chemicals, but its riches are only partly mined at present. The chemicals now made from it come mainly as a by-product of the coking of coal for steel mills. For some time the Union Carbide and Carbon Corporation has been looking into the possibility of producing chemicals by coal hydrogenation, a process hitherto exploited only for making synthetic gasoline. The company has just announced success in adapting the process to manufacture the valuable group of aromatic (ring molecule) compounds.

Hydrogenation yields a much higher percentage of most aromatic chemicals than does coking, and it produces some which are not made in the coking process at all. The Carbide and Carbon chemists have applied hydrogenation to make benzene, toluene, naphthalene, phenol, cresol, aniline and quinoline. Used for a great number of products, from high explosives to plastics and synthetic vitamins, most of these chemicals are in short supply.

The company describes its development as "a new birth of freedom for expansion" in such fields as dyes, rubber chemicals, plastics, synthetic enamel and the like. It has just completed a plant which processes 300 tons of coal per day at Institute, W. Va. This plant will provide engineering data for much larger plants.

The new process is not essentially different from the basic method originated many years ago by German chemists—reacting coal with hydrogen under high temperature and pressure. Coal is ground up and mixed with oil to form a "mud." The mixture is pumped into a tank with gaseous hydrogen, where the temperature is raised to about 500 degrees and the pressure to 6,000 pounds per square inch. The coal and hydrogen react to form a liquid which is a mixture of more than 100 compounds. These are then separated by conventional means. The company says that it has cut the hydrogenating time from nearly an hour to a few minutes, reduced the amount of hydrogen consumed, converted the liquefaction and product-refining steps to continuous processes and reduced the cost of the plant.

Radio Telescope

THE British have just announced plans for a new radio telescope which dwarfs any yet built. Its antenna will be a huge parabolic bowl 250 feet in diameter. Moreover, the dish, unlike previous ones, will be completely movable so that it can scan any part of the sky. It will cost about $1 million, to be shared by the British Government and the Nuffield Foundation.

Hampered in visual astronomy by their cloudy climate, the English have become pre-eminent in radio astronomy. At the Jodrell Bank Experimental Station of Manchester University, where the new telescope will be located, they already have a large fixed-antenna radio telescope which has located about 100 invisible stars that emit radio waves.

The Manchester workers believe that the radio signals may be coming either from stars being born, which are not yet hot enough to emit light, or from dying stars. Some astronomers think that new stars are created in the central regions of nebulae, but the hypothesis has been difficult to test because the critical sections of our own galaxy are hidden by impenetrable layers of cosmic dust. The new instrument will be able to explore these sections. It will also be used to study meteors, aurorae, the sun, the moon and planets.

Without Mirrors

A LEVITATION stunt that would put a medium to shame was unveiled by Westinghouse engineers last month. In thin air they floated a lump of solid, heavy metal. The lump could be pushed about with a glass rod, but it snapped back to its appointed space in the air as soon as it was let alone. Then the metal uncannily began to melt. Soon it became a pool of liquid—still suspended in the air.

It was done, of course, not with magic or mirrors but with magnetic and electric fields. A pair of coils produced a magnetic field and induced electric currents in the metal. The interaction of the currents with the field lifted the metal lump and held it in the air. While the magnetic field kept it suspended, a high-frequency current (about 10,000 cycles per second) of several hundred amperes was induced in the metal to melt it.

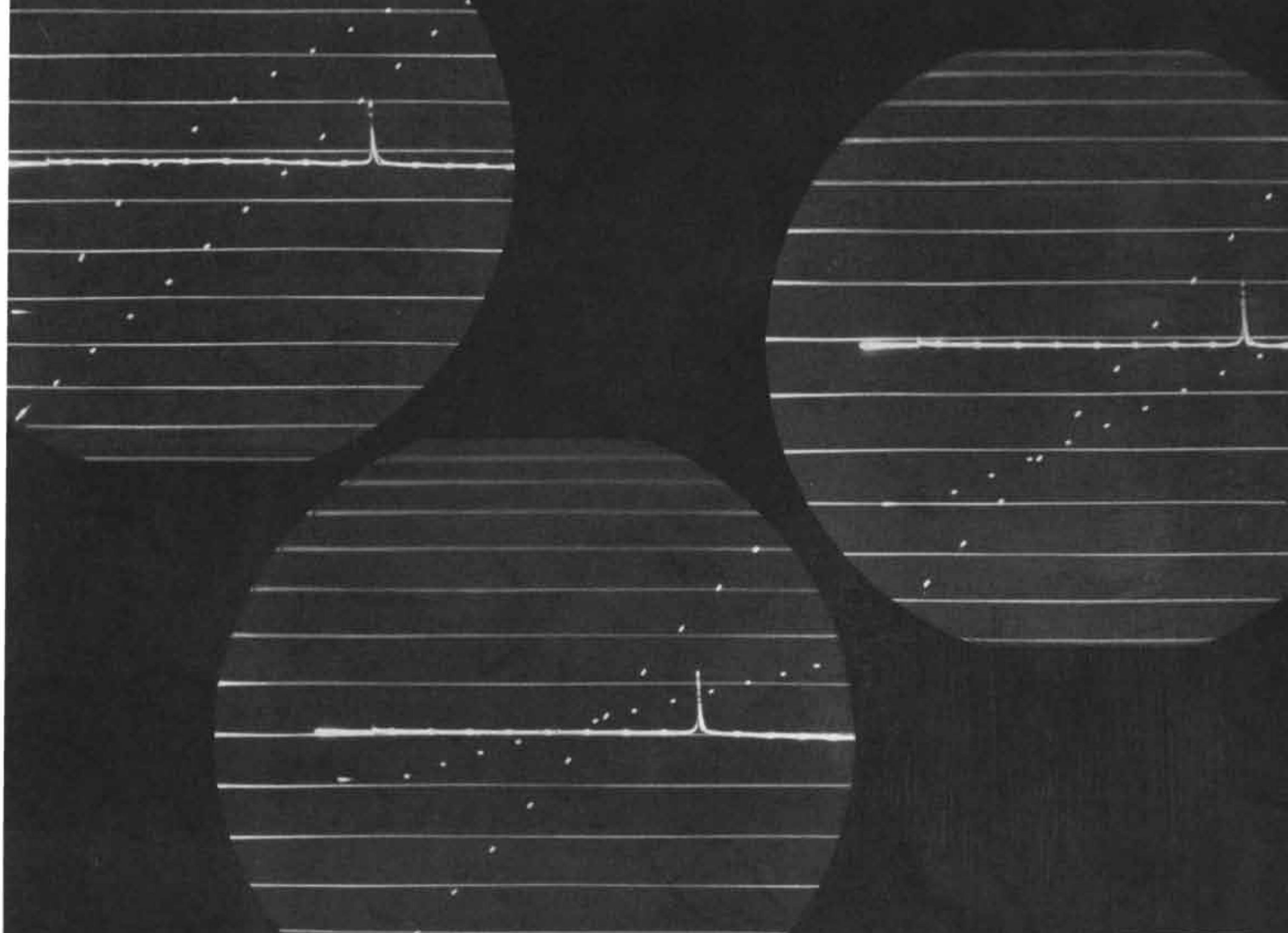
The arrangement is more than a stunt. Its purpose is to melt reactive metals of high melting point without having to do so in a crucible, the material of which may react with and contaminate the metal. It will be especially useful for handling such metals as titanium, zirconium, vanadium, tantalum and molybdenum in pure form. By adjustment of the current in the coils the metal can be drained or dropped into a receptacle. Specimens weighing more than a pound have been suspended in the field.

Exit and Entry

BECAUSE of "delays and embarrassments" experienced by foreign scientists in attempting to visit the U. S., the American Psychological Association has abandoned plans to invite the 1954 International Congress of Psychology to meet in New York, and the Congress will meet in Montreal instead.

According to the Federation of American Scientists, during the past 18 months 60 foreign scientists are known to have been refused visas or had them indefinitely delayed, and it estimates the total refused has been at least three times this number. A Federation committee reports that the State Department apparently is barring from the U. S. all members of the *Association des Travailleurs Scientifiques,* which includes about 70 per cent of French scientists. "Scientists as a group," the report says, "have had a great deal more trouble than other groups."

A number of U. S. scientists have also been running into trouble getting permission to travel abroad, the most recent publicized case being that of Linus



PHOTOGRAPHY HELPS A COSMOTRON KEEP PROTONS IN LINE

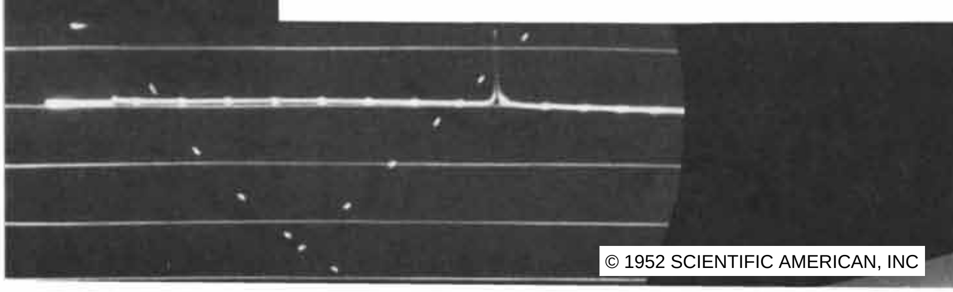
A peak power of 21,000 KVA creates the magnetic field in the cosmotron now being tested at Brookhaven National Laboratory. Protons whirl through the field of a giant doughnut-shaped magnet, over 60 feet in diameter. At every point of the protons' path along the circular quadrants and at all times during the second while the magnetic field is rising to its top value, the configuration of this field must be held within certain limits, or the protons will collide with the walls and be lost.

This monster magnet is built of laminations of ½″ steel sheets, 8 feet high, 12 in a 5.7-ton bundle, 288 bundles in all. Each bundle had to be carefully matched to its neighbors to give the utmost overall uniformity of magnetic parameters.

Photography provided a practical solution to the matching problem. The magnetic phenomena of each block were displayed on a cathode-ray oscillograph and photographed with a Kodak 35 camera. Five months and 8,000 oscillograms later (the shutter didn't fail once), a complete set of photographs like those seen here of the characteristics of each block made it possible to determine the position of each one in the magnet ring, to insure the most satisfactory magnetic field.

Quantitative records—full of detail, quickly made, available for reference whenever needed—are photography's contribution in a great many kinds of scientific and engineering jobs. Kodak makes a large variety of films and papers for them. Drop us a line, and we'll send you a complimentary copy of a new booklet that helps you make the best selection among them. Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y.

PHOTORECORDING . . . **an important function of photography**



Kodak
TRADE-MARK

Pauling, head of the Department of Chemistry and Chemical Engineering at the California Institute of Technology. Pauling had planned to attend a conference of the Royal Society of London on protein structure and to present a paper before the Royal Institution of Great Britain. He said a State Department official told him that the decision had been made "because of suspicion that I was a Communist and because my anti-Communist statements had not been sufficiently strong." Pauling had declared to the Department that he was not a Communist and had pointed out that his work on the resonance theory of chemical combination has been attacked in the Soviet Union. He has reapplied for a passport and addressed a letter to President Truman.

The State Department last month issued an explanation of its passport policy, declaring that "the Secretary of State has discretionary authority in the issuance of passports." The Department said that in view of the findings by the U. S. Court of Appeals in the trial of 11 Communist leaders and of the McCarran Internal Security Act of 1950, "it would be inappropriate and inconsistent for the Department to issue a passport to a person if information in its files gave reason to believe that he is knowingly a member of a Communist organization or that his conduct abroad is likely to be contrary to the best interests of the U. S."

The editors of *The Yale Law Journal*, in a recent issue discussing passport policy, questioned the Department's failure to allow hearings to applicants, in view of the fact that the McCarran Act restrictions are surrounded with "elaborate procedural safeguards," including public hearings on the registering of an organization, hearings for individuals listed as members of such organizations and court review of administrative decisions under the Act. Two suits challenging the Department's refusal of passports are now before the courts.

Living under Pressure

BIOLOGISTS on the Danish ship *Galathea* have been studying the animals and bacteria that live at the bottom of the deepest seas. For the first time samples have been taken from depths below 18,000 feet. The deepest haul came from the bottom of the Philippine Trench, six and a half miles under the sea.

Denizens of the Trench bottom live under about 1,000 times atmospheric pressure. The scientists were surprised to find that some bacteria brought up from these depths were able to live and multiply at atmospheric pressure. Claude E. ZoBell of the Scripps Institution of Oceanography reported in *Science* that groups of the bacteria were

FASTER ANALYSIS WITH X-RAYS

Chemical analysis by x-ray absorption is now successful on a commercial scale with the G-E X-Ray Photometer, saving hours of valuable laboratory time, and freeing the analytical chemist from tedious routine work. Petroleum refiners slash time and cost determining tetraethyl lead in gasoline, and sulphur in oils.
See bulletin GEC-412A*.

NEW MERCURY VAPOR DETECTORS

Users of mercury compounds can now determine harmful concentrations of mercury vapor with the new, completely redesigned G-E Mercury Vapor Detectors. Electronic and chemical detectors provide either instantaneous or continuous indication. Electronic detector pictured being used to check curing oven in laboratory of silicone rubber plant.
See bulletin GEC-312*.

MEASURES MOISTURE IN GASES

G-E Dewpoint Recorder gives continuous indication and record of dewpoint temperature in gas streams from ambient to minus 90 deg. F. Manufacturers and distributors of gases measure moisture content at different stages of manufacture and various transmission points.
See bulletin GEC-588*.

***To obtain these publications, contact your nearest G-E Apparatus Sales Office, or write General Electric Co., Section 687-101, Schenectady, N. Y.**

Operator observes cracking pattern of natural gas sample with G-E Mass Spectrometer.

NEW ELECTRONIC INSTRUMENTS SPEED CHEMICAL ANALYSIS

Research and production chemists benefit by better results—faster

Rapid chemical analysis, by electronic means, makes the G-E Mass Spectrometer an important tool for the modern chemist. Because it measures a basic fundamental unit—mass—it does not suffer from many of the limitations of physical methods. For basic research and routine process control of most gaseous and liquid mixtures the G-E Mass Spectrometer is ideally suited.

It automatically records peaks at mass numbers ranging from 1 to 600, and separation of a dozen or more compounds is common practice. Immediate results save time in the identification of common impurities and traces of rare isotopes. High resolution permits complete separation of high-mass elements.

Here is another example of G-E research and development—linked to produce more and better instruments for modern industry. See bulletin GEC-587*.

Convenient sample system facilitates introduction of unknown gas mixture.

GENERAL ELECTRIC

cultured in the ship's laboratory under sea-bottom and surface conditions, and while those provided with their normal environment of low temperature and high pressure multiplied hundreds or thousands of times as fast, the others managed to grow.

Animal life was not so hardy; none of the fish, sea cucumbers, mussels, sea anemones or crustaceans picked up from great depths came up alive. Fish were found as deep as 23,000 feet—pale, feeble specimens either completely eyeless or with undeveloped, useless eyes.

The *Galathea* is now returning to Denmark on the last leg of a two-year voyage which has taken it around Africa and through the Indian Ocean, the Pacific and the Caribbean. Anton F. Bruun is scientific head of the expedition.

Radiocarbon from Stonehenge

THE age of Stonehenge, Britain's mysterious megalithic monument, has been debated for many years. An answer to this long moot question has now been given by radiocarbon analysis of a charcoal sample recently found at the site: it places the date of Stonehenge at 1848 B.C., plus or minus 275 years.

This age of 3,800 years is not far from a guess made 40 years ago by the astronomer Sir Joseph Lockyer. One of the great rocks of the monument is a sandstone altar. Some 80 yards away from it in the direction of the rising sun is a stone marker, which casts a shadow on the altar at dawn on Midsummer Day (June 24). On the assumption that the builders of Stonehenge were sun worshippers, Lockyer computed the date on which the sun would have risen directly over a special notch which can still be seen on the marking stone. He found that this would have happened on Midsummer Day, 1680 B.C. and concluded that the monument must have been erected about that time.

Because the Stonehenge site has been trampled by generations of souvenir hunters, surface evidences of its age were obliterated long ago. But a party of Edinburgh University archaeologists recently made a foot-by-foot survey and had the good fortune to uncover two holes in which the stones had originally stood. One of the holes had been used as a ritual pit and contained bits of burnt wood. It was one of these fragments that was sent to the University of Chicago for carbon dating.

Chemistry of Atherosclerosis

ATHEROSCLEROSIS, one form of hardening of the arteries, is characterized by deposits of fatty substances in the blood-vessel walls. What causes the blood to deposit these substances in atherosclerotic patients? Many investigators have been studying the chemistry of fats in blood to find out. Now a group

What do <u>YOU</u> want to protect?

NEW SILVER gets its gleam during manufacture, from buffing. Silver and lint dust creates a slow-burning fire hazard. Full protection is provided by Fenwal Rate-Compensation Actuated DETECT-A-FIRE® Thermostats, installed with an alarm or release system on the dust collectors. They react the *instant* temperature of surrounding air reaches predetermined danger point.

BOOK BINDING IS REVOLUTIONIZED by NYMO® thread. A Belding-Corticelli product, it is the first new thread construction in 25,000 years. It does away with kinking, raveling... reduces friction . . . has higher resistance to abrasion. In NYMO thread, strands are fused, not twisted, together. A Fenwal THERMOSWITCH® Thermostat controls processing temperature during fusing.

HAT BRIMS ARE PERFECTLY SHAPED, thanks to an ironing machine that sets the shape of hat brims during manufacture. Fenwal THERMOSWITCH Thermostats help protect quality on these machines by keeping temperature at exact heat needed. These low-cost units are widely used throughout industry.

THIS MODEL SHOP is one of several specialized departments at Fenwal. Here Fenwal engineers translate new ideas and customer requirements into experimental prototypes. Through broad laboratory and engineering facilities, Fenwal engineers develop devices to help protect products and processes, property and people. Bring us your problem. Fenwal, Incorporated, 307 Pleasant Street, Ashland, Mass.

Fenwal

ELECTRIC TEMPERATURE CONTROL AND DETECTION DEVICES

PROTECTING PRODUCTS AND PROCESSES . . . PROPERTY AND PEOPLE

at the National Heart Institute of the U. S. Public Health Service announces valuable clues. Their findings suggest a blood test for early detection of hardening of the arteries and a possible treatment to arrest the disease.

Everyone absorbs fat into the blood after a fatty meal. The fat combines with protein to form giant lipoprotein molecules. Their presence makes the blood cloudy. In a normal person these molecules are broken down in a few hours, and the blood clears. But in the blood of persons with atherosclerosis, it has been found by John W. Gofman at the University of California, there are abnormal lipoprotein molecules which are not easily broken down.

It has been known for some time that heparin, the anti-clotting drug, can help clear milky blood. With the aid of heparin the National Heart Institute workers, Christian B. Anfinsen, Edwin Boyle and Ray K. Brown, set out to identify the natural substances in blood that participate in breaking down the giant lipoproteins. They found that heparin, with the help of a catalytic substance produced by heart and lung tissue, stimulates the production of a clearing factor in plasma. This factor, however, performs its clearing action only in teamwork with another plasma substance, which has been named "coprotein."

The investigators have partly purified all three of these factors—the one made by heart and lung tissue and the two in the plasma. They have tested this complex of factors by injecting it in patients and found that it reduces the number of abnormal lipoprotein molecules in the blood. If a lack of one or more of the three substances is responsible for atherosclerosis, it may be possible to determine this by a blood test at an early stage and check the disease by supplying the missing substance.

Jack and the Pumpkin

It would appear that when you plant a seed in Missouri, you had better drop it and jump out of the way. Leonard Haseman, of the entomology department at the University of Missouri, recently reported in *Science* the strange case of a stray pumpkin seed that took root in a Missouri faculty member's garden last summer. By the time frost killed the plant 173 days later, it had grown 1,986 feet. It grew at an average rate, recounted Haseman, of 2.43 millimeters per minute (the arithmetic is unassailable). The longest single branch reached 75 feet, which meant that it averaged five inches' growth per day throughout the season. The monster overran every living thing in 1,600 square feet of garden space and had to be pushed back constantly to prevent it from taking over a city street next to the garden. The plant produced 20 pumpkins.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

There is a saying that is as famous as it is erroneous. It is the one about the better mousetrap. The fact is that if anyone develops a new, improved mousetrap he has to beat his own path to people's homes. In other words, he has to sell if he is to prosper. In selling the more effective trap, it should be realized, he has rendered a service not only to himself and to his employees, but also to the buyer.

Revere thinks this is a good time to point out that salesmen render service to customers, and to give some thought to the functions and values of salesmanship. If by salesmanship we mean everything that influences sales, then of course we must include advertising and many other factors. However, except in the case of a product sold by mail, all the elements in salesmanship lead up to a single point, the contact between a salesman and a customer or prospect. During that interview, the salesman takes advantage of all that has been done previously to help him.

Why do people buy from one man rather than another, from one company instead of another? Revere has discovered through long experience and observation that loyal customers are created and held when the salesman and those back of him take a sincere and informed interest in the buyer's welfare. In Revere this may mean recommending and selling a less expensive alloy if it will serve as well as a more expensive one. Or it may involve suggesting use of an extruded shape, costing more per pound than plain bar, but saving important sums by reducing costly machining operations. And so on.

It is easy to recognize that such activities come under the head of "service." They are also a part of salesmanship, which renders other services as well. It is a service, we feel, to tell people about products, what they are, what they will do, what benefits they offer, how much they cost, how they should be specified, when they can be delivered. It is also a service to offer solutions to problems. In rendering such services, a salesman needs much more than a price list. He must have a firm background, derived from education, training and experience in his industry, and in addition must be able to discuss intelligently and constructively the problems of the people he serves. A sales force thus equipped, such as Revere has, can give directly or through the company's engineering service a kind of collaboration that is valuable but is not billed. If buyers had to dig out all the facts they need without the assistance of salesmen, American industry and the general public as well would be greatly hampered in seeking the best values obtainable.

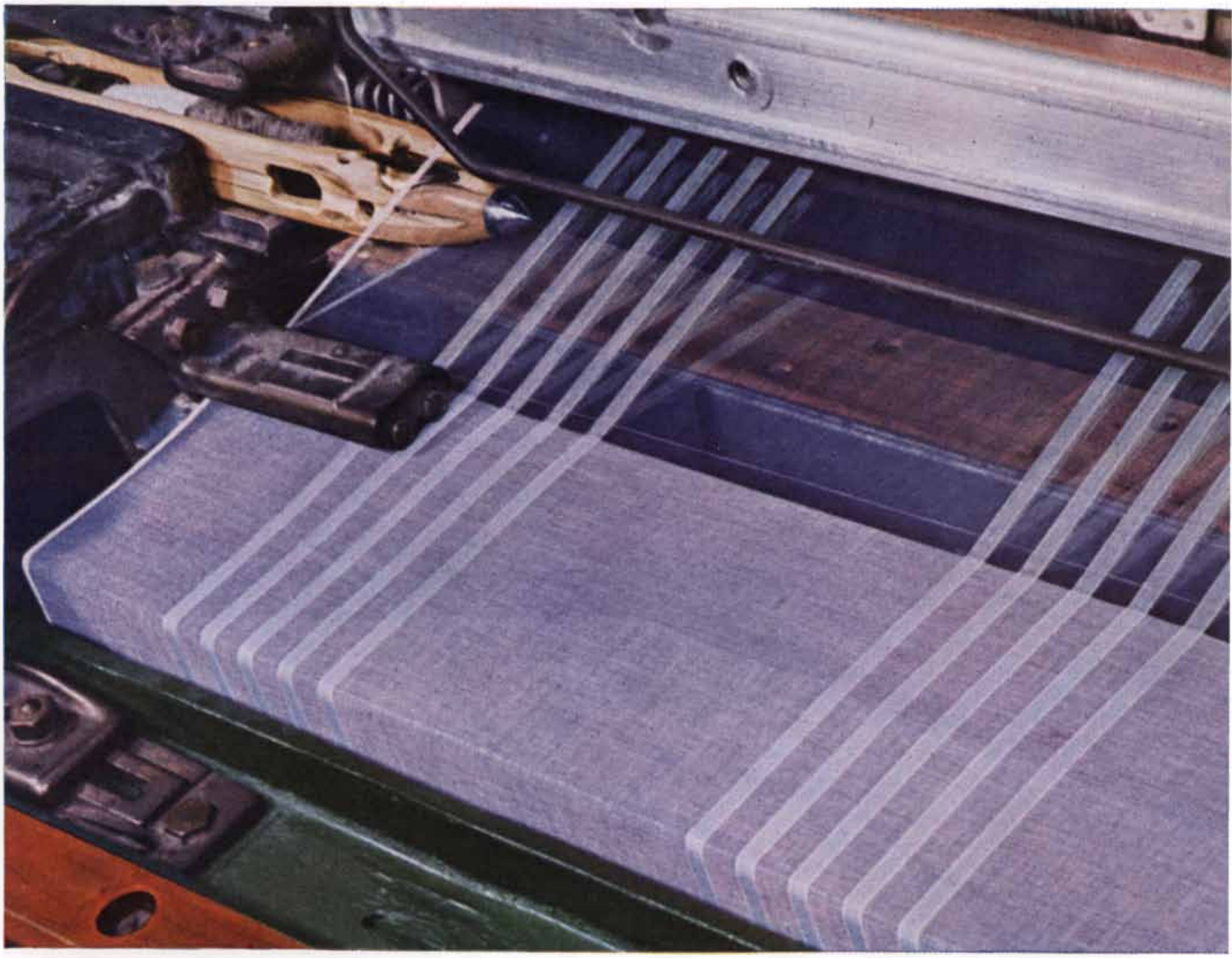
The salesman is part of a great team that has given this country more prosperity and standards of living higher than ever enjoyed anywhere else in the world. Other factors in achieving this amazing result include inventiveness, better design and engineering, faster and more economical production, the skills of management and factory employees, the editorial and advertising contributions of the thousands of helpful American publications. While we give credit to all these elements, let us not forget that productive capacity is increasing constantly, and that to move larger volumes of goods more capable salesmen and more effective salesmanship will be necessary. In the future, we believe the salesman who serves as well as sells will become more and more important, for only through sales can factories and employees be kept busy. Whenever and whatever you buy, remember that you can always find salesmen who, like those who serve the Revere customers, consider the best interests of their clients as carefully as their own. So we suggest you take your suppliers' salesmen into your confidence, and permit them to serve you fully.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

***Executive Offices:* 230 Park Avenue, New York 17, N. Y.**

SEE REVERE'S "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY



COME IMAGINEER WITH US

What happened in cloth weaving

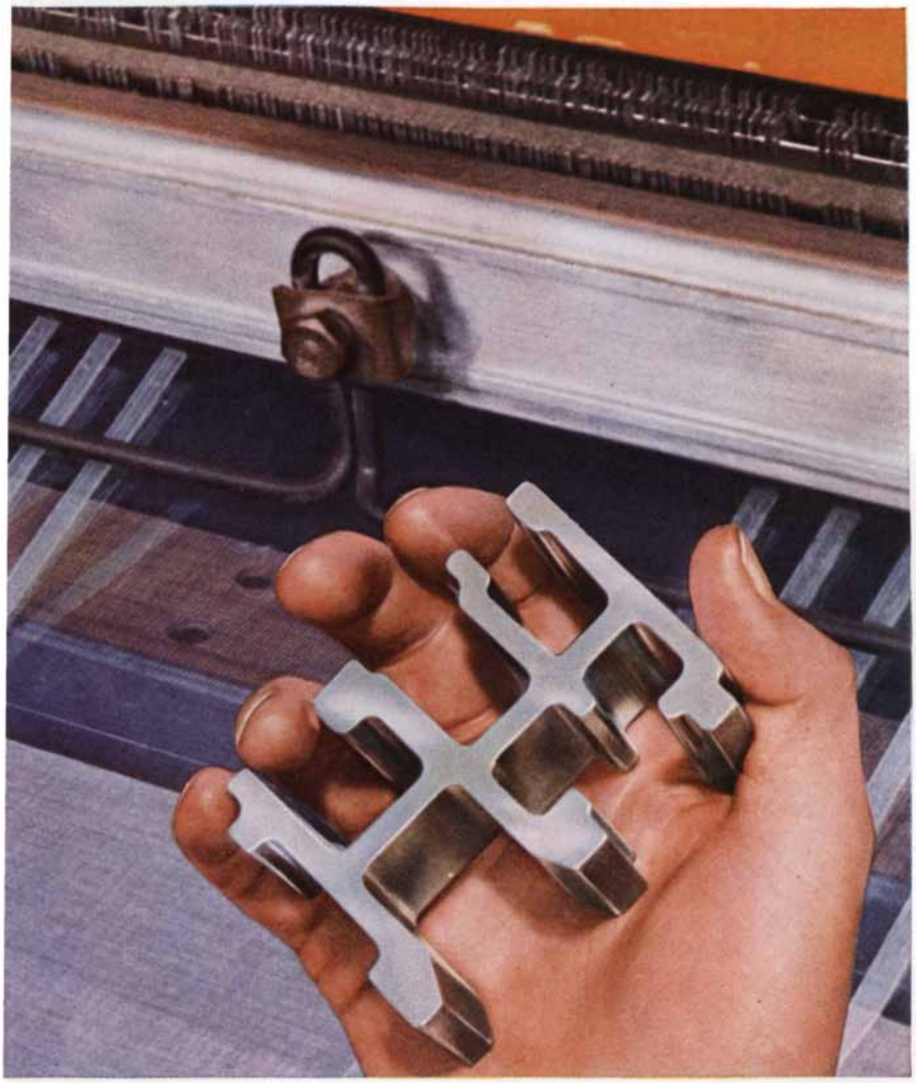
The problem was lay beams, "work-ingest" part of a loom. They separate the lengthwise threads—pack the cross threads tight. They carry the boxes that toss the shuttles back and forth. Sixteen attachments are bolted to a lay beam, yet it must be light enough to oscillate 225 times a minute.

Wood was used for lay beams, but even the best wood, steel reinforced, warps and shrinks. Attachment bolts loosen. Shuttles wear quickly. Looms are often down for repairs.

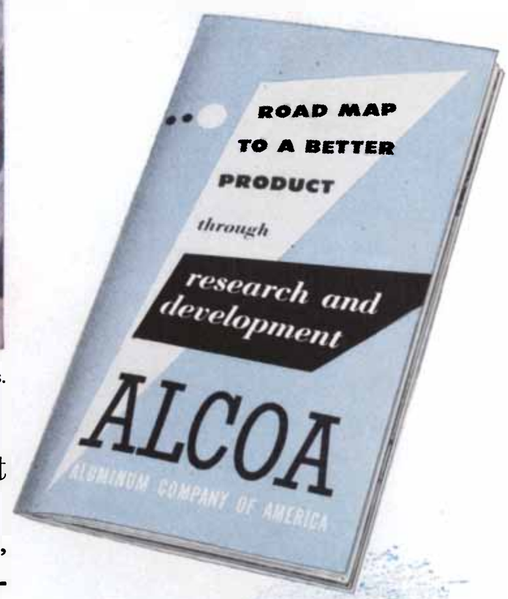
Encouraged by a leading loom builder, Alcoa engineers designed a semi-hollow aluminum beam. (Like the cross section shown above.) We suggested extruding as the low-cost way to make it. From high-strength alloys developed by Alcoa Research, we furnished samples for the loom builder to test.

From these tests came more requirements: refine designs . . . coax tighter tolerances from extrusion presses . . . develop an entirely new heat-treating process that keeps beams from warping when machined.

Does such Imagineering pay off? Shuttles now last 15 times longer. Looms run 40 cycles faster. Maintenance and down time are drastically reduced. All because a loom builder used Alcoa research, test and fabrication facilities as his own.



Draper Model X-2 loom in operation at Hoosac Mills, Corp., New Bedford, Mass.



shows how to improve your product

Imagineering not only means thinking of a lighter, longer lasting, better looking product—properties that aluminum offers. It also means solving the hard, commercial questions of price, strength, workability.

Specialists in Alcoa's Development Division will help you with the answers. Their knowledge, gained from hundreds of such problems, will help solve yours.

If basic research and testing are needed, your project will be handled by the world's greatest aluminum research laboratories. And for help in creating a pilot model or finding low-cost ways of manufacture, you'll use Alcoa's Process Development Shops. Here you'll find advanced techniques in welding, casting, finishing, forming, machining and heat-treating.

You'll get a detailed picture of these facilities from our booklet, "Road Map to a Better Product." It can be your first step toward putting 64 years of aluminum experience to work on a long-range project that could effect a major change in your company's competitive position. May we send you several copies?

ALUMINUM COMPANY OF AMERICA
2182-G Gulf Building, Pittsburgh 19, Pa.

Development Division

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

THE SOUTHERN SKY

Some of the most meaningful objects in the heavens are not visible from the Northern Hemisphere. Presenting the first photographs from the new Schmidt telescope in South Africa

by Bart J. Bok

LARGE CLOUD OF MAGELLAN appears in this reproduction of a blue-sensitive photograph made by the ADH telescope. Although the entire cloud is too large for one photograph, its "axis" appears at the upper left. The bright object near the center of the photograph is a nebula surrounding the star 30 Doradus. The reproduction shows all but the outer quarter-inch of the telescope's 10½-inch circular negative. Observer: Bart J. Bok.

THE THRILL of photographing wholly new vistas of the heavens comes to an astronomer only rarely nowadays. Most of the main broad-scale features of our visible universe were surveyed long ago. But the photographs on these pages represent just such a thrill, for they are new views of hitherto less fully charted sections of the sky. Like the exploration of sections of a dark continent previously seen only afar from the air, they bring into intimate view some virgin landscapes of our galaxy and its surroundings.

The pictures were taken in the relatively little explored southern skies with a new telescope of modified Schmidt design, the first such instrument to be installed in the Southern Hemisphere. What enables the telescope to show us new vistas of the heavens is that it combines great space-penetrating power with sharp vision over a wide field. Set up a year and a half ago in South Africa at the Boyden Station of the Harvard College Observatory, it has been photographing celestial regions only vaguely seen before. Almost every photograph has revealed some new feature of the structure of our galaxy or its neighboring regions.

THE PHOTOGRAPHS presented here will be more understandable if we first take an over-all look at the Milky Way system and consider the purposes to which our investigation is directed. The primary object of the investigation is to learn more about the structure of our galaxy—the central plane of which is marked by the band of the Milky Way stretching around the sky. A great wheel whirling in space, our star system is known to be shaped like a discus—about 100,000 light-years in diameter from rim to rim and about 10,000 light-years thick at the hub. Our Sun and the Earth are out toward the rim, some 25,000 to 30,000 light-years from the hub. According to our best current guess, the galaxy comprises close to 100 billion stars. We know that they are arranged in a nonuniform structure of some kind: in some regions they are clustered in knots, in others spread thinly. Great clouds of dust and gas drift through the galaxy. If we knew more about its structure and about the nature of the star collections and clouds, we would be in a much better position to judge the galaxy's actual size, its age, whether new stars are being formed, and so on. But we are too close to our system to see it whole.

In pictures of other galaxies we can see that some have a spiral shape—like a pinwheel with long spiral arms. Is our galaxy a spiral nebula? If so, what parts of it are its spiral arms? What is the structure of the galaxy between us and the center; are we, perchance, in a spiral arm ourselves? It was with such questions in mind that I went to the Boyden Station two years ago [see "The Milky Way," by Bart J. Bok; SCIENTIFIC AMERICAN, February, 1950].

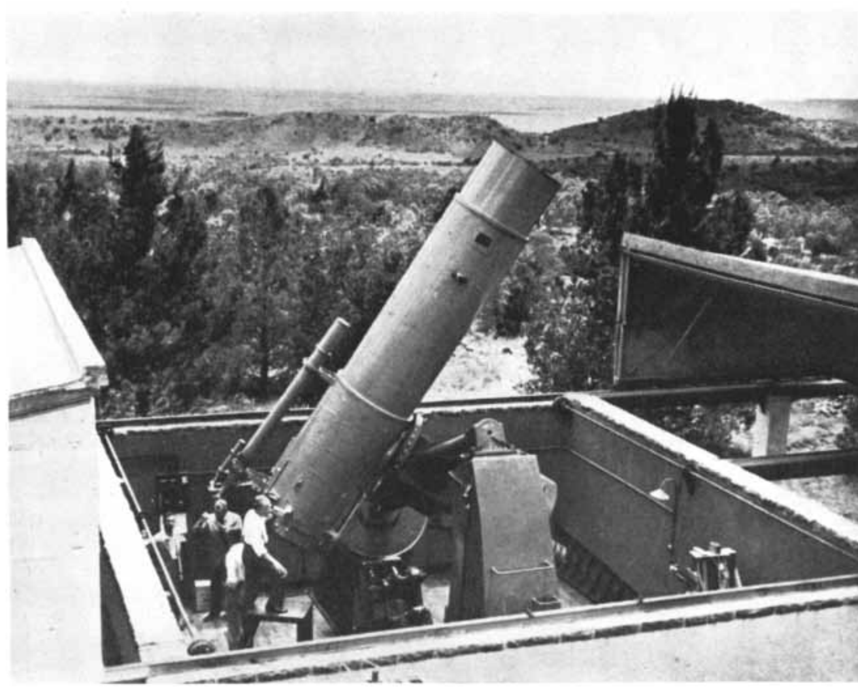
The Southern Hemisphere is a good place to study these questions for several reasons. From it one can get the best view of the center of our galaxy, for as the Milky Way turns in our heavens, the center passes directly overhead at the latitude of the Boyden Station. One of the most brilliant sections in the Milky Way cannot be seen at all from observatories in the U. S. This is the section from the Southern Cross to the beautiful Eta Carinae Nebula. In that direction lie the most conspicuous star concentrations in the solar system's neighborhood; it seems probable that here we are looking along a spiral arm of our galaxy or toward a knot of stars in such an arm.

How could we recognize a spiral arm if we saw one? It has been known for some years, principally through the work of Walter Baade at the Mount Wilson and Palomar Observatories, that the spiral arms in galaxies outside our own can be traced through patches of bright gaseous emission nebulosity and groups of blue-white supergiant stars. Hence we examined sections of the sky for the distribution of these objects. For this we used not only the wide-view Schmidt-type telescope but also the Boyden Station's 60-inch reflecting telescope and its photoelectric photometer, to provide the standards of color and brightness.

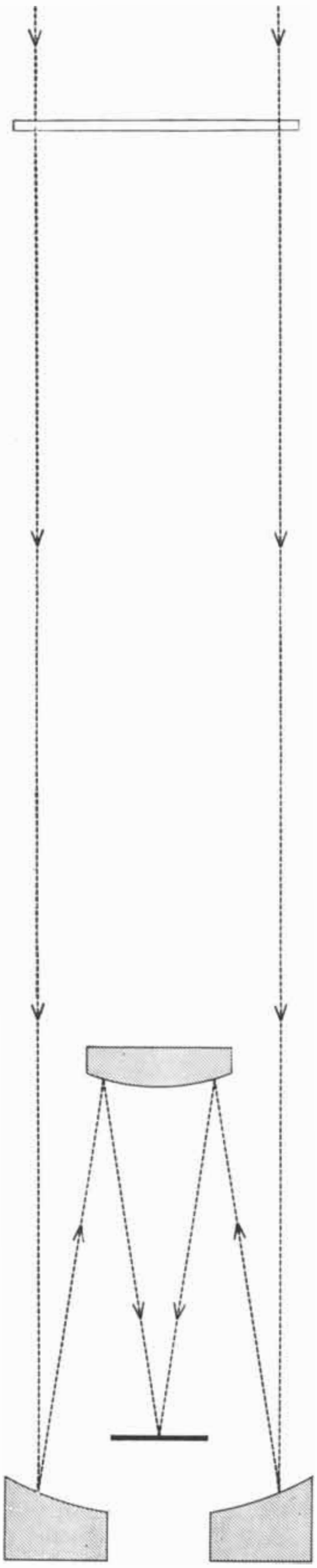
I concentrated my work on two sections of the Milky Way: the region between us and the center of the galaxy, and the section between the Southern Cross and the Eta Carinae Nebula. Much of the work is technical, concerned with the measurement of the colors and apparent brightnesses of stars, and is still in progress. In this article I shall describe certain aspects of the Milky Way's structure that stand out conspicuously on our photographs. Before I do so, something should be said about the remarkable telescope that made the work possible.

THE TELESCOPE is owned and operated jointly by the Armagh Observatory of Northern Ireland, the Dunsink Observatory of Eire and the Harvard College Observatory—it is therefore called the ADH. The instrument is a modified Schmidt, of a novel design first announced about 12 years ago by James G. Baker, a research associate at the Harvard Observatory. The optical engineering for the telescope was done by the Perkin-Elmer Corporation of Norwalk, Conn., with Baker as principal consultant. The Perkin-Elmer Corporation also executed the difficult and delicate tasks of engineering and building the tube with its precision mountings for the telescope parts and the various items of auxiliary apparatus.

The essential parts of a regular Schmidt-type telescope are a primary spherical mirror with a correcting lens placed at the center of curvature of this mirror and with the photographic plate at the focus of the telescope, so bent as to follow the spherical surface of perfect optical definition. This type of telescope



ADH TELESCOPE was photographed on the morning after its first successful focus plate had been made. At the guiding eyepiece of the telescope is the late John S. Paraskevopoulos. Second from the left is Bart J. Bok.



OPTICS of telescope are drawn to scale. From top: 33-inch correcting lens, secondary mirror, photographic plate-holder, 36-inch primary mirror.

has been described fully in earlier articles in SCIENTIFIC AMERICAN. The Baker design calls in our case for a primary mirror, which is again spherical, with an aperture of 36 inches. The correcting lens, aperture 33 inches, is placed closer to the primary mirror than in the original Schmidt design. The total length of the telescope tube is 168 inches. The light from a star first passes through the correcting lens, then is reflected by the primary mirror to a convex spherical mirror of 17 inches diameter, which in turn brings the starlight to a focus on the photographic plate, placed only nine inches above the primary mirror (*see diagram at left*). With this optical system, a field of perfect definition is obtained over the entire area of a flat photographic plate with a circular diameter of 10½ inches. The ADH permits one to photograph in perfect focus on a single plate an area of the sky equivalent to 100 times that of the full moon.

The telescope tube and its optics arrived in South Africa in October, 1950. John S. Paraskevopoulos, then superintendent of the Boyden Station (he died five months later), went to work with the help of a capable staff to mount the instrument. Mounting and adjusting a telescope of novel design at a station 7,000 miles from where it was made is not a minor undertaking. The optics had to be adjusted to within a tolerance of one or two thousandths of an inch, with no shift in any component when the telescope was aimed at different positions. The firm of Perkin-Elmer, realizing that much of its high reputation as a maker of precision optical equipment was at stake, had taken the precaution of preparing a special manual of step-by-step instructions. Part I of the manual dealt with the initial adjustments, Part II with corrections and trouble-shooting after the first test-exposures. The manual served its purpose beautifully. The first plate had the focus exactly where it should be; the optics were perfectly squared on, and we did not need to bother at all with the second half of the manual!

NOW to the photographs. The power of the ADH to cover a large area of the sky on a single plate is probably demonstrated best by the two photographs of the globular cluster Omega Centauri (*page 52*). To the naked eye Omega Centauri appears merely as a hazy star of about fourth magnitude, but it is actually a cluster of at least 100,000 stars. The circular print at the top is from a direct contact copy of the photographic plate of 10½ inches diameter. The enlargement at the bottom covers only the cluster itself and the region immediately surrounding it. Most large parabolic reflectors would hardly get all of the cluster Omega Centauri in good focus on a single photograph, but the Baker-Schmidt covers with perfection a very much larger area of the sky than that of the cluster.

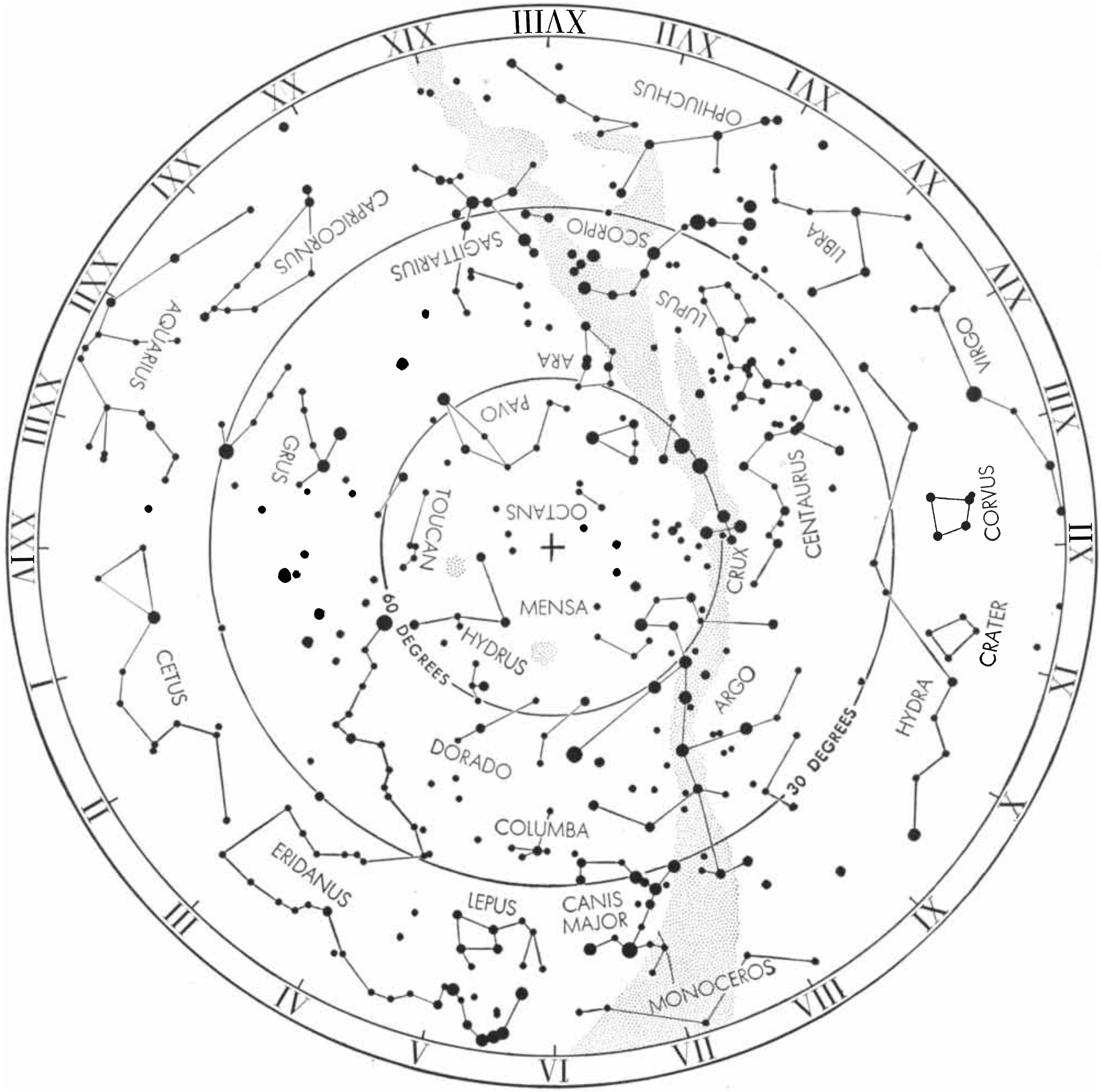
Photographs of this kind find many uses. They are excellent for studies of the star numbers at various distances from the center of the cluster and for studies of the shape of the cluster. Plots of the relation of colors of stars to their apparent magnitude at various points in the cluster can be obtained from comparative studies of photographs of the same cluster on blue-sensitive and red-sensitive plates. The Baker-Schmidt photographs also are ideal for the discovery and study of faint variable stars in globular clusters; we depend on such variables entirely for our knowledge of the distances of the clusters from us. Omega Centauri, one of the nearest, has been estimated by Harlow Shapley to be about 20,000 light-years away.

The photograph of the Large Star Cloud of Magellan (*page 46*) gives further proof of the power of the ADH. The Large Magellanic Cloud is too big for a single ADH plate; this print shows only the star-rich region which Shapley has called the "axis" of the Cloud, a section with many star clusters and patches of dark and bright nebulosity.

The Large Magellanic Cloud and its fellow, the Small Magellanic Cloud, are satellite systems to our galaxy. These small galaxies accompany the Milky Way as the Moon does the Earth; they are probably bound to it permanently by gravitational forces. The Large Cloud is estimated to be 80,000 light-years from us.

The ADH plates open whole new areas of research on the Magellanic Clouds, which have been studied at the Harvard Observatory for more than 60 years. At the moment the greatest interest attaches to a precise knowledge of the varieties of stars, clusters and nebulae in the Clouds. Astronomers now divide star groups into two general types—what Walter Baade has called Population I and Population II. The first consists mostly of blue-white giant and supergiant stars, clouds of interstellar gas and cosmic dust; the second, of red giant stars and a great abundance of dwarf stars, with hardly any clouds of dust or gas. In the spiral galaxies the arms seem to be composed mainly of Population I, and the remaining parts mainly of Population II. Shapley and his associates are making a detailed examination of the ADH plates of the Large Magellanic Cloud, and the results to date seem to show that it is mostly Population I. It looks almost as if the Large Cloud is a piece of spiral arm broken loose from our galaxy.

WE TURN now to several photographs throwing light on the main field of our research—the structure of the southern Milky Way. The photo-

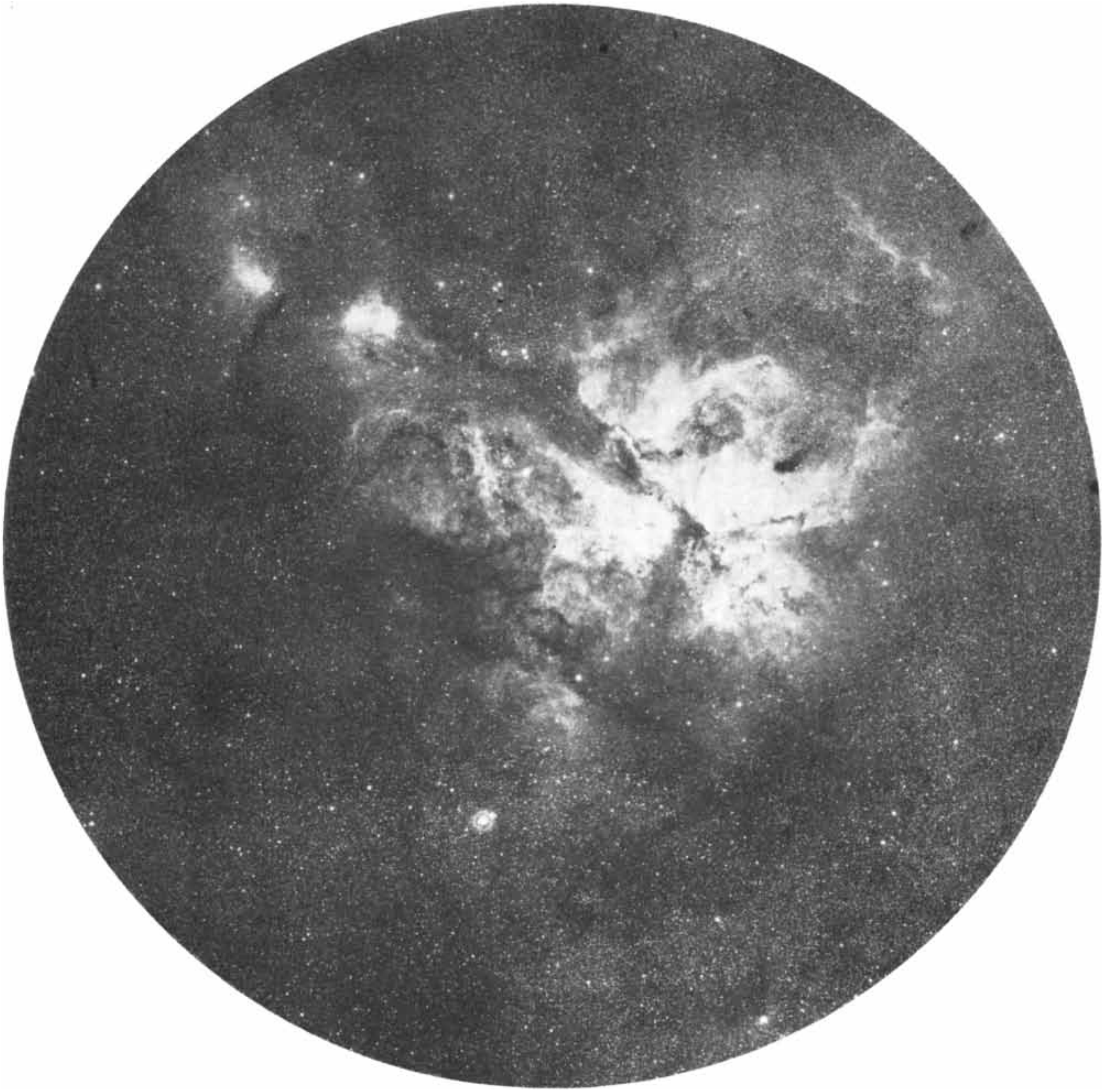


STAR CHART locates the principal objects and constellations visible from the Southern Hemisphere. The stippled band running from top to bottom is a schematic outline of the Milky Way. The two small stippled areas near the center are the Clouds of Magellan. The circles labeled 30 and 60 degrees indicate declination, or latitude on the celestial sphere. The Roman numerals mark right ascension, or celestial longitude, in hours.

graphs on the next two pages are of the Eta Carinae Nebula: at the left a full-scale picture, at the right an enlargement of the dense central section. One of the most interesting features of the full-scale print is the pair of roundish dark objects near the upper right edge of the plate. These are a fine pair of "globules," small clouds of cosmic dust which may be caught in the act of contracting slowly into tenuous stars. Students of stellar evolution are much interested in these little globules. But what we are chiefly concerned with here is the character of the nebula itself.

The Eta Carinae Nebula and associated stars mark the heart of a collection about 5,000 light-years from us. Is it a knot in a spiral arm of our galaxy? The ADH plates have enabled Dorrit Hoffleit and myself to examine in detail the concentration in Carina of blue-white supergiants and bright gaseous nebulosity (*i.e.*, collections of fluorescent gas which shines in the ultraviolet light from nearby stars). This photograph and others show a dense and intricate network of such nebulosity in Carina. (Some of the fine detail that was caught on the plate is lost here because the picture is a small-scale copy of the original photograph.) Furthermore, the ADH survey discloses that the whole section of the Milky Way from Carina to the Southern Cross, stretching over 15 degrees in the sky, is overlaid with bright nebulosity of the kind that characteristically appears along the arms of spiral galaxies. On page 54 are two photographs of regions not far from Carina, both of them "alive" with gaseous emission nebulosity. The brightest, loop-shaped nebula in the top photograph bears a marked resemblance to the loops shown on photographs made with the 200-inch Hale telescope of outer portions of the great spiral in Andromeda.

The Carina section is not the only part of the Milky Way that shows concentrations of such nebulosity and blue supergiants. W. W. Morgan of the



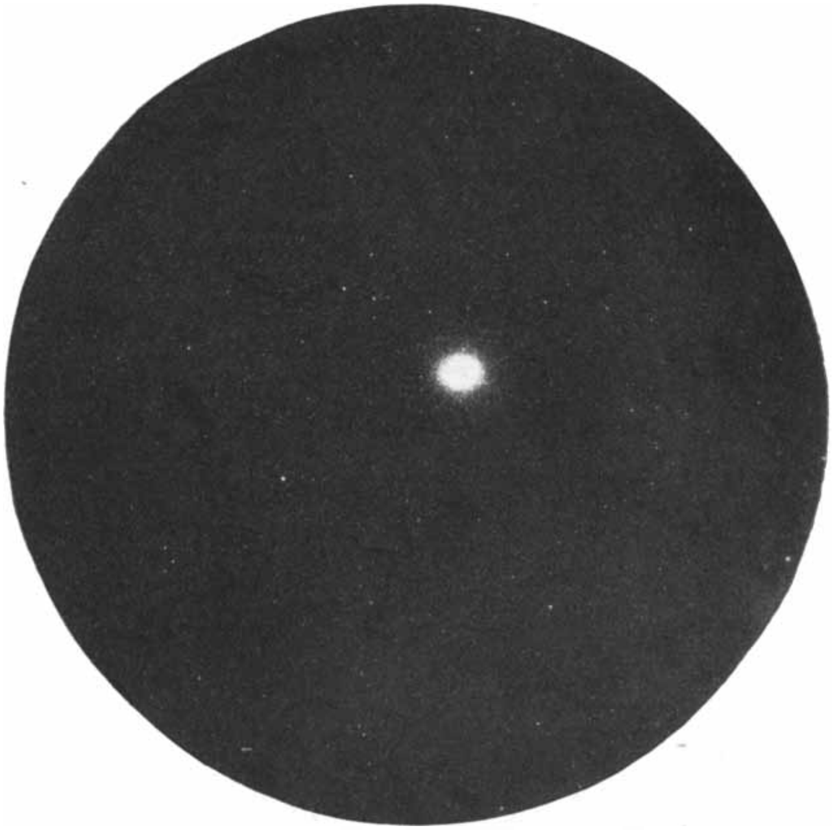
ETA CARINAE NEBULA is shown on a reproduction of a full negative. Observer: M. J. Bester. On the opposite page is an enlargement of the same region. Observer: W. D. Victor. The full plate is centered on a right ascension of 10 hours 43 minutes and a declination of 59.4 degrees South (*see the chart on the preceding page*).

Yerkes Observatory and Jason J. Nassau of the Warner and Swasey Observatory have begun to trace spiral arms in the northern Milky Way. Bright nebulosities seem to be more abundant in the Carina section, however, than anywhere else in our galaxy.

Astronomers are still in considerable doubt about the nature and extent of the spiral arm of which the Carina concentration seems to be a part. Morgan believes that this arm may be a part of the inner structure of the galaxy, and that no section of it comes anywhere near our sun. I have suggested in the past that the arm may stretch from our sun toward Carina. Conclusive evidence should be forthcoming soon, when spectrographs now being made give us better estimates of the distances from us of the key blue-white stars in the Carina section.

The globules, believed to be embryo stars, of which we saw two samples in the Carina picture, are a fascinating subject in themselves. On page 55 is an ADH photograph of the region of Messier 8 and the Trifid Nebula, in another part of the southern sky. Like the Carina section, it has extended emission nebulosities. Against that bright background are numerous tiny black dots, which most likely are globules. It is surprising to find so many globules in a region where, according to the spectra of the associated stars, ultraviolet light must be abundant and most atoms must be highly ionized. Offhand this hardly seems the kind of place where globules would be provided with the peace and quiet apparently needed for the birth of a star out of a cloud of dust. But we cannot deny the presence of these globules.

LET US turn now toward the center of the Milky Way system. On page 53 is a photograph of the Sagittarius and Scorpio section, which is generally agreed to be in the direction of the center of our galaxy. Here we see an overwhelming abundance of faint stars,



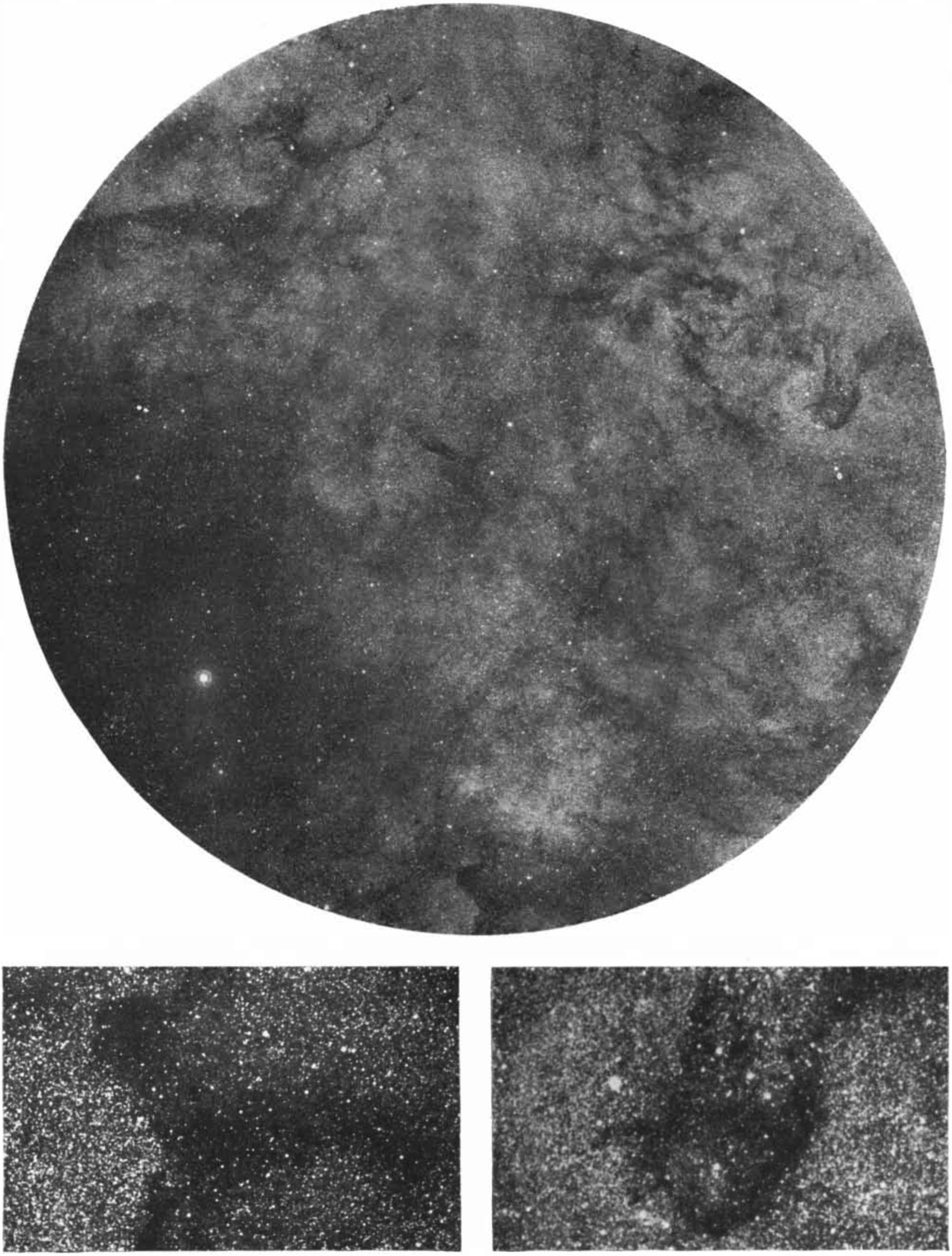
GLOBULAR CLUSTER OMEGA CENTAURI appears on the reproduction of a full negative shown at the top of this page. An enlargement of the cluster itself is at the bottom of the page. Observer: W. D. Victor. The full negative is centered on a location of 13 hours 24 minutes and 47 degrees South.

and without question there must be many, many more that we cannot see, for large regions are hidden from our view by extended turbulent clouds of cosmic dust. Where are the bright emission nebulosities that were so conspicuous on our other photographs? They are simply not present. As we have noted, the central part of a spiral galaxy is generally composed of Population II stars, with little nebulosity or dust, and these pictures confirm nicely the long-held belief that here we look toward the center of our galaxy.

But what about the great clouds of dust that lie in that direction, obstructing our view? The answer seems to be that the clouds are fairly close to us and nowhere near the central region itself. During our stay in South Africa my colleague Uco van Wijk and I recorded the colors of some of the stars in the direction of the center. According to the lines shown in their spectra, these stars must be very blue. But in our photoelectric measurements the light from most of them was red: it was reddened by passing through clouds of dust. From the fact that even the nearer stars were too red for their spectral types, we deduced that most of the cosmic clouds producing the observed reddening are within 5,000 or 6,000 light-years of us—only one-quarter to one-fifth of the distance from the sun and earth to the center of the galaxy.

To obtain the spectra of stars we need an objective prism, big enough to fit over the correcting lens of our telescope. A Schmidt-type telescope without an objective prism is only half a telescope. We have such a prism for our ADH, covering the full aperture of 33 inches and weighing close to 500 pounds. Mounted in front of the correcting lens, it produces a small spectral band for every star bright enough to be recorded. The prism arrived in South Africa almost a year after the telescope, and it is only now going into full-scale operation. On pages 56 and 57 is an enlargement of a section of one of the spectrum plates it has made. The picture shows the spectral bands of the stars in a field fairly near the Small Magellanic Cloud. The stars shown are mostly of the cool variety; some, notably the object with two conspicuous bright lines to the right of the center of the photograph, have surface temperatures only about one-half that of our sun, itself a cool star. This year we are photographing the Carina and Sagittarius sections of the Milky Way. On these spectrum photographs the blue-white giant stars should stand out conspicuously, and we should be able to make a complete census of them to the 12th apparent magnitude.

The usefulness of the ADH telescope is augmented by another device—photography in the infrared. Following the



STAR CLOUDS in Sagittarius and Scorpio, generally thought to lie in the direction of the galactic center, are shown in the reproduction of a full negative at the top of this page. At bottom left is an enlargement of the area at the bottom edge of the full negative. At bottom right is an enlargement of an area near the right edge of the negative. Observer: W. D. Victor. The negative is centered on 17 hours 53 minutes and 32.5 degrees South.

BRIGHT NEBULAE were photographed on a red-sensitive negative. Observer: W. D. Victor. Location: 11 hours 10 minutes, 60 degrees South.

SIMILAR NEBULA was photographed on a blue-sensitive negative. Observer: M. J. Bester. Location: 11 hours 30 minutes, 62 degrees South.

TWO NEBULAE, Messier 8 (*top*) and the Trifid Nebula (*bottom*), appear on the same plate. Against them are dark "globules" that may be stars in formation. Observer: W. D. Victor. Location: 18 hours, 24 degrees South.

OBJECTIVE PRISM photograph, reproduced from a section of the full negative, shows the spectra of stars

lead of Nassau and his associates at the Warner and Swasey Observatory, test photographs were made at Boyden Station last year, and these have indicated great possibilities for research in the near infrared at wavelengths of about 8,000 Angstroms. The light of distant stars can penetrate the cosmic clouds much more easily at these wavelengths than in the normal blue range. Moreover, in the infrared we are in a position to search for and study the varieties of stars that are characteristic of the regions between the spiral arms and of the central portions of spiral nebulae.

THIS ARTICLE has deliberately been focused on the story of one telescope. I have hardly mentioned the part played by the Boyden Station's 60-inch Rockefeller reflector in our attack on the problems of the southern Milky Way, or the contributions being made by many other observatories to Milky Way research in general. Nor have I gone into the investigations being conducted with the ADH telescope itself by its Irish co-owners, among which are multicolor studies of stars by H. E.

near the Small Cloud of Magellan. Observer: M. J. Bester. Location: 0 hours 45 minutes, 69 degrees South.

Butler of the Dunsink Observatory and studies of the southern Coalsack, the most distinct dark nebula of our Milky Way, by E. M. Lindsay of the Armagh Observatory.

The work of this useful telescope has just begun. What it has shown us so far is a new outlook on our galaxy and the promise of more thrilling discoveries to come. Some of the pieces of the jigsaw puzzle are beginning to fit together. Looking toward the center of the galaxy, we can detect a network of dense dust clouds floating through space within 5,000 light-years of us or less; and beyond that, up to 25,000 light-years away, we can see the thickly huddled stars and star-clusters of the hub itself. Toward Carina we can see apparently unmistakable evidences of a spiral arm flung across the galaxy. We are still groping our way about the very large house in which we live, but our vision is improving.

Bart J. Bok is professor of astronomy at Harvard University and associate director of the Harvard Observatory.

LETHAL HEREDITY

Death is not only the end but also a part of life. As an inherited characteristic of living things, it is a significant clue to the mechanism of genetics

by Willard F. Hollander

CHARLES DARWIN pointed out that evolution depends on three prime movers. Variation, heredity and death—these are the three elements of the process by which nature selects and perpetuates the species of life most fit to live on our planet. The third member of this trinity is too commonly overlooked. Without death we would have no evolution, and it plays a bigger role than is generally attributed to it. Death's function is not confined to elimination of the less fit: paradoxically, it also has a part in protecting and preserving the fit.

Consider a beehive. If you consider it at too close a distance, you are likely to be met by a banzai attack of one or more workers—those sterile females that are always on the job nourishing and defending the hive. The bee will jab a barbed sting into your skin, where it goes on pumping venom from its poison sac. But the bee herself flies away to die, for her sting is torn out of her abdomen.

What good is this performance to the bee? Obviously, no good to the suicidal one that has left her sting in you. But her death is a sacrifice protecting the hive. From the standpoint of survival of the hive her life is expendable, because she is sterile and would produce no young. Her instinctive act, based on heredity, derives its evolutionary value from the welfare of the hive as a whole.

Even more spectacular than the sacrifice of the female bees is that of certain male animals. The female praying-mantis and many female spiders climax their nuptial ceremonies by killing and devouring their unfortunate spouses. This ritual seems arranged for by heredity, as is the attack of a bee. Shall we accuse the female spider of wanton genocide and cannibalism? On the contrary, there is nothing wanton about it. Only after the male has transferred his precious burden of spermatozoa to the female is his life forfeit. Up to that point his death would matter, but not after. The female can be given credit for putting his otherwise worthless carcass to use. The male may be considered a sacrifice for the benefit of the female and offspring. Why lament his passing?

The May fly, which is said to possess the distinction of being the shortest-lived animal, lasts only a day or so as an adult. Mother Nature has apparently made a terrible blunder here: the adult May fly has no mouth for eating, so it is condemned to die of starvation. But in its one orgiastic day of adulthood the insect's eggs are fertilized and laid—generation follows generation to its foredoomed end. Evolution puts no premium on a long life-span *per se*; after an animal has provided for the next generation, its continued survival is unimportant from the evolutionary point of view.

SACRIFICIAL death is a common occurrence within the bodies of individual organisms. Some kinds of lizards when grasped will break off a large portion of the tail. The sacrificed piece, writhing about very actively, is likely to distract the predator, so that the lizard itself may escape. It then regenerates the lost tail-end at leisure. Crabs and other crustaceans also readily lose appendages when in difficulty, and regenerate them later. Sea cucumbers when irritated may voluntarily spew out the entire digestive tract—almost the *ne plus ultra* of sacrifice!

Our own bodies possess a similar capacity for sacrifice in the general interest. We may liken the human body to a beehive: it is a tremendous cooperative colony of cells. Our white blood cells, like worker bees, rush to attack intruders, and they die by thousands in pus formation. In the development of animals during the embryonic stage, certain complex structures are formed according to hereditary plan, only to be destroyed later. The human embryo early forms a fairly respectable tail, but soon sacrifices it. A tadpole absorbs its tail and gills during its metamorphosis to froghood. As embryos, mammals and birds generally have what are known as aortic arches, a series of arteries in the neck like those of a fish, but these mostly degenerate long before birth.

Death, indeed, forms an organic part of life. Practically every higher animal has some lifeless tissue which is an essential and functionally perfect part of its being. Hair, feathers, scales, horns, claws, fingernails—in fact, the entire skin surface of most vertebrates and of many invertebrates—are composed of dead cells. Continuous growth from beneath, or periodic molting or regeneration, may renew these structures as they become worn. Plants, too, have specialized dead structures, ranging from the spines of a cactus and the down of a dandelion seed to the corky bark of trees and shrubs.

In short, death is of great service to living things. Individual structures or organisms are expendable. For evolution the point of reference is the organism or the group as a whole; only *its* death matters.

SCIENTIFIC interrogation of nature has yielded a great store of knowledge about the intimate relation of death to variation and heredity, the other parts of the key to evolution. Some of this information is statistical. For example, the variations in the human life-span have been extensively analyzed. Alexander Graham Bell, one of the first to attack the problem, showed very clearly that people's length of life was correlated with that of their parents. When both parents died before the age of 60, the average life-span of their children was about 33 years; when both parents lived to 80 or more, the average life-span of their children was about 53 years. This difference of 20 years seems largely attributable to inherited differences of constitution; as the saying goes, "if you want to live long, choose long-lived ancestors."

Another significant correlation is that between weight and life-span. After maturity there is a marked divergence in life expectancy between people who are overweight and those who are underweight: usually the heavier the individual, the shorter the average life-span. Heredity of course is a powerful factor in the development of a tendency to overweight.

Comparison of the life-expectancy curves of modern populations with those of primitive and ancient peoples discloses a curious paradox: at young ages the primitives have a much shorter life-expectancy than the moderns, but once they have passed middle age, their life-expectancy is longer. The explanation may be that the less rigorous conditions of civilization permit a much greater percentage of constitutionally weak individuals to reach middle age, whereas those who survive the hardships of primitive life to middle age are hardier types and likely to live longer.

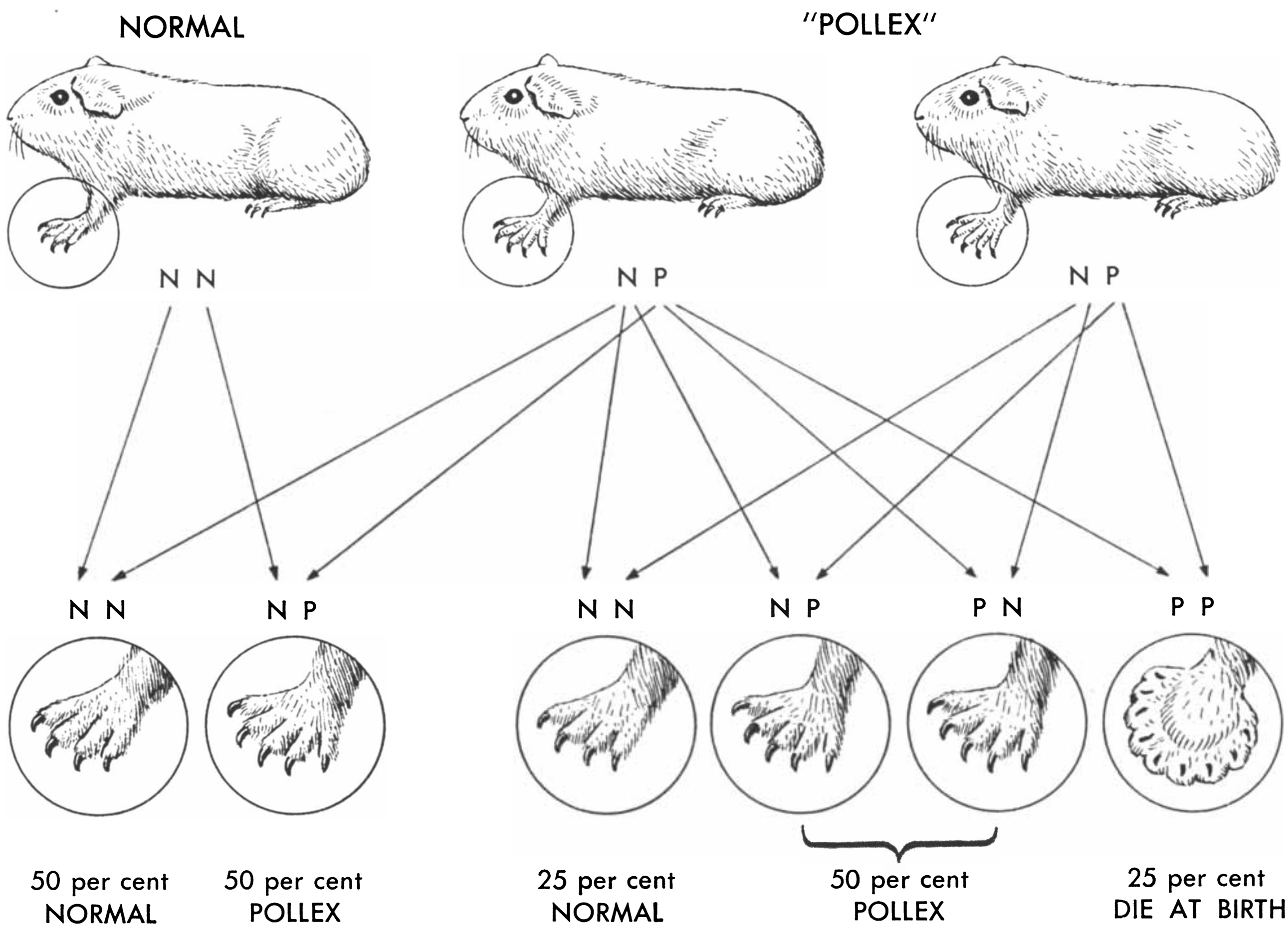
NOW LET US look at some specific hereditary variations, or mutations, among animals and plants. Almost every species produces defectives or freaks of one kind or another—some lethal, some merely disadvantageous. In nature most departures from normal cannot survive long. A pigeon with defective feathers, for example, or a rodent with defective teeth, generally dies soon after its parents cease to care for it. When man intervenes to protect and encourage such freaks, as he often does in the laboratory, they may thrive and multiply.

Mutations are generally inherited as units, according to Mendelian principles. Take for an example albinism in the rabbit. A rabbit with this common color mutation is at a serious disadvantage in the wild state, because the lack of pigment impairs its vision and deprives it of camouflage. When an albino rabbit is crossed with a normal one the albinism seems to disappear—all the first-generation offspring are normal. In other words, albinism is a recessive trait. But if one of these hybrids is mated with an albino, about half of their offspring will have albino genes from both parents and will show albinism. If two hybrids are mated together, we expect to obtain three times as many normal as albino progeny. Finally, if a hybrid is mated with a pure normal, we expect no albino young. By this last type of mating a recessive defect may be transmitted from generation to generation *sub rosa*. Under such circumstances an organism may carry defective genes entirely unsuspected: it is quite impossible to tell whether an animal or plant bears such genes merely by examining it.

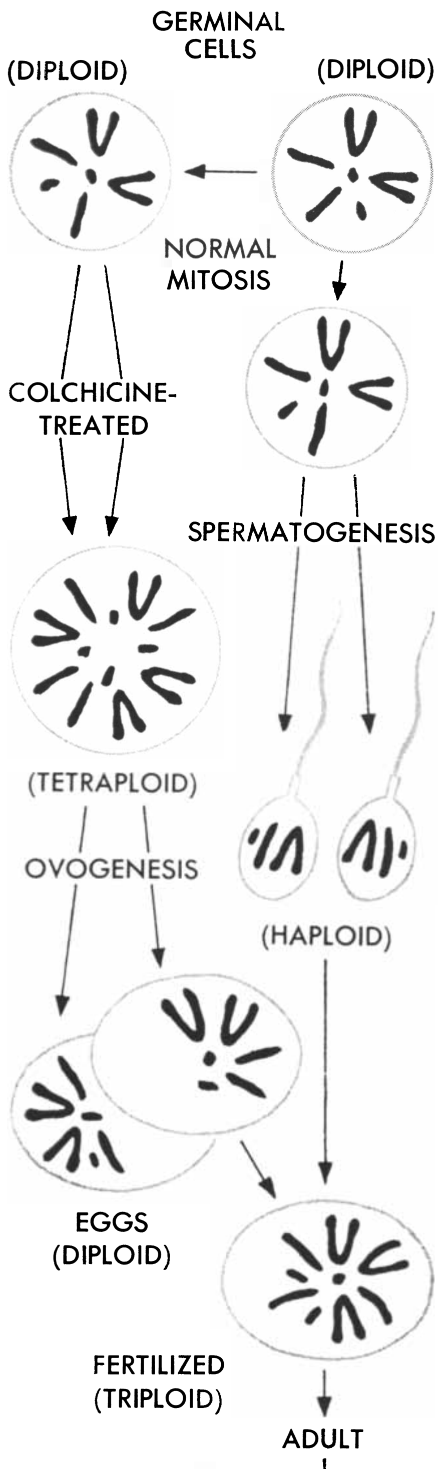
Some mutations are dominant, and therefore incapable of hiding. An example is the extra-toed condition found rather commonly in house cats. Extra toes are no handicap to a pet cat, and the trait multiplies merrily. But in the wild this clumsy type of paw would be a disadvantage to a cat.

Sometimes a mutation is so radical that nothing can be done to prolong the animal's life to maturity. This is what is known as a lethal mutation. Often it kills the animal while it is still an embryo. Most lethal mutations are recessive, however, and are carried unsuspected by normal-appearing animals.

Certain lethals are partly recessive but are betrayed by a mild defect or by an apparently irrelevant trait. This identification mark may be called a "badge" of lethality. A good example is the short-legged condition of the Dexter breed of cattle, originating in Ireland. Two Dexters mated together may produce three types of calves: normal, Dexter and "bulldog." The "bulldog" calf, seldom born alive, is very deformed and almost legless. An analogous case is found in the creeper and Japanese bantam breeds of chickens, which have short



LETHAL BADGE of the guinea pig is "pollex," or five toes instead of the usual four. Participating in the development of a four-toed guinea pig are two normal genes (NN). Participating in the development of a five-toed guinea pig are one normal and one abnormal gene (NP). The results of matings between these types are shown at the bottom. When two of the abnormal genes are combined in one offspring, it is dead at birth.



legs. The lethal offspring are unable to hatch. Sewall Wright of the University of Chicago has described an interesting lethal badge in the guinea pig. On individuals of one family of guinea pigs he found thumbs, which are normally lacking in this animal. When two of the thumbed freaks were mated, about a fourth of their offspring died before birth from hemorrhages. The lethal embryos had many extra toes on each foot.

Among other examples of lethal badges are hairlessness in dogs, deafness with blue eyes in white cats, and crests coupled with white color in canaries. In mice, which have been studied extensively, many badge types have been discovered. One of them, recently found by Leonell Strong at Yale University, is a looped tail. When two loop-tailed mice are mated, about one out of four of their young has a cleft vertebral column (*spina bifida*) and an exposed brain; the defective animal dies at birth.

Do LETHAL mutations exist in man? The answer must be yes. It is hard to get people to give information on such skeletons in the closet, but babies with fatal congenital malformations are known to be born in large numbers—up to 20,000 a year in the U. S. Miscarriages and abortions of defective fetuses are still more common. Though some of these defects may be due to accidents or infections, it would be rash indeed to say that heredity played no part.

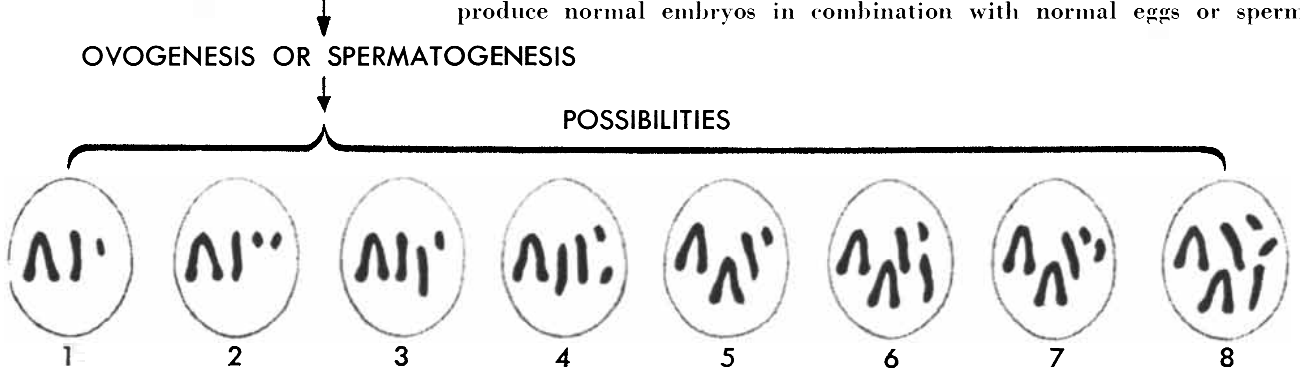
The Norwegian investigators Otto Mohr and Christian Wriedt have identified a lethal badge in man in the form of a shortened second phalanx of the index finger. One marriage of two such persons was reported: they had a child who lacked fingers and toes and had other skeletal deformities leading to death at an early age. No doubt other traits that we see now and then are actually lethal badges, but they are so rare, and the marriage of two people with the same defect is so improbable, that we lack evidence of their lethality.

The quickest way to expose lethal traits is by intense and continued inbreeding. In man such matings are generally illegal or taboo; the experience of the race indicates bad results. But brother-sister matings in animals and self-pollination in plants are a standard laboratory practice. The outcome is generally detrimental—unless inbreeding has been customary in the species. When inbreeding begins, the heredity seems to be breaking down. All sorts of defects and weaknesses appear. The average life-span decreases. After a few generations the family often becomes extinct.

But if the family can weather the first few generations (5 in the case of plants, 10 in animals), a leveling-off sets in. Members of the family may show defects or weaknesses, but not new ones, and there is striking uniformity. The type has become fixed. This is the situation already reached in nature by self-pollinated plants such as wheat and peas. No more lethals or defects are hidden—every such trait has been exposed and discarded, if that is possible. Inbreeding therefore is best considered not a destroying agent but a sorting or purifying method. The hybridizing of two purified inbred families or "strains" generally produces a highly vigorous and uniform progeny; the simplest explanation is that the two strains combine the effects of their good genes and are not likely to possess the same recessive defects.

The abundance of hidden lethals and hereditary defects exposed by inbreeding must be seen to be believed. It seems safe to say that very few individuals

DOUBLED CHROMOSOMES cause lethal effects. Germinal cells, which give rise to eggs or sperm, normally have two sets of chromosomes (diploid). Eggs or sperm normally have one set of chromosomes (haploid). If a germinal cell is treated with the drug colchicine, it develops four sets of chromosomes (tetraploid), and eggs or sperm descended from it have two sets. In this diagram a diploid egg is fertilized by a haploid sperm, giving rise to an organism with cells containing three sets of chromosomes (triploid). The chromosome combinations in eggs or sperm descended from such cells are shown at the bottom of the page. Only possibilities 1 and 8 would produce normal embryos in combination with normal eggs or sperm.

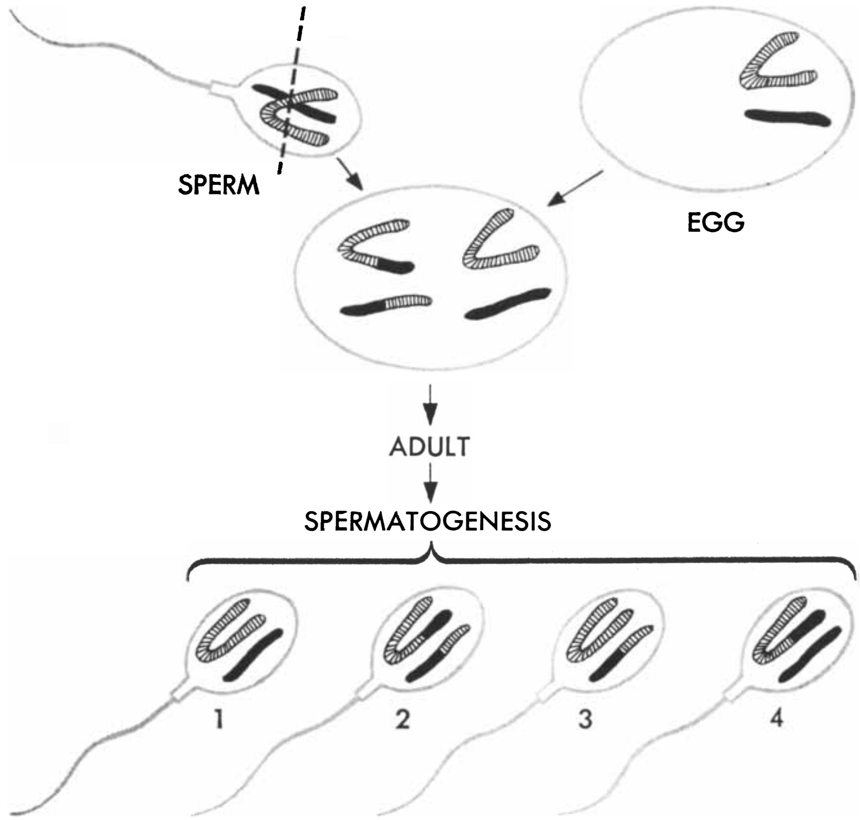


of an ordinary mixed population fail to harbor one or more. Whence came this multitude of skulking malefactors? A partial answer to this question has been obtained with the little fruit fly, *Drosophila*. It has been shown that when mutations are induced in fruit flies by X-rays, mustard gas, supersonic vibrations or some other artificial means, most of them are lethal. In nature cosmic rays, radioactive elements and certain chemicals presumably produce mutations in animals and plants at a low but steady rate.

The primary effect of a mutagenic agent appears to be damage to one or more chromosomes in the nuclei of cells. The damage may be anything from an invisible minor change to a complete fracture. Fractures may heal by reuniting; however, if several fractures are induced in the same cell, wrong ends of chromosomes may unite, and serious consequences are then sure to follow. The nucleus may lose parts of chromosomes completely, or the chromosomes may be improperly combined in the formation of sperm and egg cells. If both sets of chromosomes do not have identical damage, the offspring of the combination of a sperm and an egg may seem normal, but the potentiality for tragedy in later matings is still there.

When an entire chromosome is lost, the animal or plant may be visibly abnormal but viable. When both the paternal and the maternal members of a chromosome pair are lost, the effects are always lethal. Similarly, the addition of one extra chromosome may not have seriously adverse effects, but two are generally lethal.

On the other hand, when an organism doubles its whole set, acquiring twice the normal chromosome number, it may have little difficulty and reproduce normally. This is what happens when a plant is treated with the drug colchicine. Such a plant may grow exceptionally large flowers with double-size pollen and ovules. A cross between this plant and a normal one, however, produces a hybrid with an odd multiple of the chromosome number. A hybrid of this sort runs into trouble in reproduction, because the dividing cells cannot have equal sets of chromosomes. It seldom produces viable offspring.



BROKEN CHROMOSOMES similarly lead to lethal effects. In this diagram an X-ray (*dotted line*) breaks the chromosomes in a sperm, causing them to recombine in an abnormal way. An egg fertilized by such a sperm ultimately gives rise to the sperm chromosome combinations at the bottom. Sperms 1 and 2 produce normal offspring; sperms 3 and 4, abnormal.

PERHAPS the greatest problem facing the modern biologist is to learn just how heredity operates. The late Raymond Pearl of Johns Hopkins University likened a living system to a spring-driven clock. He thought that heredity, like the spring, determines the "total energy output" capacity of an individual. It has just so much energy to use up in its lifetime. For example, the fruit fly becomes less active at low temperatures and lives longer. Pearl also drew an analogy between natural death and the wearing out of a machine; he suggested that as the body ages, "organ systems get out of balance and wreck the whole machine."

These analogies are useful in guiding our practical efforts to lengthen life. Breeding, however, remains the most important factor. Disease, that potent ally of the Grim Reaper, may be beaten back by quarantine and by drugs, but without hereditary resistance a population is like tinder waiting for a spark. The American Indians, for example, apparently were far harder hit by the white man's measles than by his bullets.

The effectiveness of selective breeding over many generations may be striking. In agriculture genetics is playing a larger and larger role. New varieties of truck crops are announced every year, and our tremendous harvests of wheat and other grains are vitally dependent on continued breeding of resistance to rusts and other enemies. Poultry breeders are coming to select for "livability" as well as for high egg production.

In human beings applied genetics is a personal matter, seldom willingly turned over to group control. Several medical centers have human heredity clinics which give advice, but in general heredity is ignored as a medical blind alley, leading to fatalism. This is particularly unfortunate because man is now able to damage heredity more efficiently than ever before in history. Research and education in prophylactic measures, particularly concerning radiation hazards, should be increased.

The occurrence of a lethal condition in a family is a tragedy. The consoling aspect of the matter is the tendency for lethals to be self-effacing. We should be concerned, however, with the accumulation of defective genes in the population. Conceivably such recessive defects may eventually accumulate to the point where eliminating them will be virtually impossible. But that will be a long time in the future, and we can hope that before then the advances of science will have solved the problem of detecting the hidden recessives.

"Death," said a cynical philosopher, "being merely the end of life, is really nothing." How we fret over nothing! But as nothing is the reciprocal of infinity, so death may hold the answer to the riddle of life.

Willard F. Hollander is a geneticist at Iowa State College.

Atomic Pile Chemistry

To separate plutonium and the uranium from which it is made is a difficult chemical problem. Any economic nuclear power plant will have the added problem of reclaiming its partly used fuel

by John F. Flagg and Edwin L. Zebroski

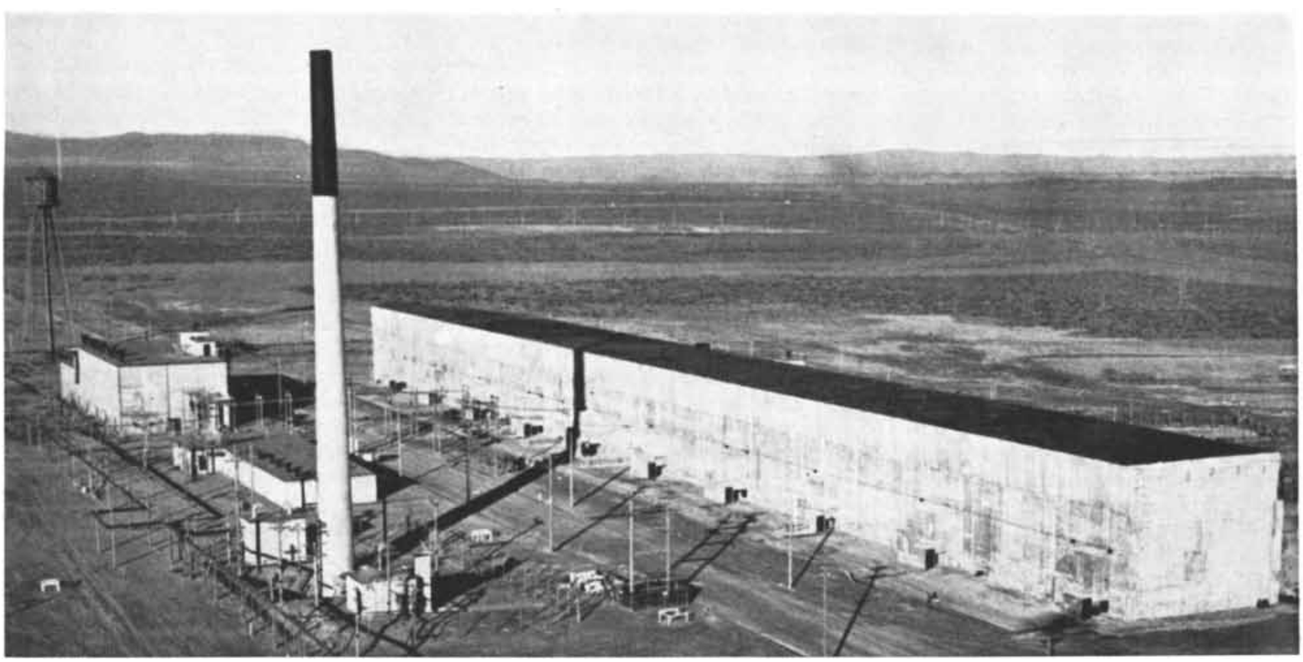
ATOMIC POWER, at least for some uses, now seems not very far away. Already an experimental reactor of the Atomic Energy Commission has generated 100 kilowatts of electricity, and as everyone knows, construction is underway on nuclear engines designed to propel submarines or ships. We are approaching the time when we shall be able to test the possibilities of atomic energy for general use.

How soon atomic power will become available at reasonable cost depends on many things, but one of the most decisive is a matter of chemistry. The whole issue may turn on whether we can succeed in obtaining reasonably complete "combustion" of the nuclear fuel.

The "burning" of uranium in an atomic furnace is so strange an affair that to get any picture of it at all we must overturn our familiar ideas about the behavior of a fuel. Let us try to see how it contrasts with a conventional fuel such as coal. Imagine a lump of coal in which only a tiny proportion of the lump (one part in 140) is combustible. The combustible atoms are scattered all through the lump. As each burns, it gives off sparks that ignite others, and the burning proceeds by a chain reaction. But the ashes of the burned atoms, deposited throughout the lump, soon begin to absorb some of the sparks and smother the fire. Furthermore, as the proportion of combustible material drops, the chances of the sparks hitting enough inflammable atoms to keep the fire going also drop.

The result is that the fire goes out and the lump of coal becomes useless as fuel after only a small percentage of its combustible material has been used up. Yet we are dealing with an expensive kind of coal, and we cannot afford to throw away most of it unburned. We must take the lump of coal out of the furnace, remove the ashes from it and recover the unused fuel. Moreover, there is another reason for reprocessing the coal. During the burning, some of the noncombustible material in the lump has absorbed sparks from the fire and thereby has been converted to usable fuel. This precious material also must be recovered; indeed, unless the furnace manufactures, or "breeds," more new fuel than was originally put in, our rare coal may be too expensive altogether.

The business of reprocessing the coal is not an ordinary chemical operation. The lumps of coal are so "hot" that they have to be placed behind several feet of concrete and treated by remote control. The lumps must be dissolved and put through a series of complicated chemical separations. The ashes are present in such tiny amounts that we must mix in a chemically similar "carrier" material to give them enough bulk so they can be precipitated from a solution. The new fuel bred in the furnace



PLUTONIUM SEPARATION PLANT at the Hanford Plutonium Works consists of a long concrete "canyon" (*right*) in which the various chemical reactions are conducted. The entire process is operated by remote control behind its massive shielding. At the left is a 200-foot smokestack for the discharge of radioactive waste gases.

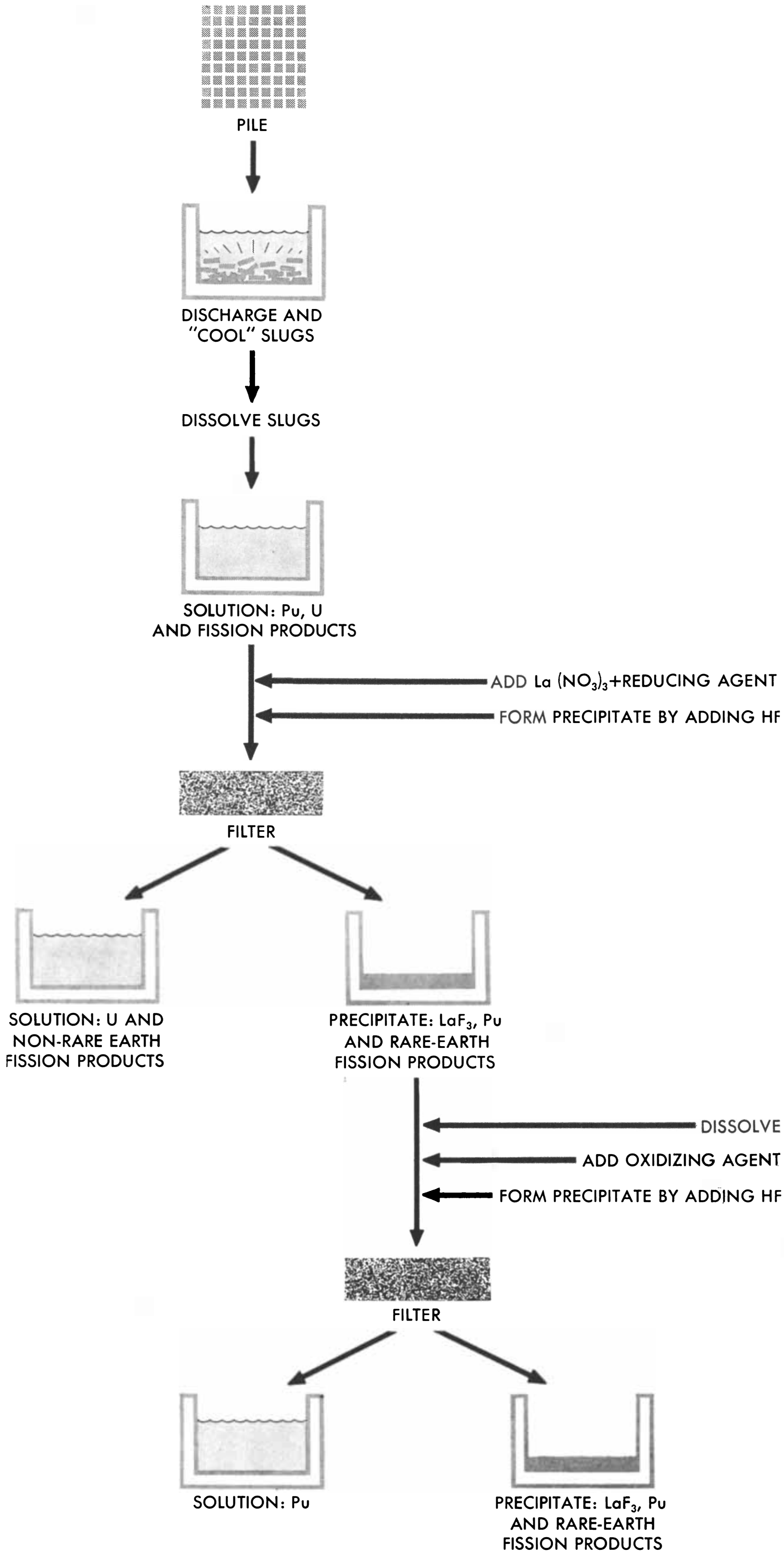
also is minute in amount and difficult to separate. As for the coal itself, we cannot separate the combustible from the noncombustible material by any chemical process, because they are chemically identical.

After removing the ashes and recovering and purifying the fuel, we put it back in the furnace to burn some more. It begins burning briskly but soon dies down, so that we must take it out and refine it again. Thus to burn all or most of the fuel in our lump of coal we must reprocess and feed it into the furnace again and again and again, each time adding fresh fuel to keep the fire going.

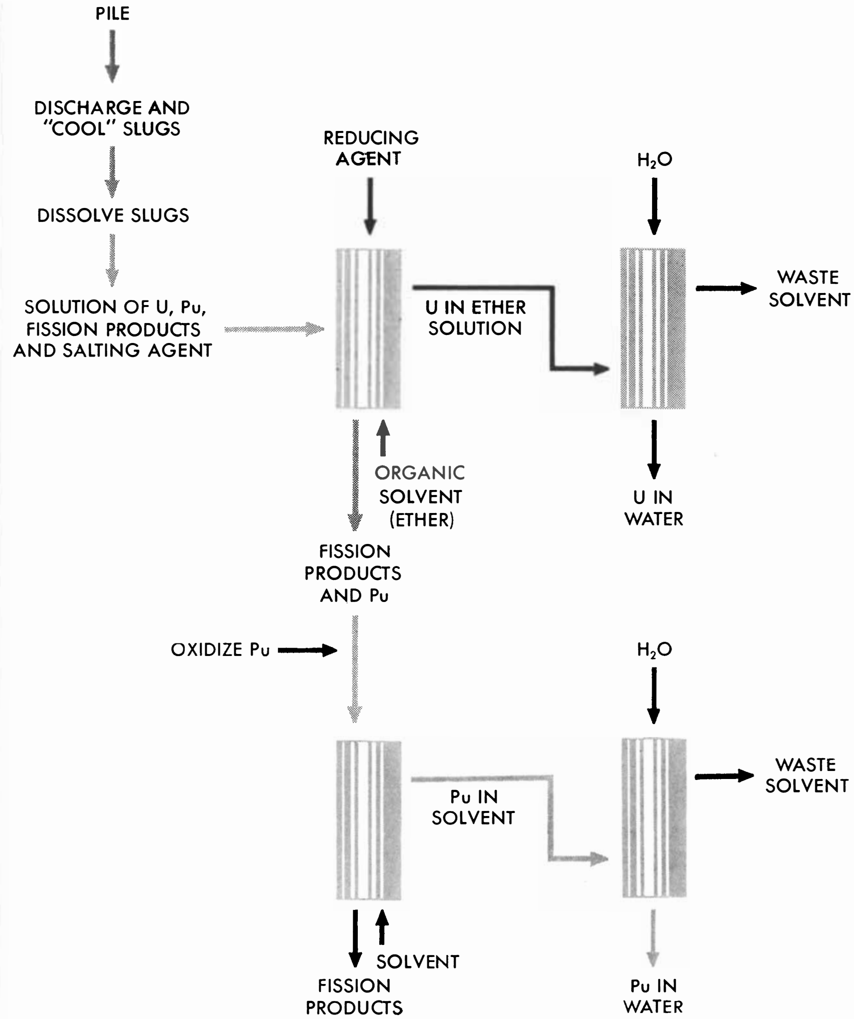
THE STRANGE coal we have been describing is, of course, uranium; the combustion process is nuclear fission. Uranium 235 is the primary nuclear fuel, the only fissionable material found in nature. Refined natural uranium consists of a mixture of 140 parts of nonfissionable U-238 to one part of fissionable U-235. A U-235 atom fissions when it captures a slow neutron—the spark of our analogy. In breaking apart it liberates energy, emits two or three new neutrons (average: 2.5), and leaves as "ash" its fragmentary remains, or fission products. One neutron must be captured by another atom of U-235 to keep the chain reaction going; the other one or two neutrons are available for other reactions. If they are captured by U-238, they convert these atoms into fissionable plutonium, which may itself be used for fuel. In a breeder reactor, plutonium would be manufactured in a blanket of natural uranium wrapped around the "firebox" (reactor core) to capture the excess neutrons.

A uranium furnace is rather more complicated than our coal analogy indicated. The fuel itself is damaged by the radiations in the pile—another reason why it must be reprocessed. In some reactors the uranium lumps are encased in aluminum, which must be removed from the fuel in reprocessing. The furnace also contains a moderator (graphite or heavy water), a cooling liquid to transfer the heat to the steam boiler where it is to be used, and an array of controls and safety devices. All these materials are subjected to neutron bombardment, which gradually changes their physical properties.

The Hanford Plutonium Works, the only production-scale reactor installation in the U. S., originally had no provision for recovering unburned uranium; after plutonium was extracted from the uranium slugs, the remaining material was discharged to waste tanks—fission products, unused U-235 and all. Where power is the objective, any economic plant will have to have a complete processing plant, which will be as essential as the reactor itself. Research on fuel processing has been going forward, con-



PLUTONIUM SEPARATION PROCESS involves the use of lanthanum (La) as a "carrier." Plutonium and the rare-earth fission products are carried with lanthanum; uranium and the non-rare-earth fission products are not.



SOLVENT EXTRACTION METHOD is better adapted to the recovery of uranium than the precipitation method that is depicted on the preceding page. It can be operated either as a batch process or as a continuous one.

currently with the development of power reactors. Some of the processing problems can be discussed outside the realm of security restrictions.

Let us assume that a reactor has reached the point where it must be shut down and its fuel discharged. The fuel slugs contain a mixture of U-238, U-235, plutonium and fission products. To appreciate the problems involved in separating these materials, let us see what quantities we have to deal with. Plutonium and fission products are manufactured in roughly equal amounts, at a rate which depends on the power level at which the reactor operates. For every 1,000 kilowatt-day of energy production, approximately one gram of U-235 is fissioned. This means there will be one gram of fission products and about one gram of plutonium, thinly distributed in a considerable bulk of uranium slugs. In one and one-half tons of uranium, after 100,000 kilowatt-days of operation, there would be only about ¼ pound of plutonium and ¼ pound of fission products. And in this relatively tiny amount of fission products there may be more than 200 isotopes of 34 different elements, ranging from zinc to europium in the periodic table.

When the reactor is shut down, the fuel slugs are pushed out of the pile into a deep pool of water—a shield to contain their intense radioactivity. The slugs must be left in the pool for several months to cool off: that is, to allow some of the hottest isotopes, of short half-life, to decay. Then the slugs, behind thick concrete shields, are dissolved, and the separation process can begin.

SEVERAL separation methods are available. One is precipitation. To precipitate the tiny traces of plutonium and fission-product elements in the solution, one must introduce carrier substances chemically similar to them. Lanthanum acts as a carrier for plutonium. In the solution both the uranium and plutonium ions are in the oxidized state, with a valence of plus six. A reducing agent such as sulfur dioxide is added to reduce the plutonium to a valence of plus three or four. Now lanthanum nitrate is added and then hydrogen fluoride. This precipitates lanthanum fluoride, and with it the reduced plutonium and some of the fission products—the rare earths. The other fission products and uranium remain in the solution and are filtered off. The precipitate is then redissolved and an oxidizing agent added, which brings the plutonium back to the plus six state. Lanthanum fluoride is again precipitated, but this time only the fission products come down; the oxidized plutonium remains in solution.

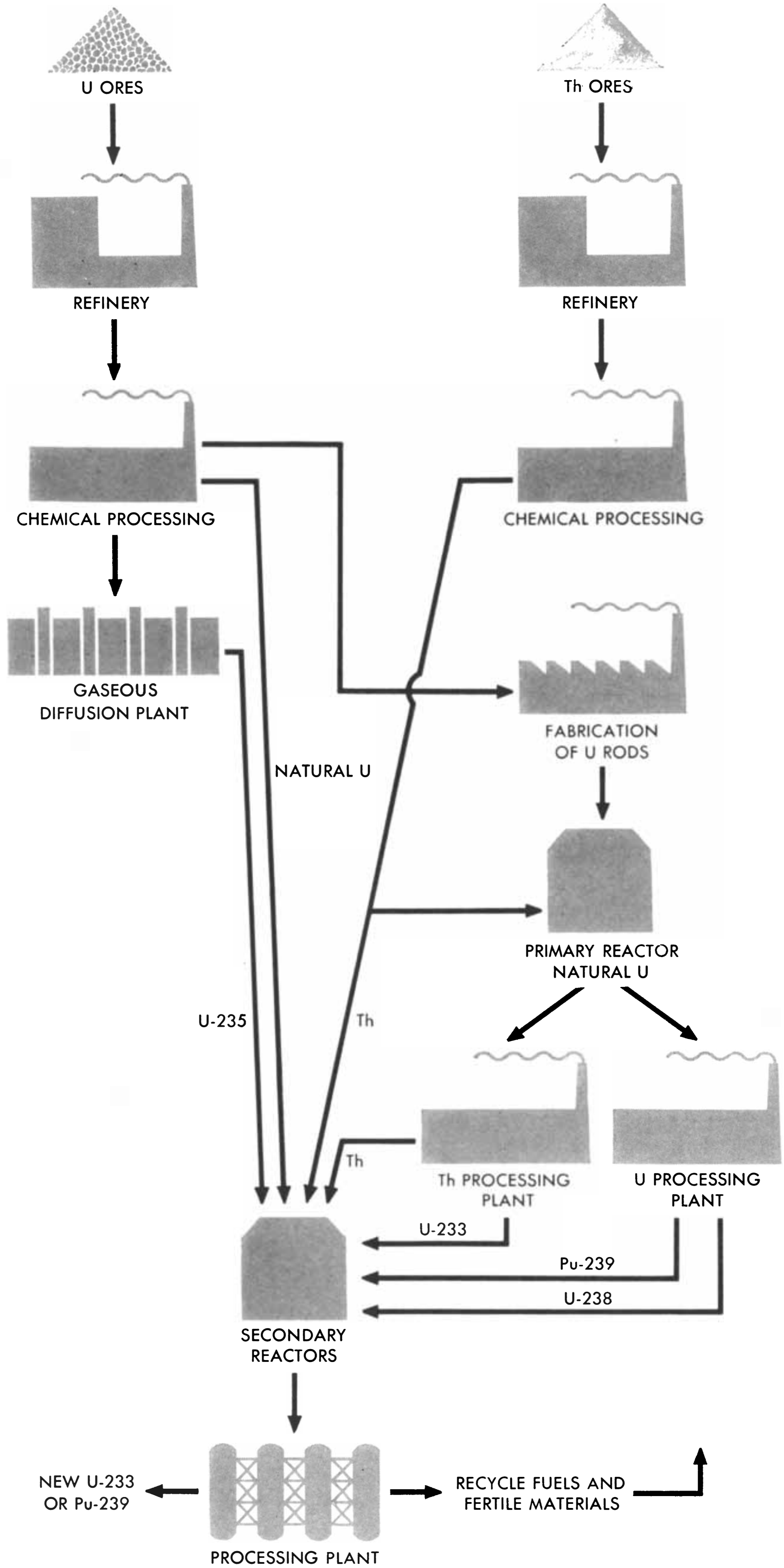
Precipitation processes offer the advantage of flexibility and easy expansion of the laboratory procedures to production-scale operation. The yields, however, may not be as high as with other separation procedures. Precipitation is an expensive way to recover uranium, because of the engineering difficulties in handling precipitates in large tonnages.

A second possible separation method is ion exchange (see "Ion Exchange," by Harold F. Walton; Scientific American, November, 1950). Washed through large beds of synthetic resin exchanger, the mixed solution of fuel could be separated into its uranium, plutonium and fission products. Ion exchange has already been used successfully to separate rare earths and transplutonium elements having very similar chemical properties. It has the advantage of being relatively simple, both as to operations and equipment. But in a production-scale operation large volumes of liquids would have to be handled, and the radioactive fission products might damage the exchange resins.

THE THIRD method is solvent extraction. It makes use of differences in the solubility of substances in different solvents. Long used in the petroleum industry, the technique was first applied in the nuclear field to purify large tonnages of uranium for the reactors. Uranium nitrate, when mixed with a "salting agent" such as calcium nitrate, is much more soluble in ether than in water; alone, it is more soluble in water. If a water solution of the uranium salt uranyl nitrate, in the presence of calcium nitrate, is pumped through a packed column in one direction while ether is sent through from the other end, the ether will take up most of the uranium salt, leaving impurities in the water. The uranium can then be "stripped" from the ether with water in the absence of the calcium salting agent. By repeated extraction and water-strips uranium can be refined to a high degree of purity.

In the same way the uranium and plutonium in reactor slugs could be separated from fission products. Plutonium might then be separated from uranium by reducing the former to the plus three state, in which it is insoluble in ether.

Solvent extraction gives sharp separations and can be carried out either by



FULL UTILIZATION of nuclear fuels would require a complete cycle of fuels and fertile materials (isotopes such as uranium 238 that are not fissionable but which can absorb neutrons and decay into fissionable material). Chemical processing would have a key role at several points in the cycle.

ISOTOPE	HALF-LIFE	PER CENT
Sr^{89}	53 d	4.6
Sr^{90}	25 y	5
Y^{91}	57 d	5.9
Zr^{95}	65 d	6.4
Ru^{103}	42 d	3.7
Ru^{106}	1 y	.5
Te^{127}	90 d	.03
Te^{129}	32 d	.19
I^{131}	8 d	2.8
Xe^{133}	5.3 d	6
Cs^{137}	33 y	6
Ba^{140}	12.8 d	6.1
Ce^{141}	28 d	6
Ce^{144}	275 d	5.3
Pr^{143}	13.8 d	6
Nd^{147}	11 d	2.6
Pm^{147}	3.7 d	2.6

FISSION PRODUCTS of principal importance are listed. Their half-lives are in years (y) or days (d).

continuous or batch operation. But the method involves special problems of protection. In addition to the usual hazard of fire or explosion of the volatile solvent, there is the possibility of a resulting spread of radioactivity. Another disadvantage is that very large volumes of solution would have to be handled and stored.

In practice it may be best to use a combination of separation methods, for example, solvent extraction and ion exchange or carrier precipitation.

The disposal of radioactive wastes will be one of the big factors in the operation of atomic power plants. One suggestion is that the radioisotopes might be converted into a stable "mineral" and buried out of the way by incorporating them into a special concrete or ceramic.

We have been considering only uranium as the nuclear fuel. Thorium also is a fertile material; when irradiated with neutrons, it is transmuted into fissionable uranium 233. The problems of recovering thorium and U-233 do not differ greatly from those of uranium.

WHAT OF the design of the processing plant? The chemical separation methods must be highly efficient, for every ounce of the fuel is precious. A single pound of U-235 can produce

$15,000 worth of electricity, assuming a heat yield of about 10 million kilowatt-hours, 30 per cent efficiency in converting the heat into electricity, and a price of 5 mills per kilowatt-hour. Since the fuel may have to be reprocessed 10 times or more, a small loss at any stage of the cycle would be multiplied.

The processing plant will require huge buildings and intricate networks of equipment and instruments. Many operations will have to be performed behind concrete shields by remote control. Ordinary commercial equipment, which needs continual maintenance to keep it functioning properly, will not do for these operations. The components will have to be specially designed for maximum reliability. When a breakdown does occur, the faulty piece will have to be removed and replaced *in toto* rather than repaired. Aside from the radioactivity problem, plutonium is extremely poisonous, and great care must be taken to avoid breathing it in the form of dust or fumes.

Furthermore, it must be borne in mind that we are dealing with a fuel which flares up spontaneously whenever it reaches a critical mass. About two pounds of U-235 in water will sustain a chain reaction. Though it would not blow up in a bomb-type explosion, the heat and radiation could be disastrous. Hence we must be sure that nowhere in the maze of tanks, pipes and other equipment could a critical mass of fissionable material ever accumulate, by any possible combination of equipment failure and human error. This means that there is a limit to the possible size of the equipment, and hence to the economies realizable from large-scale operation.

Processing will certainly represent a substantial part of the cost of atomic power. In recent articles in SCIENTIFIC AMERICAN two authorities gave two different estimates of the cost of uranium fuel: Sam H. Schurr calculated it would cost less than .02 mills per kilowatt-hour of electrical energy generated, and Lawrence R. Hafstad placed the cost at more than one mill per kilowatt-hour. Schurr assumed 100 per cent conversion of U-238 to plutonium and charged reprocessing to operating costs rather than to the cost of fuel, while Hafstad's figure was based on separated U-235. The 50-fold difference between their figures may be a rough index to the economic role of processing.

In short, the realization of atomic power will depend heavily on the chemist and the chemical engineer. The opportunities are great, the stakes high.

John F. Flagg and Edwin L. Zebroski are research associates of the Knolls Atomic Power Laboratory, operated by the General Electric Company.

Animals of the Bottom

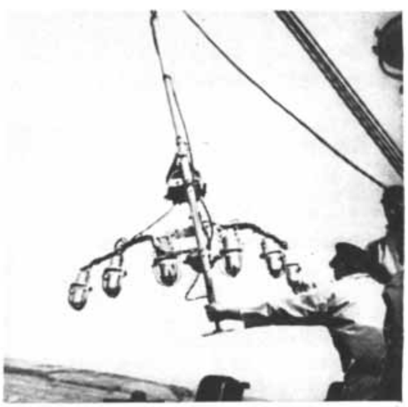
An English laboratory uses the underwater photograph to count the populations of starfish et al., and to study their place in the whole society of marine organisms

by Henry G. Vevers

IT IS IMPORTANT to man to obtain censuses of the populations of wild animals so that he can estimate how many animals of a given kind he may kill or catch for his use without danger of depleting the stock. In the sea we need counts not only of the marketable fishes but also of animals and plants on which they feed or which compete with them for food. Much of the sampling of animals and plants in the sea is done by sweeping them up with various kinds of nets, but it is not possible to get accurate samples of the larger animals of the sea bottom in this way.

For the past two years the Marine Biological Laboratory of Plymouth, England, which overlooks the harbor from which the *Mayflower* sailed in 1620, has been sampling life on the sea bottom by photography. An automatic camera has been developed to take pictures at depths beyond the range of divers. The apparatus is designed to take a photograph covering an area of either one-quarter of a square meter or one square meter at a time. From a series of such pictures, systematically mapping a given area, we can assess the density of its populations of invertebrates—mollusks, crabs, starfishes and sea anemones.

The main requirements for underwater photography are a good supply of artificial light and strong watertight containers for the camera and lamps. The Plymouth apparatus uses a Robot camera (35 mm. film), six 500-watt photoflood lamps arranged in a semicircle, a solenoid and other electrical equipment, all enclosed in metal or glass domes. For lighting probably an electronic flash would be even better than the photofloods, and we hope to have one in future cameras. All the equipment is mounted on an upright tubular pole, at the foot of which is a brass plate connected to a small protected mercury switch. When the foot touches the bottom, the mercury switch is inverted and this completes the circuit; the solenoid in the camera case then hits the release trigger of the camera, and a picture is taken. Electrical power from the ship's mains is supplied to the camera and lamp circuits by a multicore rubber-covered cable, and on deck there is a control box which carries switches and ammeters for the two circuits, and also a counter and a buzzer to signal each exposure.



CAMERA for underwater photography is swung overboard. It is mounted above the semicircle of lamps.

The apparatus is lowered over the side of the ship by a steel warp, and the electrical cable is let out by hand. When the foot of the pole touches the bottom and triggers the taking of a picture, the counter in the control box registers the number of the exposure, and the buzzer notifies the crew. They then raise the apparatus at least one meter above the bottom, and the ship is allowed to drift for a known time before the camera is again lowered for another picture. With each film-loading we can take 45 to 48 photographs. By recording the time and position at the start and finish of each film, and the time interval between exposures, it is possible to plot the position of each photograph.

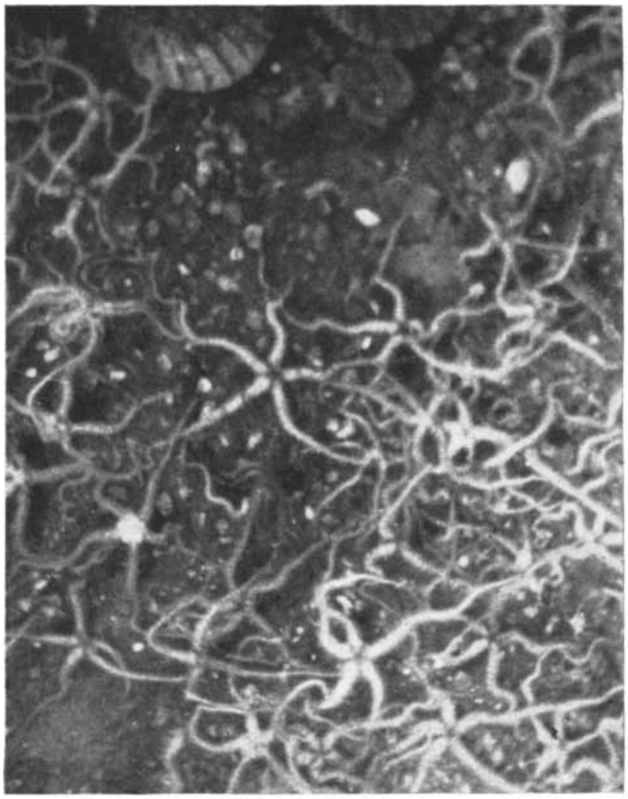
THE RESULTS obtained with this apparatus have already given much new information on the relative numbers of certain animals in the trawling grounds south of Plymouth. In some areas there are very few animals; in others the pictures show clumps of moss animals (Bryozoa) that give shelter to young crabs and mollusks useful as food for bottom-living fishes. But perhaps the most interesting finding is the enormous numbers of brittle starfish (*Ophiothrix fragilis*). It has long been known that this species is very common in the waters of northwestern Europe. The photographs have shown that the true density is even greater than was thought. Over very large areas they are present at the rate of more than 100 per square meter, and in a few places there are as many as 500 per square meter; the brittle-stars completely cover the bottom and often lie piled on one another. As this species of brittle-star is not eaten by marketable fishes, an area covered in this way is valueless from the viewpoint of the trawl fisherman.

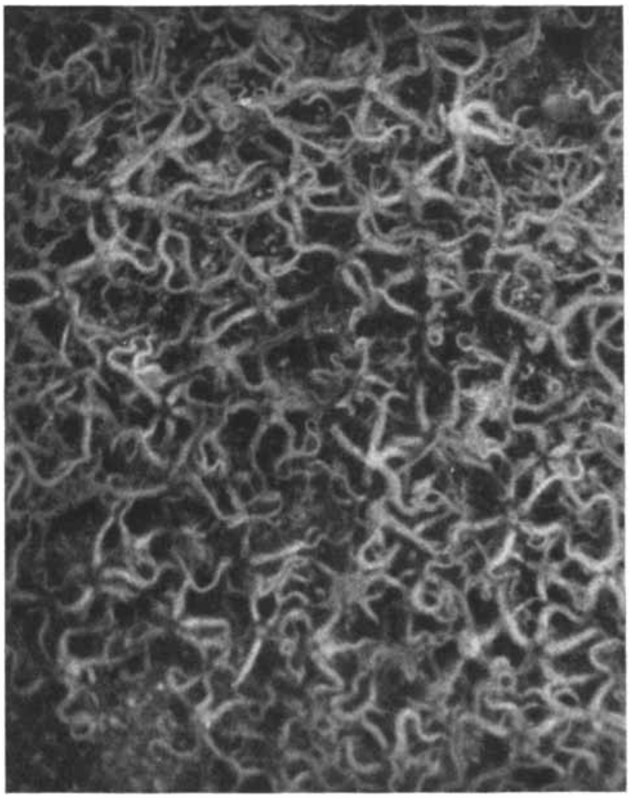
These brittle-stars feed mainly on the decaying fragments of dead animals and plants. Since they cover large areas of the sea bottom at the rate of over 250 million individuals to the square mile, spreading out their long delicate arms to gather in the detritus brought by currents and gravity, their total food consumption is enormous.

The presence on the sea bottom of dense populations of a single species of animal raises many points of interest to the biologist. If the aggregations only appeared at certain seasons, they might be correlated with breeding and spawning behavior. In actual fact the dense brittle-star populations have been found at all times of the year. The photographs also show that this type of brittle-star tends to crowd together in dense masses even when there is some vacant space alongside the crowded masses. Moreover, they seem to avoid certain other animals, including sea anemones, which have sting cells in their tentacles.

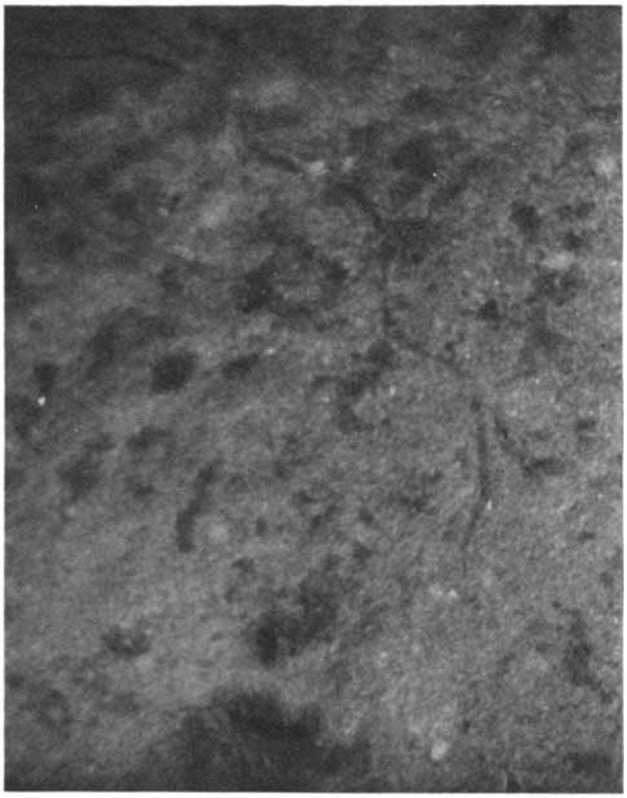
The photographic method of assessing bottom populations in the sea throws much light on their feeding habits and on their general behavior toward one another and toward other species of bottom-living animals. In this way we can begin to know more about the complicated relationships of the many different kinds of animals on the sea bottom.

Henry G. Vevers is a biologist at the Marine Biological Laboratory in Plymouth, England.

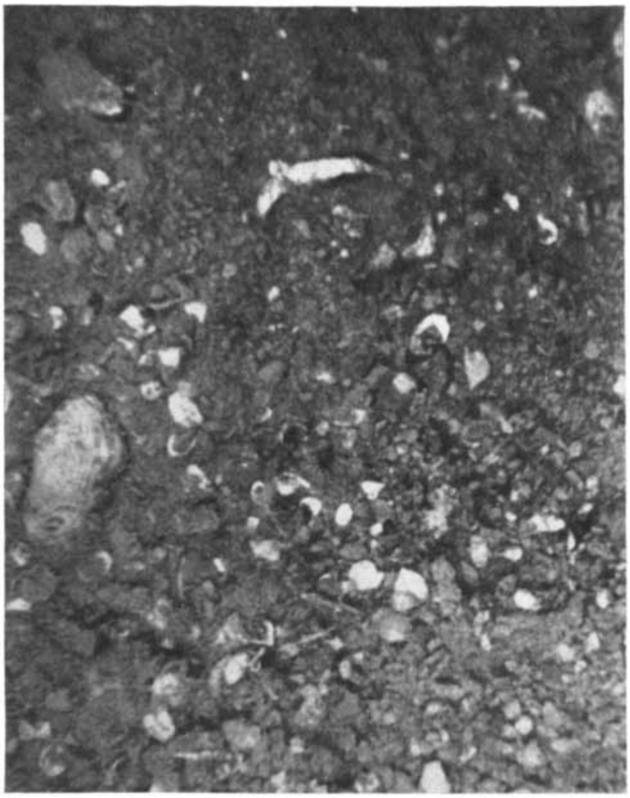




BRITTLE STARFISH in some places litter the bottom in surprisingly large numbers. The photograph at the left, made at 25 fathoms, shows an area populated by more than 100 brittle starfish per square meter. The photograph at the right, made at 30 fathoms, shows an area populated by 500 brittle starfish per square meter.



TRACK winding from right center to upper left was probably made by a hermit crab dragging its body along the bottom. This photograph was made at 28 fathoms.



SHELLS cover the bottom at 30 fathoms. Brittle starfish inexplicably form themselves into dense colonies even when there is a relatively clear space close by.

THE UMBILICAL CORD

Until recently curiously little was known about this lifeline of the fetus. Now physiologists, mathematicians and engineers have discovered some impressive things about its performance

by Samuel R. M. Reynolds

UNTIL the moment of birth a developing baby is entirely dependent upon the placenta. This vital organ, lying outside the fetus' own body, serves it as lungs, intestines and kidneys. From the placenta the baby gets its oxygen and predigested food, and to it it sends its wastes. The connecting link that carries this two-way traffic is the umbilical cord. From the time when the embryo is considerably smaller than half a small pea until the baby is born, the umbilical cord is its lifeline.

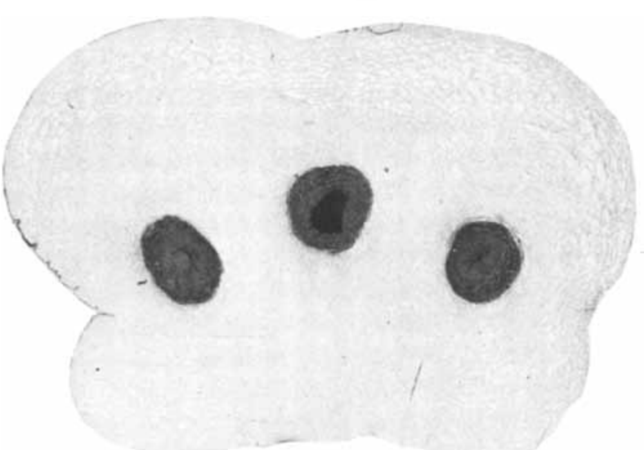
One might suppose that the functioning of so vital a structure would have been thoroughly investigated, but the fact is that it has interested relatively few people. Recently, however, we have learned some surprising things about the way in which blood flows through the umbilical cord and about the nature of the cord itself.

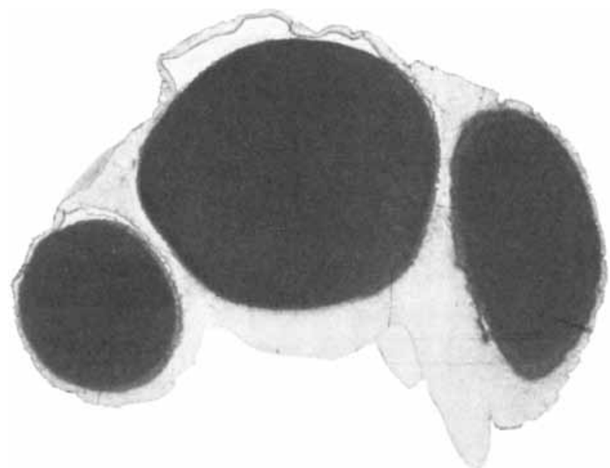
The fetus operates its own circulatory system. Its tiny, rapidly beating heart pumps blood through two arteries in the umbilical cord to the placenta. There the blood picks up water, sodium, phosphorus, iron, oxygen and other vital substances and flows back to the fetus through a single vein in the cord. Within a few months the blood must transport through the cord enough material to build a six- to eight-pound baby, and of course the total bulk of fluid exchanged between the placenta and the fetus is vastly greater.

The embryologist Louis B. Flexner and his associates at the Carnegie Institution of Washington have made some measurements of this circulation. At the age of 14 weeks the human fetus weighs about two ounces and grows at the rate of about a quarter of an ounce per day. To gain at this rate the two-ounce fetus must daily "drink" and discharge (*via* the blood) about six quarts of water alone. At 31 weeks, when the fetus weighs three pounds, the cord must carry nearly 70 quarts of water per day. And water is only part of the whole blood volume. At 31 weeks the tiny fetal heart pumps roughly a fifth of a quart of blood per minute (nearly 300 quarts a day). The blood flow through the umbilical cord is rapid—it travels at an estimated rate of seven inches per second, about four miles per hour.

To carry such a load the umbilical cord must indeed be a remarkable organ. Let us examine its structure. The first striking fact is the wide variation in length of the cord. Its average length at birth is about two feet: that is, the cord is generally longer than the baby itself. But it may vary from as little as five inches to well over four feet. A physician in Valparaiso, Chile, recently reported a case in which the cord at birth was four feet eight inches long. It looped once around the baby's body, then over the shoulder, under an armpit and twice around the neck, with a good length left over to its root in the placenta. Twisting, twining and even loose knotting of the cord is the rule rather than the exception when it is average or above average in length.

About the cord's thickness it is difficult to be precise, because it cannot usually be measured except at the baby's birth, when blood is not flowing through it normally. Indeed, the fact that the cord is generally seen only after birth, when its blood vessels are collapsed, has led to a widespread misconception about its structure. Textbook pictures of the cord almost always show the blood vessels surrounded by a thick blanket of soft material called Wharton's Jelly, which is commonly supposed to serve as





CROSS SECTION of a human umbilical cord at the left shows its vein (*center*) and arteries (*left and right*) collapsed after birth. The cross section at the right was cut from another cord that had been clamped off with its blood vessels distended, as in life. The vessels are surrounded with a soft substance called Wharton's Jelly.

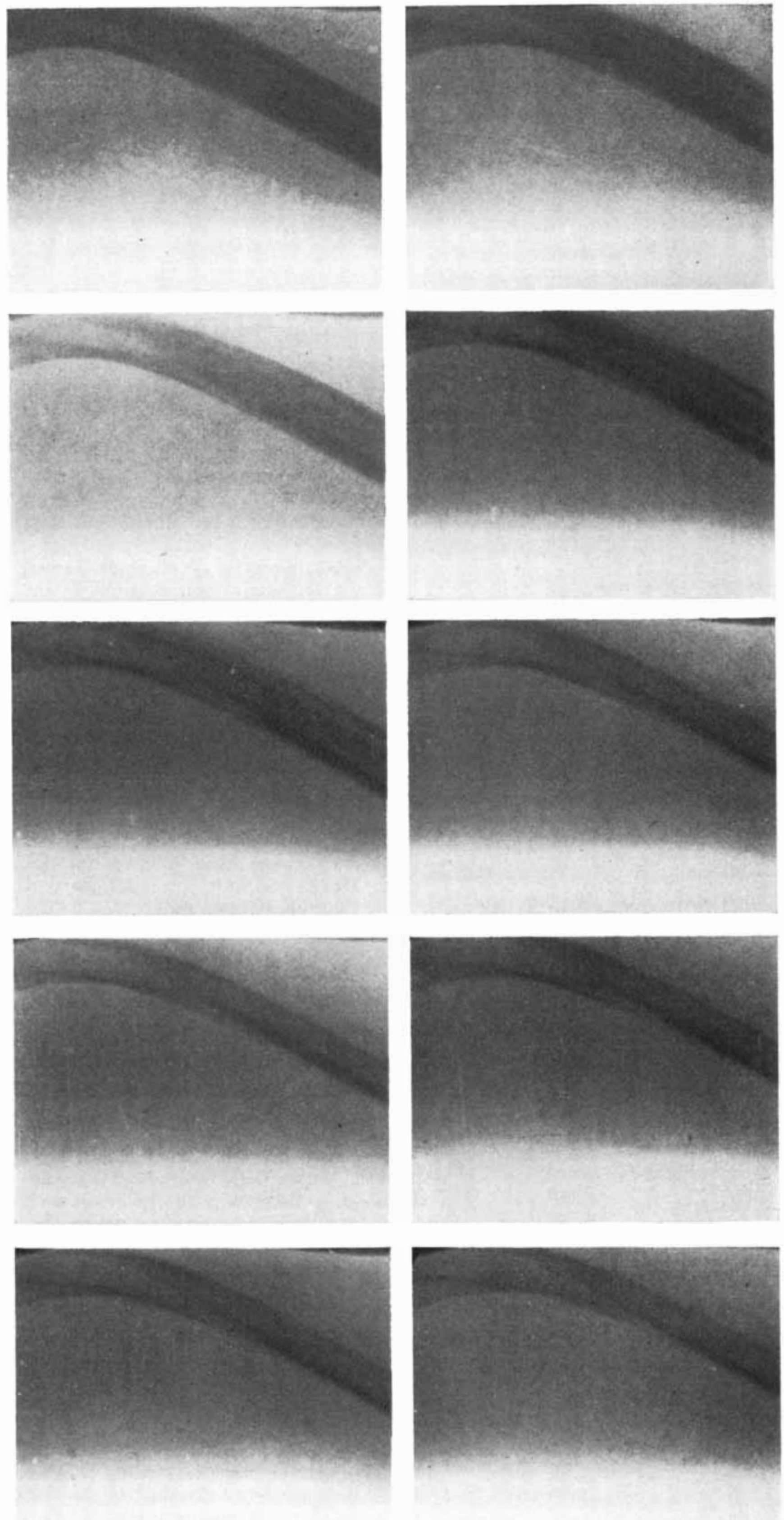
a cushion protecting the vessels. The picture is wrong: in the cord's normal state, when the vessels are distended by blood flowing through them, the jelly is not a cushion but a thin, tautly drawn band of tissue. We have demonstrated this by studies of a distended cord obtained in a Caesarean operation at Johns Hopkins Hospital.

That is really the beginning of the story which I have to tell about the characteristics of blood flow in the umbilical cord. When the jelly is stretched taut by the pressure of blood flowing through the vein, it acts as a tight membrane which is trying to collapse the vein at all times. The blood in the vein must be under appreciable pressure to keep the channel open for the abundant flow which is essential for fetal life. This pressure makes the umbilical cord a semi-rigid structure—an erectile type of organ. Why should this be necessary? And how is it achieved?

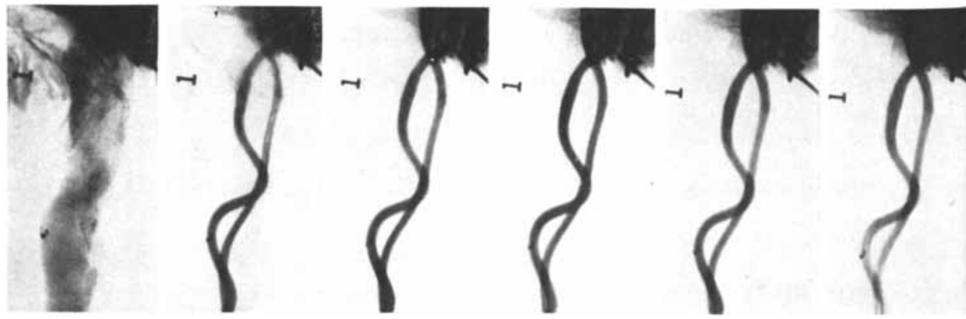
ONE AFTERNOON in the winter of 1948 the Harvard University obstetrician Seymour Romney came to the Carnegie laboratory to discuss problems of blood flow in the placenta. He brought with him a number of models prepared by filling the blood vessels with a latex compound and then dissolving the tissues. What remained was a rubber "skeleton" of the lumens (bores) of all the larger blood vessels in the placenta. All of us who saw these preparations that day were struck at once by the fact that at the place where the blood vessels come into the placenta from the umbilical cord and branch out, the arteries and veins were about equal in number and of roughly the same diameters. This must mean that blood flowed in the veins at approximately the same speed as in the arteries. That seemed strange, considering that in the veins the blood is under much lower pressure. Whence came the energy to drive the blood through the veins at such high velocity?

We decided to investigate the situation in the umbilical cord, which is easily accessible and contains only three major blood vessels—two arteries and a single vein. From a number of observations in experimental animals and a few human cases, we calculated that the cross-sectional area of the two arteries combined is smaller than the cross-sectional area of the vein, and that the velocity of blood flow in the umbilical vein is between 70 and 75 per cent of that in the two umbilical arteries.

At this point we called in two hydraulic engineers and a mathematician at Johns Hopkins University to help us look into the mechanism responsible for the rapid flow in the vein. G. F. Wislicenus, a noted specialist in hydraulic engineering, was at once impressed by the fact that the umbilical vein is distended un-



PULSATING BLOOD in a sheep's umbilical artery is shown by X-ray photographs printed left to right. The faint outline of the artery wall in the latter pictures indicates that it does not contract when the pulse falls.



EBB AND FLOW in a sheep's umbilical cord is shown by X-ray photographs. In second picture an X-ray-opaque substance begins to pass through

der considerably more pressure than ordinary veins are. The pressure in the umbilical vein appears to be at least 20 to 25 millimeters of mercury, which is about 10 times the pressure in the large veins near the heart in a normal adult. It is about half as great as the mean pressure in the umbilical artery.

When Professor Wislicenus learned of the unusually high pressure in the vein, he asked:

"How does the umbilical vein end in the baby?"

A rough pencil sketch was drawn. Blood flows from the umbilical vein to the fetal heart by two pathways. One is a roundabout route through numerous small branches into the liver and thence through the hepatic veins. The other route is much more direct: from the umbilical vein a special duct called the *ductus venosus* leads into the inferior vena cava and so to the heart. Beyond the duct blood flows rapidly but at the low pressure of one to two millimeters of mercury.

As soon as Professor Wislicenus saw the sketch, he put his pencil on the *ductus venosus* and asked:

"Where is the valve here that controls the pressure in the vein?"

"There is no such valve," we replied.

"Oh yes, there must be if the pressure in the vein is as you say it is. If there were no valve, the blood would flow in the path of least resistance; it would take the direct way to the heart and avoid entirely the resistance offered by the liver."

We went back to our laboratory, hunted through a new book on *The Foetal Circulation* just published by A. E. Barclay, M. M. L. Prichard and K. J. Franklin of Oxford University, and within a few minutes found the very structure Professor Wislicenus had postulated. There were even X-ray moving pictures of the *ductus venosus* closing under certain conditions. This closure had been thought to be due simply to a sphincterlike contraction of the vessel to block back flow after the umbilical cord was cut and prevent undue loss of blood; no one had ever suggested a function for this structure during the life of the fetus. When Wislicenus said that it was a valve which served to regulate the pressure in the umbilical vein, he was asked what sort of a hydrodynamic mechanism might be expected to operate under these conditions.

"It may be that as the arteries are distended by pulsating pressure, they press upon the vein, which lies beside them in the same sheath. Since a floodhead of blood is pushing into the vein at the placental end, the arteries' pressure on the distended vein should force blood toward the baby end, where the pressure is lower. In other words, it is a supercharged system and appears to be acting like a pistonless pump."

THIS WAS the beginning of a new conception of the mechanism of venous return from the placenta. Like most early concepts, it required modification in the light of later observations. But it opened our eyes to new avenues of exploration.

The mathematician we consulted was F. W. Light, Jr., a former physician who was teaching higher mathematics at Johns Hopkins. He had maintained an interest in the mechanism of pulsating arterial flow, and had long concerned himself with the idea of expressing mathematically the characteristics of such flow.

Light asked three questions: (1) What are the pressure gradients along the umbilical arteries and vein? (2) What changes in diameter occur along the artery as the pulsation due to the pumping of the heart rises and falls? (3) What are the velocity and quantity of blood flow in the arteries and vein of the umbilical cord? Not only did Light want each of these bits of information; he wanted them from the same vessels at one and the same time and without cutting or entering them.

How could the necessary data be obtained? The answer seemed to lie in the book on fetal circulation by the Oxford workers. This group, working at the Nuffield Institute for Medical Research, had obtained numerous superb X-ray photographs of the blood flow at frequencies of three to six pictures a second. What could be simpler, I thought, than to place a sheep fetus

the arteries. Starting with the eighth picture it comes back through the sheep's two umbilical veins. Here again vessels are not deformed by pulse.

with the umbilical cord still attached to the placenta over a camera, inject an opaque substance and get a moving picture of it passing through the cord's arteries or vein? The deformation of the arteries could be measured from the picture, the blood flow could be timed, and blood pressure could be determined by conventional techniques.

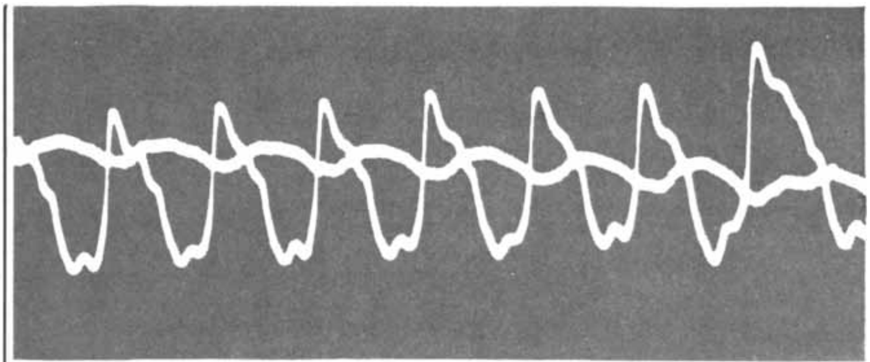
With this end in view, arrangements were made for me to spend nearly a year at the Nuffield Institute, working with the enthusiastic cooperation of a group of investigators there, especially Prichard of the Barclay team, the radiologist G. M. Ardran and G. S. Dawes, the director of the Institute. The facilities at the Institute and the experience of its workers were uniquely fitted for investigation of the questions Light had asked. In particular, it had excellent equipment for making X-ray movies.

To measure the pressure gradients in the umbilical arteries while blood was flowing through them, we had to develop a specially adapted technique, for we found that the usual method distorted the pressure. A popular method is to insert into the blood vessel a small hypodermic needle filled with a salt solution and connected to a sensitive electrical pressure-recording device. But we found that the insertion of the needle into the artery deformed the wall of the artery and distorted the blood flow. Instead, we inserted as large a needle as possible into the first branch of the umbilical artery and advanced its blunt tip to within about one-half millimeter of the true wall of the main artery. This yielded an accurate measure of the lateral pressure in the umbilical artery as the blood went rushing by the branch on its way to the placenta. We had not interfered with more than a very small part of the total outflow of the artery, and we did not touch the pattern of stream lines at all. At the same time, the cord was placed over a specially built camera which moved 5-by-7-inch films directly beneath the entire cord at the rate of two per second. By running through 24 plates and having them synchronized with a known phase of a single pulse pressure-wave at the start, it was possible to determine exactly when in the course of succeeding pulse-waves a given picture was taken.

THIS EXPERIMENT answered two of Light's questions. First, we found that the diameter of the artery is the same throughout its length. Since the artery is trying to collapse all the while, it is clear that the blood pressure also must be essentially the same along its whole length. This was a surprising finding, because one would assume that friction between the flowing blood and the sides of the vessel would progressively reduce the pressure and hence the diameter of the vessel as the blood moved farther from the heart. There must be some pressure gradient, of course, but it was not sufficient to affect the size of the vessel.

The answer to the second question was even more surprising. We could find no evidence that the periodic pulsation of the blood pumped by the beating heart produces any significant expansion of the artery. To anyone who has ever put his finger on the pulse and felt the pulse-beat pushing on his finger, this must seem incredible. Yet in excellent motion-pictures taken at 25 frames per second and in frame-by-frame comparisons of the artery's diameter we were unable to detect any broadening of the artery whatsoever as the pulse-wave passed along the vessel. Furthermore, we found that this situation is not peculiar to the arteries in the umbilical cord. We made motion-picture studies of the aorta of a cat. The section of the aorta immediately next to the heart did swell as the heart pumped blood into it. But the load was quickly dissipated, and along the rest of the aorta there was no measurable increase in the vessel's diameter.

What is it, then, that the doctor feels when he takes your pulse? We can only guess, but we have one significant clue. Sometimes an artery can be seen to move with the pulse-beat. This occurs only when the artery is curved, and it is due to the fact that the pulsating bloodstream pushes intermittently on the curved wall of the artery, moving it sidewise. This gives it a kind of lashing motion. When one presses on the pulse



PRESSURE RECORDING of the human umbilical arteries (*large waves*) and vein (*small waves*) shows that they are out of phase with each other.

with a finger, he bends the artery into a curve, and the pulsation he feels is the beat of the pulsating stream against the deformed part of the vessel.

The third point that concerned Light —the velocity of blood flow—is easily determined by injecting a radiopaque substance into the bloodstream and measuring the rate of travel of its shadow on a film. Since the diameter of the vessels may also be measured from the shadow cast in the same pictures, it is possible to calculate the quantity of blood carried in the arteries or vein in a given time. From such measurements a number of useful and significant facts have been learned.

In the first place, the quantity of blood flowing through the two umbilical arteries is, within certain limits, independent of the diameters of the arteries. It is governed, rather, by the needs of the fetus. The flow is of the order of 300 to 400 cubic centimeters of blood per minute per kilogram of body weight of the fetus. This amount, which goes to the placenta, is approximately two-thirds of the total output of the fetus' heart. It is striking testimony to the importance of the placenta as the seat of fetal nutrition and elimination.

In the second place, the volume of blood flow gives us a means of figuring out the pressure gradient in the umbilical arteries. Although there is no visible evidence of a fall of pressure, there must be some fall due to the frictional resistance of the sides of the vessel. From the known volume of flow, the radius of the artery and other physical constants of the system, we have calculated that the pressure drop is of the order of one-half to one millimeter of mercury for each centimeter of length of the vessel; thus in a cord 10 centimeters long the total fall of pressure is equal to 5 to 10 millimeters of mercury.

Now this is a very small frictional loss of energy. The frictional resistance of the vessels is so small that the blood will pour from the placenta to the fetus by virtue of even a small difference of hydrostatic pressure between them. Since the larger a vessel is, the less the proportionate friction along the walls, we can see now the purpose of the relatively high blood pressure in the umbilical vein: it keeps the vein distended to minimize friction.

THE MECHANISM by which this pressure is maintained and the blood is kept flowing rapidly remains to be worked out. Evidently Wislicenus' original idea of the "pulsameter" pump, with the pulsations of the artery pressing on the vein, is not quite correct. For one thing, we have seen that the artery does not swell as it pulsates, and for another, we have found that in an animal such as the sheep the arteries in the umbilical cord are not even adjacent to the vein but are separated from it by an appreciable layer of jelly.

How might a pulsameter pump operate in this situation? We measured the pressures simultaneously in the umbilical artery and in the umbilical vein. It was found that the pulse pressure-wave in the umbilical vein was almost exactly 180 degrees out of phase with that in the artery! The pressure in the vein decreased as that in the artery rose, and *vice versa*. Here was evidence of a pulsameter pump, but the time relations were exactly the opposite of what had been originally suspected, for if the artery pulsation pressed on the vein one would expect the pressure in both vessels to rise simultaneously. The only explanation that can be offered at present to account for the actual state of affairs is that the artery increases slightly in length during each pulsation. But we do not know that this is so.

Dr. Light has now been supplied with the facts he asked for and has begun work on interpreting them. Further teamwork among the physiologists, engineers and mathematicians, as well as new experiments, must tell us the rest of the story of the mechanism that operates the lifeline which brings babies to birth.

Samuel R. M. Reynolds is a member of the Carnegie Institution of Washington.

Your Chance to get into a New Field in Private Industry

Help Develop

NUCLEAR POWERED AIRCRAFT ENGINES

THE TIME to get into important nuclear energy research work, and at the same time build a sound future in private industry is now.

Today you can find such an opportunity at the Pratt & Whitney Aircraft Division of United Aircraft Corporation. For only recently this firm was selected by the U. S. Government to develop an aircraft engine powered by nuclear energy.

Right now new members are being added to a team of outstanding scientists to work out this challenging assignment.

This is your opportunity . . . an unusual chance to get into nuclear energy work with practical applications as a goal . . . to work under conditions that are ideal for creative talent . . . with a company that has achieved leadership in its field in over 25 years of operation.

We need today Physicists, Mathematicians, Chemists, Metallurgists, Designers, and Engineers who will serve as members of a team. They must be more than theorists. They must combine a sound knowledge of their field with imagination and the ability to apply their talents to realistic and practical work.

You will enjoy working and living with us. Your work will be important to the community as well as the nation. And we have the resources and research equipment to stimulate and further the most advanced scientific thinking.

We believe you will like the Hartford area, for it is a congenial New England community with outstanding social and cultural advantages. And equally well, you will appreciate the benefits which Pratt & Whitney offers—group life, hospitalization, accident and health insurance—plus a cooperative retirement income plan.

Why don't you have a talk with us . . . we will assist you in any way possible . . . hold any conversation you have with us in the strictest confidence. Simply send your resume to Frank W. Powers, Department R at the address listed below.

PRATT & WHITNEY AIRCRAFT

DIVISION OF UNITED AIRCRAFT CORPORATION

EAST HARTFORD, CONN.

What GENERAL ELECTRIC People Are Saying

I. J. KAAR

Electronics Division

SEMI-CONDUCTORS: The electronics industry has, since its early days, been completely dependent upon the device which gave it life—the vacuum tube. The key of all electronics has been and is still the ability to control a greater power by a smaller power—a greater power in the form of an electric current flowing through a vacuum, by a much smaller power applied to control elements inside the vacuum.

Now, with justifiable confidence, I say that on the horizon are potential successors to vacuum tubes—devices with many advantages over vacuum tubes and but few disadvantages. These fantastic devices are called "diodes" and "transistors" and are made of Germanium. They are smaller, lighter, and potentially cheaper than their tube counterparts. They require no hot filament or hot cathode, hence require much less power to operate and, as far as we now know, have an indefinitely long life. With such a new tool at hand who knows what may happen in electronics?

The properties of Germanium that make it valuable arise from the fact that it is a semi-conductor—midway in its electrical properties between such metals as copper and such insulators as glass. More importantly, its ability to conduct electricity depends strongly on the amount and nature of its impurities. When one type of impurity is present in a layer of Germanium and another type in an adjacent layer of Germanium, current will only flow easily in one direction between the layers. This is useful in changing alternating current into direct current, so by analogy to the vacuum tube having similar properties, such a two-layer device is called a "diode." It has been found within the past several years that when three layers of Germanium are used, the outer ones containing one type of impurity and the inner one another type of impurity, the two boundaries between the outer layers and the inner layer roughly correspond to the input and output circuits of a vacuum tube. That is, a small amount of control power applied to one boundary can influence greatly the flow of current across the other boundary and hence amplification can be achieved. Such a device is called a "transistor." It has already been demonstrated that for almost every function a vacuum tube can fulfill there is a counterpart achievable by a "transistor."

Diodes have been made in small sizes by the millions for several years now. About six million were made last year and were extensively used in television receivers. Larger sizes for high-power applications are in pilot plant production. Transistors are still in the laboratory or in very small pilot plant production, but already enough have been made to compare this new art with the vacuum tubes as of about 1920, or to television and radar in about 1940. In one direction our scientists are seeking to make high-power or large "transistors"; in another direction they have already made them smaller than the head of a match. Several thousand of the small ones could be operated on the power required by one vacuum tube such as is used in your radio or TV set.

It is not difficult to extrapolate from here some of the implications for the future. A really *personal* radio of hearing aid size running indefinitely on one set of batteries is within sight. The giant digital computers or magic brains, which at present use several thousand vacuum tubes and occupy a large room, can conceivably become small enough, and incidentally reliable enough, to apply to every day business and industrial problems as we now apply comptometers. In military electronics the simplicity and ruggedness of the transistor as well as its small size and low-power drain will have a direct effect on all equipment, particularly that which is airborne. In the telephone business it will become entirely practical to build amplifiers for use on cables at the bottom of the sea.

But what will happen to tubes? Will they disappear or become a ghost industry? Some kinds of tubes *certainly* will not, unless as yet undiscovered methods of using "transistors" are found. At present the frequency obtainable with "transistors" is definitely limited. This limit is high enough, however, so that most of the tubes used in radio and television are at least conceivably replaceable.

Considering the magnitude of the expansion process in earlier electronic revolutions and assuming that this coming growth period may be comparable, it is possible or even likely that two kinds of tubes, the television picture tube and the high frequency tube, may fully load all existing tube facilities and perhaps even require expansion to keep pace with the industry. And lest you infer from what I have said that the tube industry, as such, is doomed, let me hasten to assure you that a prodigious amount of work remains to be done in the transistor field—work which is mainly research—before we can be certain that we can manufacture them with the same facility or in the same quantities that we now make vacuum tubes.

But we do stand once again at the starting line of a new electronics business—not one, I think, to obsolete existing businesses, but one to supplement and augment them and to broaden our markets and create new jobs.

New York Society of Security Analysts,
New York City
June 2, 1952

You can put your confidence in—

GENERAL ELECTRIC

BOOKS

An encyclopedic survey of architecture as it is expressed in form and function

by Frederick Gutheim

Forms and Functions of Twentieth-Century Architecture, edited by Talbot Hamlin. Columbia University Press (4 vols., $75.00).

MOST general books on architecture have been histories; this monumental attempt to evaluate architecture in the mid-20th century is particularly valuable because it comes at the problem through the more direct considerations of form and function. After all, few architects designing today are attempting to perpetuate historic forms. Eclecticism is almost a thing of the past. We are well embarked upon the task of creating an architecture which, whether we like it or not, responds to the values and outlook of our time. Indeed, as John E. Burchard, dean of humanities at the Massachusetts Institute of Technology, has remarked, if you don't like modern art and architecture, you don't like modern life.

Fortunately, for most purposes the question of whether or not a building is liked is subordinate to other considerations. Does it meet its purpose? Is it economical to build and maintain? Did it give maximum value for the money invested? These are the questions we ask, and it is a rare building that is loved at first sight. Most buildings today—one suspects, in any day—are loved only after long acquaintance.

In this four-volume work, containing nearly 4,000 illustrations, our most distinguished architectural historian, assisted by more than 50 building-type specialists, has produced an architectural encyclopedia that is not apt to be duplicated in this generation. Whatever the faults of the enterprise (they are the faults of any encyclopedia), we must acknowledge the major importance of the book, both as a work of reference and as an architectural balance sheet. Nothing like it has been published in architectural literature for more than half a century.

Future scholars will not only consult Hamlin's book for the facts it contains; they will measure our age by it. In it they will see our strengths and our weaknesses, our enthusiasms and delusions, our blind spots and our convictions. They will draw their inferences from what it leaves out as well as from what it includes.

For example, among the 51 chapters dealing with individual building types in the third and fourth volumes, there is no treatment of laboratories. Surely few building types are more challenging, and few today are in a state of such accelerated development in design. But instead of a unified, authoritative treatment of this important type of building, we are given scattered references under "Buildings for Education," "Buildings for Public Health" and "Factories." Yet space has been found for individual treatment of such minor building types as "Camps and Dormitories," "Settlement Houses" and "Boarding Schools"!

This is not carping, nor do I mean to belittle the admirably thorough treatment given nearly every part of the field. The omission is evidence of the central problem which must have faced the editor of so extensive a work, and which accounts for its slightly dated viewpoint when measured by books of smaller scope. The situation parallels the difficulty faced by the architect of a large and complex building, designed and built over many years. The most recent developments are perforce left out, and their omission is a reminder of the rapid rate of progress in building.

In 1951 building became the nation's largest single industry. For the first time agriculture took second place. Despite its craft survivals (and they are criticized within the industry as well as outside it), the art of building is in a state of rapid technological evolution, from the processing of raw materials and components to the manufacturing of equipment. More than half of the cost of many buildings today is accounted for by items of mechanical equipment not invented a half-century ago. This is an architectural era of steel, concrete and glass, but even the traditional materials of the builder are highly commercialized and greatly changed from their form of only a few years ago. Brick of uniform strength and color, cement of exact specification, lumber of precise grades—these are only some of the changes that have transformed the common structural materials. Smaller and more efficient heating plants, radiant heating, air conditioning, modern insulation methods combine to create a wholly new atmosphere in today's buildings. Color coordination, sound zoning, controlled ventilation, a new acoustical environment are only a few of the things today's architect must remember as he goes about his work of designing and specifying the buildings in which we live and work.

Beyond these obvious invasions of science into the ancient art of man, that building animal, Hamlin shows clearly that the process of architectural design itself has become scientific. Its fact-finding processes, its analytical methods and its tested results alike respond to the spirit of the age. An architect who addresses himself to the relatively simple problem of designing, let us say, a modern shop, is expected by even a modest client to support his design by cogent reasons arising from the use of the building as a merchandising device, or as a warehouse or from its construction. Those unfamiliar with modern architectural practice are frequently astonished to learn that the man they pictured as a species of artist turns out to be part engineer, part businessman, part scientist.

Possibly the most serious of the omissions from this gigantic work is a description of the modern architect himself, and his changed function in today's building industry. This particular oversight will be made good shortly when the American Institute of Architects publishes its Carnegie-financed survey of the architectural profession at the mid-century.

A re-examination of the fundamentals of architecture in the light of modern thought and architectural experience has led Hamlin to organize his work into two basic parts. In the first, the editor himself has written of the Elements of Building and the Principles of Composition. He has thus laid a foundation for later special treatments and established a framework that allows him to command the enterprise as a whole and make the best use of his specialists.

Functionalism is the doctrine of modern architecture, and "form follows function," as many 19th-century estheticians believed and the architect Louis Sullivan wrote. Hamlin shows us how the human use of a building shapes its final form. Public and private spaces, services, circulation and equipment he identifies as the basic elements of the building. These are accommodated within structural elements which are next described for us—walls, doors, windows, columns and piers, ceilings and floors, arch and vaults, and roofs. Although the book is not a history, this section of Hamlin's work is rich in historical illustrations from the world's architecture.

How is the architect to organize the building? In the second volume, the author introduces us to the esthetics of architecture, showing the importance of unity, balance, proportion, scale and rhythm. Perhaps the best chapter in this part of the book is one on that critical but elusive architectural quality, character. And certainly the most important is one on the controversial term, style. The author proceeds to a consideration of architectural design and structural methods, and concludes with a discussion of building materials. All in all, it is an impressive excursion—remarkable for its clarity of exposition, its freshness of statement and the vigorous sense of movement and direction which it gives the reader.

Enough has been said by way of description and comment to make clear that this is a book more of facts than of ideas, a superb work of reference, but not a great individual creative achievement. Hamlin is the architect's Diderot, not his Darwin. But it is also a work of literary distinction, easily read and, although written for architects, illuminating to any imaginative reader.

Architecture, as Hamlin pointed out in the title of perhaps his best-read work, is "an art for all men." Few of us can escape the influence of the buildings in which so much of our lives is spent, which frustrate or support our activities, stimulate or depress our spirits and act as an ever-present environment. Architecture is not merely an art with deep humanistic roots and implications; in all the world's great civilizations it has been found a true mirror of culture. Today's new building, as presented here, is a mine of insights into our own civilization. To the world of science architecture offers not only its services but also opportunity. Few great sectors of modern life more eagerly await the contributions of modern science, and few offer more brilliant rewards.

Frederick Gutheim is an official of the American Institute of Architects and the author of The Potomac *and* Houses for Family Living.

THE RISE OF THE SKYSCRAPER, by Carl W. Condit. University of Chicago Press ($5.00). Le Corbusier's celebrated indictment of the buildings of contemporary cities, "We live in architectural zoos," admits of at least one group of notable exceptions: the structures erected after Chicago's great fire of 1871 by a handful of extraordinarily creative and imaginative architects usually called the Chicago school, among whose leaders were Sullivan, Jenney, Root, Burnham, Richardson and Warren. In this thoughtful, well-written, richly illustrated book Mr. Condit describes the major contribution of the Chicago school to modern building methods and design. It was a contribution not confined to Chicago—though many of the most famous structures such as The Rookery, the Ashland Block, the Auditorium, the Reliance Building, the Monadnock, and the Home Insurance Building, were erected in that city—nor to the category of office buildings, hotels and apartments. The Chicago school designed warehouses, railway stations, factories, schools, churches, theatres, "even tombstones"; examples of their work are to be found in a dozen or more principal U. S. cities. They were responsible also for the development and mastery of steel framing, the use of hollow-tile fireproofing, the glass curtain-wall, sound insulation, movable partitions and other revolutionary structural innovations. What these brilliant men designed was often as beautiful as it was useful; their achievement, writes Condit, was not an accident but represented "deliberate acts of intelligence and creative ingenuity" by a number of artists and engineers bent on shaping a new style of architecture to meet the demands of a new era. They succeeded in developing an "aesthetic discipline of the powerful forces of 19th-century industrial techniques . . . [and] the whole forward movement of contemporary architecture is in the direction of that synthesis."

EARLY AMERICAN ARCHITECTURE, by Hugh Morrison. Oxford University Press ($12.50). This erudite work, profusely illustrated, presents an account of architecture in the American colonies "from St. Augustine in 1565 to San Francisco in 1848." The field is vast and hundreds of specialists have tracked through it and reported their findings in a massive body of literature. Mr. Morrison, chairman of the Department of Art at Dartmouth College, is the first, however, to attempt a history of all types of buildings in all the colonies. He describes his purpose as "grimly didactic," and remarks that "if any entertainment or amusement has crept in, it is purely coincidental." But this is too modest. The truth is that his book is readable as well as informative. Morrison has been discriminating in the selection of his material, skillful in matching his text to the pictures, and has supported the architectural descriptions with interesting details about the people of the colonial period, the life they led, their tools, furniture, gardens, and so on.

LET THERE BE BREAD, by Robert Brittain. Simon & Schuster ($3.00); LAND FOR TOMORROW, by L. Dudley Stamp. Indiana University Press

($4.00). It was in 1798 that Thomas Robert Malthus published anonymously *An Essay on the Principle of Population as it affects the Future Improvement of Society.* The main argument of this famous pamphlet—that population increases in a geometrical ratio and food only in an arithmetical ratio, and that "population is necessarily limited by the checks of vice and misery"—aroused bitter controversy. For a time in the 19th century, as new lands and resources were developed, Malthus' principle fell into disfavor. Today, with the world's population sharply increasing and with a scarcity of new frontiers, the truth of his basic assertion is, as Professor Stamp writes, again very much "in date."

Both of the books here under review discuss aspects of the problem that occupied Malthus; they may profitably be read together. *Let There Be Bread* is an enlightening and eloquent account of the battle against hunger. Robert Brittain, a poet, publicist and commentator on science, starts from the premise that "the human family does actually have, today, the collective knowledge and the necessary material means with which it could produce all the food it needs." His book discusses many examples of improvement in land use: how areas hitherto regarded as too dry, too cold or uncultivable for other reasons can be (and in some areas already have been) made to yield valuable crops; the development of gigantic irrigation projects in Africa (*e.g.*, lifting the Nile to make it flow over mountains) and Asia (*e.g.*, the projected change of course of the Ob River in the U.S.S.R.); the use of sea vegetation (*e.g.*, chlorella) for food purposes; the destruction of food crops by insects (20-30 per cent of the world's entire supply), rats and fungi; the food values to be obtained from intelligent conservation of waste; the shortcomings of contemporary farming methods, even those practiced in the U. S.; the benefits to be derived from crop rotation, improved breeding techniques and the like. Mr. Brittain repeatedly expresses his indignation at man's cupidity, intolerance and short-sightedness. He does not shriek at the reader or attempt to frighten him out of his wits—the contemporary fashion in these, as in so many other matters—but neither does he minimize the seriousness of world food shortages. Yet on balance his is a hopeful and encouraging book. Indeed, its main defect is its exuberance. For Brittain's figures do not always stand close scrutiny, and his appraisals often rest upon observations evidently filtered through an eager and sympathetic eye.

Land for Tomorrow, a group of lectures on the "underdeveloped world" delivered at the University of Indiana by a noted British social geographer, provides a counterbalance to Brittain's overdeveloped optimism. Stamp deals with population distribution and growth, the world's lands, food supplies, land use and kindred topics. His book is sober, disinterested and authoritative. He is apt to give statistics and similar data in place of Brittain's more general conclusions and to regard as perhaps possible at some uncertain future date projects which Brittain pronounces immediately feasible. Both writers stress the point that in speaking condescendingly of "backward" or underdeveloped areas, we betray our ignorance of the fact that the U. S. itself lags in effective use of resources, and especially in farming methods. The U. S., Argentina and Canada, says Stamp, are among the "outstandingly underdeveloped countries of the world": in farming efficiency the U. S. is excelled by Belgium, Denmark, Netherlands, New Zealand, Britain, Ireland, Egypt and Germany. Without sharing Brittain's expectations, Stamp is confident that advances in science can simplify the problems of feeding the human race, "if only man can overcome the barriers he himself has erected between the nations."

Both studies are well written, interesting and valuable. The approach of both men is rational and constructive, both are undespairing.

A Land, by Jacquetta Hawkes. Random House ($3.75). The author of this fresh and beautiful book, daughter of the eminent biochemist Sir Frederick Gowland Hopkins, is both a poet and an archaeologist. She has fused these skills in a remarkable work of science and imagination, an account of how the British Isles were formed, of the prehistoric animals and plants that inhabited them, the action of the sea, the wind, and the rivers in making, destroying and remaking the land, the features of the landscape from which events of remote ages may be recaptured, the architecture and other man-made objects that not only embody Britain's social and technological history but offer clues to the pattern of its geological evolution. The distinctive quality of Mrs. Hawkes' book lies in its extraordinarily evocative imagery: the vision of the old in the new, the interaction between the rocks and man, the consciousness and memory of man that span the whole history of life. The author might have spared us some of her social diagnoses, but her book is nevertheless a literary event.

The Columbia Lippincott Gazetteer of the World, edited by Leon E. Seltzer. Columbia University Press by arrangement with J. B. Lippincott Company ($50.00). A new geographical dictionary incorporating the famous *Lippincott Gazetteer*, which was last revised in 1905. The *Columbia Lippincott* sets a standard of comprehensiveness and dependability for reference works of its class. It lists 130,000 places, including important historical ones that no longer exist, and provides accurate, essential information—mainly from official sources—regarding such features as location (in "straight-line distances" in miles from larger places or, where more useful, in geographic coordinates), size, population, climate, geological aspects, industries, agricultural output, cultural and educational resources, historical attributes and the like. Careful notation is made of place name changes, the dates when these occurred, appropriate cross-references, the latest census data, a practical and consistent pronunciation system, and, for languages such as Arabic, Chinese, Greek and Russian which do not use the Latin alphabet, transliterations as well as English names. The gathering of this large store of diversified knowledge was a cooperative international undertaking by more than 150 expert contributors under the editorial direction of Leon E. Seltzer, with the assistance of Theodor Shabad, noted for his studies of the geography of the U.S.S.R. This is a book which will fulfill admirably the special demands of scholars and the general needs of home, office and school.

Doctors In Blue: The Medical History of the Union Army in the Civil War, by George Worthington Adams. Henry Schuman, Inc. ($4.00). It is not an inspiring record Mr. Adams spreads before us of the Union Army's Medical Department, of the politicians, doctors, officers and government officials who dealt with the problem of caring for the sick and wounded. The Civil War, as Adams points out, took place at the end of the medical "middle-ages," immediately before bacteriology and aseptic surgery were to alter drastically both the doctor's methods and the patient's prospects. The battle to save casualties was fought under appalling handicaps—filth, disorganization, inadequate supplies, incompetence, indifference and corruption. The general quality of the medical services was epitomized in the widespread belief that "however bad the wound may be, art can make it worse." Nevertheless, between 1861-1865 a substantial improvement took place in the administration of the Army's medical functions, in the field-relief and ambulance system, distribution of medical supplies, design and operation of hospitals, observance of sanitary precautions, and even in the level of medical and surgical practice. Adams is not an exciting writer, but a considerable portion of his material requires no literary embellishment, and its base of solid research makes it an impressive as well as readable study.

Energy Sources: The Wealth of the World, by Eugene Ayres and Charles A. Scarlott. McGraw-Hill Book Company, Inc. ($5.00). A lucid, balanced survey of the world's energy resources, the reserves and consumption rates of various fuels, regional differences, and the prospect of replenishment and substitution when existing fuel sources are exhausted. The authors believe that within 30 to 40 years the oil supplies of the world, certainly those of the U. S., will have begun to run low; that within a century coal, despite immense reserves (perhaps seven trillion tons), will have lost its place as "king of energy sources." They hold out little hope for deriving substantial amounts of power from nuclear sources; on the other hand they are convinced that technical advances will make possible the conversion of solar energy (*e.g.*, peat bogs, land vegetation, solar collectors, waterfalls, heat pumps) into a more than adequate substitute for fossil fuels. Besides presenting valuable statistical information, the book contains a thorough and intelligent discussion of topics ranging from the technology of fuel production and the problems of conversion to the need for conservation, the outrageous wastefulness of fuel use in the U. S. and the inefficiency of the internal combustion engine—especially as designed for the modern, overpowered automobile. Illustrations and charts.

JANE'S FIGHTING SHIPS, 1951-1952; edited by Raymond V. B. Blackman. McGraw-Hill Book Company, Inc. ($22.50). As befits our restful period, the 53rd edition of *Jane's* is the biggest "normal peacetime" issue to date. There are new photographs, drawings, notes and tables; every page has been revised, rearranged or expanded; 50 extra pages have been added. The naval trend of the last year continues along the line of larger, swifter aircraft carriers and improved submarine "killers." The frontispiece photograph, a place of honor reserved, presumably, for the "ship of the year," depicts *H.M.S. Relentless,* a 1,700-ton fleet destroyer of the "Rotherham" class converted to a fast frigate, bristling with radar lattices and new armament and capable of 34 knots. Among other data to be found in *Jane's* are descriptions of the U. S. proposed giant flush-decked aircraft carrier *James V. Forrestal* (59,900 tons); details on the rapidly expanding submarine fleets of the U. S. and U.S.S.R. (the U. S. now has "guided missile" and "radar-picket" subs and is building an atomic submarine at $40 million and a hydrogen peroxide-powered type at $37 million; no fewer than 370 Soviet submarines are in service). Information is "presented with reserve" on the 42-45,000-ton Russian battleship *Sovyetski Soyuz*, first of a class of three, reported launched at Leningrad in March, 1950; and the guide contains miscellaneous fine points about the vessels of various nations from Iraq and the Irish Republic to Ceylon, Hungary and Israel.

THE AMATEUR SCIENTIST

The pleasures and pitfalls of archaeology, and more on the making of ruling engines

Conducted by Albert G. Ingalls

WHAT contributions can an amateur make to archaeology? Many people collect arrowheads. Not a few have dug into the works of the ancient mound-builders. Some own collections of artifacts that run into the thousands. But for archaeology much of this work is worse than wasted, because collections not adequately documented are worthless, and often the digging destroys invaluable information.

Frank H. H. Roberts, Associate Director of the Smithsonian Institution's Bureau of Ethnology, explains in the following how the hobby of collecting artifacts can be made a scientific avocation deeply rewarding both to the amateur and to his professional colleague:

"Archaeology fascinates most people. It is the means by which the past is made to live again, and it opens up new and exciting perspectives of time. The study of man's early history, growing out of the pleasant pastime of gathering antiquities for curio cabinets, long ago passed the stage where stone axes were thought to be thunderbolts and arrowheads were looked upon as 'fairy stones,' when the man who found a pot was called an archaeologist and he who found two became a great archaeologist. It has become a very complicated subject with numerous ramifications.

"The material remains which an archaeologist is lucky enough to find are only the starting point. They must be studied in relation to the environment in which they are found. The place where the people who made the objects lived will tell far more of the story than the objects themselves, because its climate and natural resources at the time were determining factors in the growth and development of the cultures which produced the artifacts. Detailed studies of the soil in which the objects lie, and a complete record of what is found there, are absolutely essential, for the process of excavating destroys the source of information. For that reason professional archaeologists have been loath to encourage laymen to make a hobby of archaeology and have insisted that excavations should never be undertaken except by an experienced person. This attitude on the whole is not snobbishness, as many amateurs believe, but is the outgrowth of a real concern for irreplaceable information.

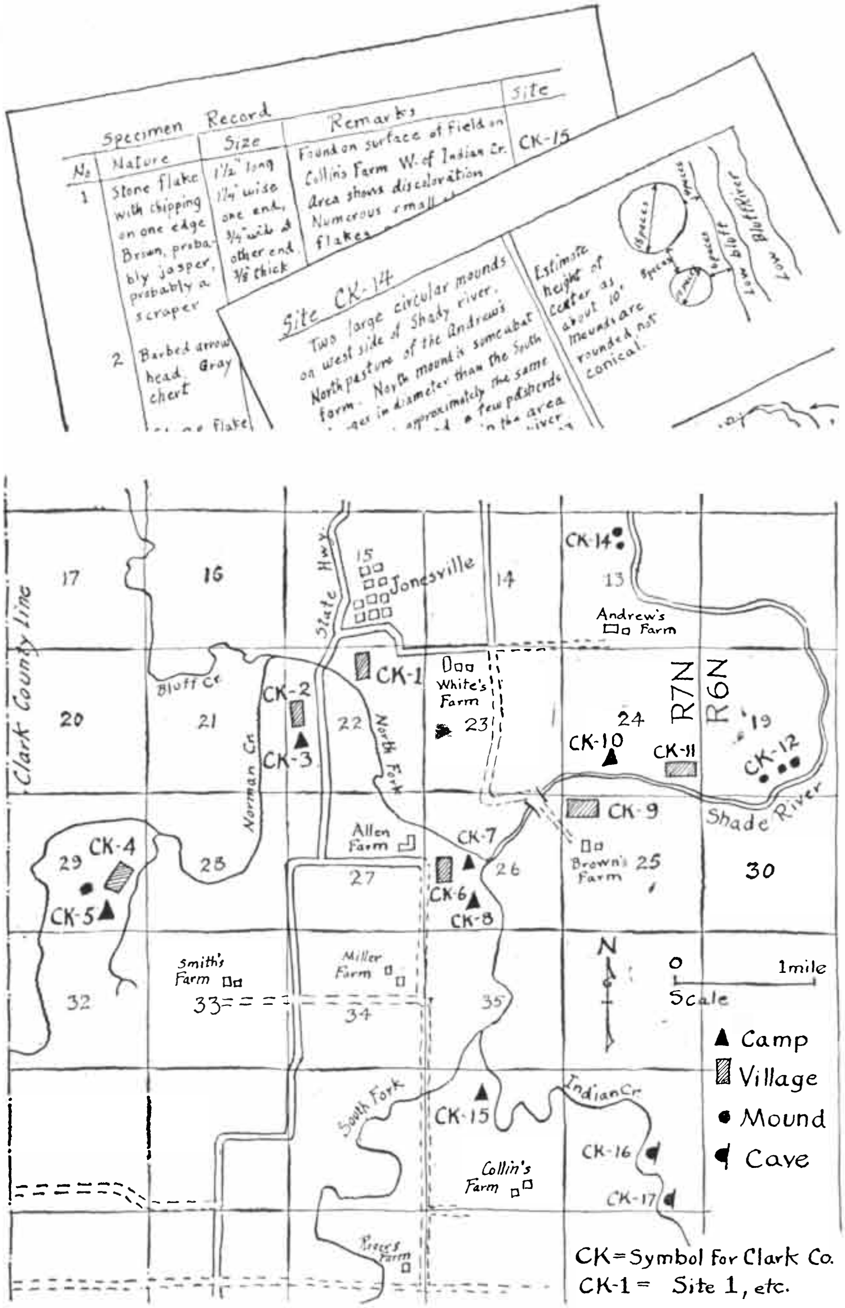
"What constitutes the difference between a professional and an amateur is not easy to define. Is the mark of a professional full-time employment at the job, or is it organized training and skill? Some men who make their living as archaeologists are purely amateur in that they have had virtually no training in the techniques of the science, while on the other hand some of those who are concerned with archaeology only as a pastime would qualify as professionals in skill and experience.

"To most people the word archaeology is synonymous with digging. Its glamour as an avocation certainly comes in no small part from the fact that in many of us there still lingers the small boy's delight in hunting for buried treasure. But an amateur can also profitably engage in other phases of archaeology which will not only give him satisfaction but contribute to knowledge. One can carry out many interesting archaeological projects without touching a shovel.

"A person interested in the traces of aboriginal occupation of the area in which he lives can obtain considerable pleasure from preparing a map showing their location and character. Getting the necessary information for such a map entails walks about the countryside and enjoyable chats with the local residents. Many farmers keep the 'curios' turned up by their plows and generally are delighted to show and talk about them. The research may even require a bit of reading in a library to determine what Indian tribes lived there in former days or to find out if there are references to the archaeology of the area. In the course of tramping about the fields the investigator may find an occasional arrowhead, other stone implement or potsherds. A record giving information as to how and where they were found will make a useful supplement to the map and may prove helpful to some professional when a comprehensive study is made of the region. If you find a number of artifacts, it is useful to sort them according to types and show their distribution.

"A map of this kind becomes still more valuable if it indicates the types of vegetation and the general character of the topography. By comparing it with old maps, often available in local historical society libraries, you may be able to find changes that have occurred in the terrain since the earlier maps were made. The earlier character of the ground may have had a definite bearing on the location of an Indian village, and often it explains conditions which might

The amateur excavation of an Indian skeleton



Sample archæological records and map

otherwise be puzzling. Old maps also occasionally lead to the discovery of archaeological features which were destroyed by cultivation and are no longer apparent on the ground.

"Collecting arrowheads of course is one of the most popular hobbies. Some people collect them mainly by purchase or trade. Those who buy their artifacts run considerable risk of having fraudulent objects palmed off on them, as there are a number of men in the U. S. who are experts at making 'Indian' things. In any case, a collection by purchase has little actual value, because there is no record of where the artifacts were found. Occasionally a large collection containing very fine specimens is offered for sale after the death of its owner and, much to the disappointment of the heirs, brings far less than expected, even less than the original cost of the items, solely because no information accompanies them. Every person who makes a hobby of collecting arrowheads or other aboriginal objects should keep a careful record of where and how each was obtained, asking the seller for this information when a piece is purchased. Each specimen should be numbered and listed in a notebook, so clearly that anyone can readily identify it.

"In recent years there has been an encouraging trend toward the organization of societies by laymen interested in archaeological subjects. Many of these groups seek the help and advice of professionals and are making a serious effort to follow accepted archaeological procedures. Some of the local groups have formed state-wide societies, and in the eastern U. S. several state societies have combined in a regional association.

"State organizations and local societies have developed programs of investigation and contributed considerably to the archaeological knowledge of their own regions. In Connecticut and Massachusetts, for example, some excellent excavation projects have been carried out by amateurs under the general supervision of a few professionals. In Missouri amateur societies have cooperated with the University of Missouri in making surveys to locate and record all archaeological manifestations throughout the state. Their work has been particularly helpful because it has been done in areas which will be flooded before long by the construction of large dams. In Texas local societies have salvaged materials which were being destroyed by construction operations and have kept a valuable record of their activities.

"Contrary to a rather widespread impression, the professional archaeologist is not opposed to the amateur and is not continually seeking to keep him from what can be a worthy avocation. What the professional is anxious about is that the amateur should learn the best procedures and do his work properly. The sincere amateur will find that most professionals are more than willing to advise and assist him with his problems and to suggest ways in which his efforts can be of service."

THERE IS virtually no literature on the making of precision screws for ruling engines, which were described in an article in this magazine last month. Some of the basic principles of the manufacture of these screws are illustrated in the drawings herewith. Roger Hayward, who drew them, is himself an amateur mechanic; he wrote the sections on the lathe and on molding and casting in John Strong's *Procedures in Experimental Physics,* widely known among amateur telescope makers because of its excellent chapter on precision optical work.

In the group of drawings on the opposite page, the first, at top left, shows a spiral spring which illustrates what a mechanic means when he speaks of a "drunken" screw-thread. In a perfect spiral the helix angle, or angle of the threads with regard to a plane perpendicular to the axis, is everywhere the same. Here part of the spring is bent to show the nature of the distortion of a drunken thread: the helix angle increases and decreases with each half-turn. A screw-thread may be thought of as a spiral inclined plane around a cylinder—when the spiral is even and regular, the thread if unwound would form a straight line; when it is drunken, the line would be crooked.

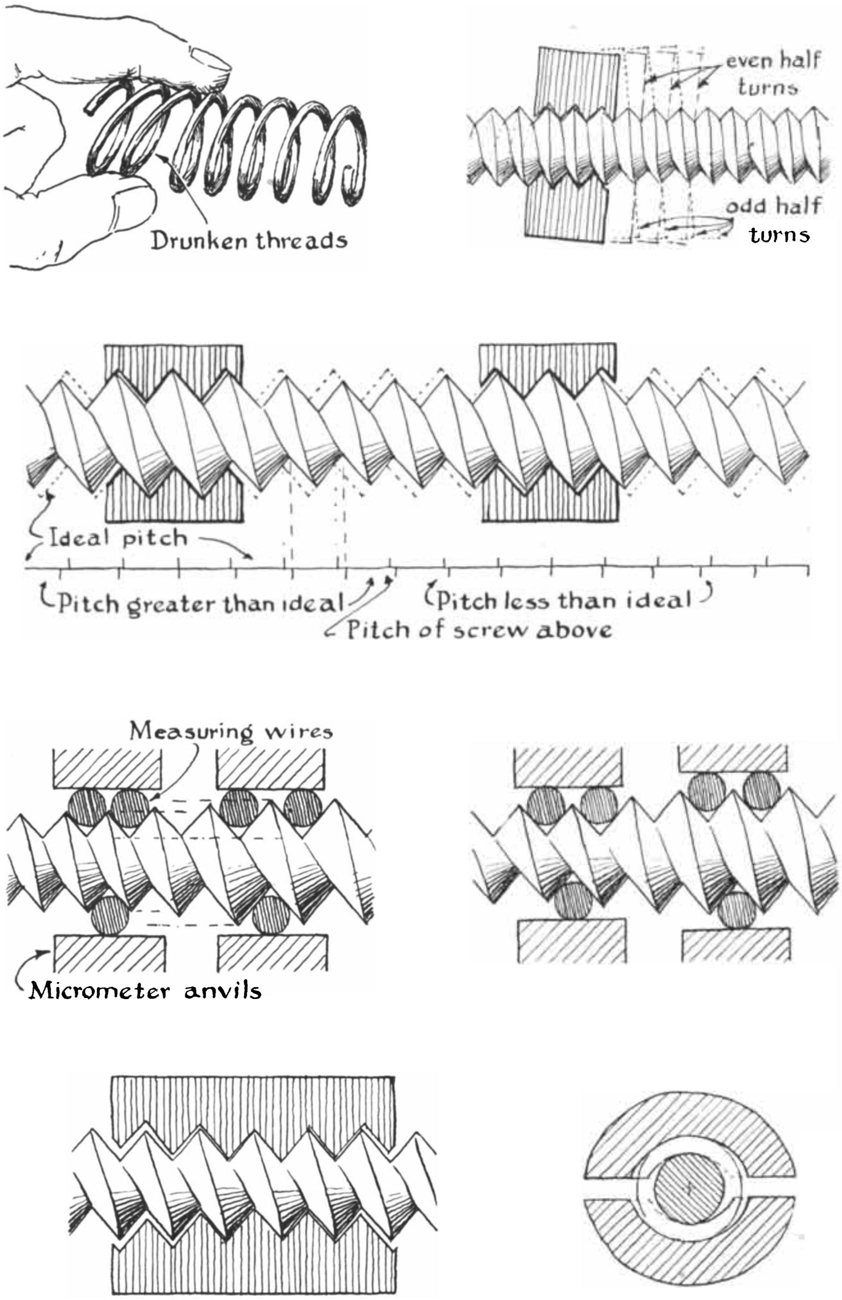
The next drawing (*top right*) shows how a short nut would wobble in advancing on a drunken thread. In a ruling engine this wobble would produce a periodic error in the spacing of the grating grooves and put "ghosts" in the grating spectra.

The third drawing (*second row*) describes with necessary exaggeration a faulty screw of varying diameter and varying pitch. Pitch is defined as the distance between the corresponding points on two adjacent threads. The drawing shows how diameter and pitch are closely related and, in fact, additive and not separately identifiable. In this particular screw the varying pitch compensates for the varying diameter. A single short nut could be moved along its length with equal friction—an early test for uniform diameter that was not quite watertight. All would seem well until the nut was connected with the diamond of a ruling engine. The screw would put progressive errors ("errors of run") on the grating.

Now suppose that two separated short nuts are placed on the screw, as shown in the same drawing, and the screw is rotated within them. The nut at the left would travel faster than the one at the right, because the pitch is "greater than ideal" in the left-hand part.

Next, suppose that the nuts are rigidly interconnected, in fact are parts of a single long nut, and emery grains in oil are introduced. When the screw is rotated, grinding action will take place on some of the threads to correct the pitch. This, of course, is the method used to refine a screw.

The third row of drawings illustrates one method of measuring the diameter of a screw. The circles are cross sections of wires of known diameter that are placed in the valleys of the thread. The flat sections are the anvils of a micrometer delicately touching the wires. The screw on the right is an example of varying pitch in the threads, which is not revealed by the wire method. The root diameter is uniform along the screw, but the screw's major diameter increases, as shown by the outer pairs of dashed lines. Yet the micrometer reads the same. The reason is that the greater pitch at the right-hand end of the screw allows the wires to enter farther into the valleys, compensating the discrepancy. On the other hand, in the drawing at the right the pitch is uniform, though the root diameter and the major diameter are not. Now the tapering of the screw is revealed by a difference in the space between the anvils. The wire method of measuring slightly compresses the screw at the two small areas of contact with the wires. To avoid this, Dave Broadhead, whose method of making screws for the Strong ruling engine was described in this department last month,

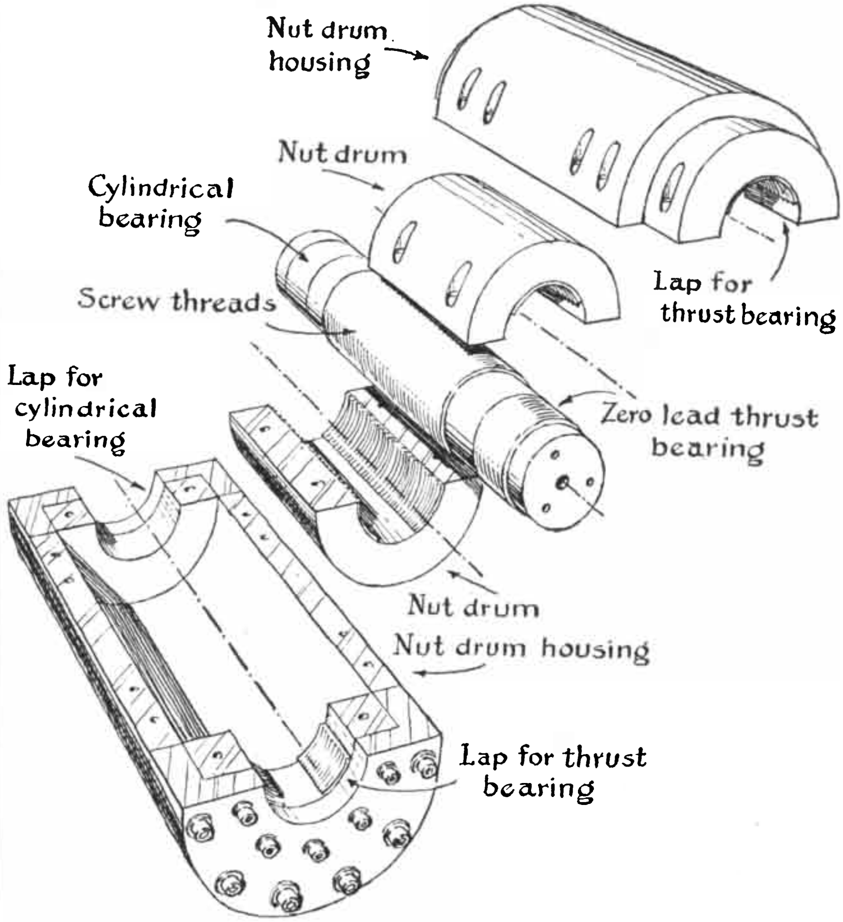


Interpretations of the esoteric philosophy of the screw-thread

measured with micrometer anvils in contact with tips of 20 threads at a time. This method must be used with caution, else it will damage the delicate thread-tips. Micrometric methods of measuring are used only down to one-10,000th of an inch. Thereafter the interferometer is used. The screws on the Strong engine are 1¼ inch in diameter, threaded over a length of 10 inches with 40 threads per inch (.025 pitch) at 45 degrees.

After making an apprenticeship screw precise in diameter within one-500,000th of an inch and others for the Strong engines Broadhead felt that "it is a good gamble if the screws are uniform in diameter within one-10,000th of an inch after *systematic* lapping with a long lapping nut and no cheating with a short one." He calls the control of one end of a long lapping nut on the threads at the other end a "telephoning effect."

"The effect at one end," he adds, "is modified by this control from the other, provided the ends are in contact with the screw—and here lies the rub, or rather the lack of it; for the ends are actually connected only to the extent that the lap and threads are stiff. The smaller the errors dealt with, the stiffer it must be. Getting contact between the mirror and lap is a must in mirror making, but is not as easy with a metal lap since it can't be cold-pressed. Thus the lap wears to a bell-mouthed shape (*shown in the lower left-hand drawing*) and then will no longer span enough of the screw to reduce long errors of run. It is really a



Strong's invention for centering the pivot axis on a screw

short lap, yet you may foolishly think of it as a long lap.

"Bell-mouth lap is more difficult to avoid than turned-down edge on a mirror. In the first place, the fresh grit reaches the ends of the lap first. I countered with an extremely thin abrasive mixture, two grains (by weight) of 303½ emery to a gill of thin oil, and used just enough of it, or half a teaspoonful each three hours, with clear oil dripping on the lap between times, to keep a little black color, indicating removed metal, in the drippings from the lap. In the second place, the thrust of the screw tends to give the lap halves a rocking, oscillating motion, despite the push-pull screws that hold them together. These screws are 'rubber' when we work in such minute dimensions. I countered with lapping in vertical position and trying to reduce the thrust by careful counterbalancing and reduction of friction on the guides. Thirdly, no matter how carefully the screws are adjusted, one end of the lap and later the other will be sure to be tighter than the first. Bell-mouth lap is the inevitable result. I countered by using three pairs of push-pull screws on the nut halves and adjusting each by watching a milliammeter in series with the armature of the highly efficient, sensitive ball-bearing electric motor that rotates the lap. The current is proportional to load (torque).

"When initially threaded, the lap fits the screw tightly, but it starts wearing out of fit at once, because the screw gets smaller and the lap larger in radius. The push-pull screws can take up this wear in one dimension (*the vertical in the lower right-hand drawing on page 85*) but cannot take it up in the other. Soon the lap contacts the screw along only two small and opposite areas. To counter this loss of 'wrap-around' I sometimes channel the center of the lap lengthwise, thus giving it four 'halves,' and sometimes remove the central 'facets' along its length.

"The meanest thing on a screw, much worse than scratches on a mirror, comes when emery and debris roll up in tiny balls and bend the tips of the threads before the lap can be stopped. The bent tip then becomes an error which spreads by telephoning effect to the entire end portion of the screw, affecting the lead while it is being reduced by lapping. A damaged thread cannot be lapped individually. When the tape recorder announces that a thread-tip has been bent, you are set back a week in your progress, even if you stop the motor at once.

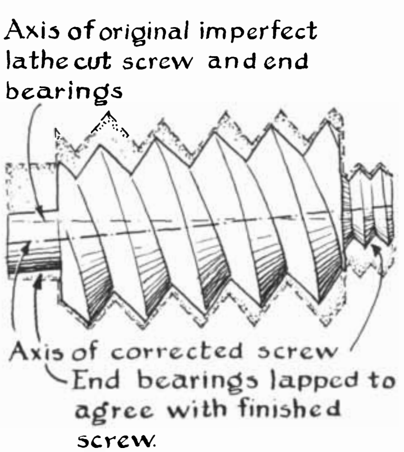
"The lapped screw is polished after 'figuring,' instead of before as in a mirror, by running it in soft grit, and finally with oil alone, for many hours. No true polish is possible, since the threads cannot be moved in various directions in the nut.

"In screw-making we stand today where the old-time mirror makers were before the invention of the knife-edge test."

The ruling-engine article last month called attention to the great difficulties connected with bringing the geometric axis of the pivots near the end of a screw into coincidence within one-millionth of an inch with the axis as determined by its helix of threads, to prevent the nut from wobbling in the ruling engine and putting periodic errors on the grating. J. A. Anderson rates this five times as difficult as making the screw itself. The axis-coincidence job was formerly accomplished by correcting one side of one pivot, which left it out of round so that it had to be ground round again in its own bearing, and then correcting the other end similarly, and by alternating ends until no error could be detected with an interferometer. In place of this inelegant method Strong invented the automatic mechanism shown on the opposite page.

Surrounding the screw is an internally threaded "nut drum." Surrounding this nut drum is a "nut drum housing," with an open space as thin as tissue paper between the two. This narrow space is filled with liquid grease. Lapping abrasive is applied only to the "lap for cylindrical bearing" (*see drawing*) and "lap for thrust bearing."

Here is how the invention works. When the screw is rotated the nut drum moves easily in a lengthwise direction but with great difficulty sidewise due to the wobbling screw, because the grease film in the space must be mashed and squeezed laterally in the space between the drum and housing to overcome high viscous friction. The reacting force is exerted on the sides of the pivots that need abrasion. Automatically the axes are driven toward coincidence, as shown in the illustration below.



Effect of the Strong invention

INDEX OF ADVERTISERS

JULY, 1952

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.

AMERICA'S OLDEST ROADS

THE TRAVELS OF PEDRO CIEZA DE LÉON, A.D. 1532-1550. Translated and edited by Clements R. Markham. Hakluyt Society, 1864.

SCIENCE IN THE ART MUSEUM

TECHNICAL STUDIES IN THE FIELD OF THE FINE ARTS. Published for the William Hayes Fogg Art Museum, Harvard University. Vol. I-X, July, 1932-April, 1942.

THE JUNCTION TRANSISTOR

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

p-n JUNCTION TRANSISTORS. W. Shockley, M. Sparks and G. K. Teal in *The Physical Review*, Vol. 83, No. 1, pages 151-162; July 1, 1951.

A REVOLUTION IN ELECTRONICS. Louis N. Ridenour in *Scientific American*, Vol. 185, No. 2; August, 1951.

THE SOUTHERN SKY

THE MILKY WAY. Bart J. Bok in *Scientific American*, Vol. 182, No. 2; February, 1950.

THE MILKY WAY. Bart J. Bok and Priscilla F. Bok. The Blakiston Company, 1941.

LETHAL HEREDITY

THE BIOLOGY OF DEATH, I-VII. Raymond Pearl in *The Scientific Monthly*, Vols. XII and XIII, pages 193-214, 321-335, 444-457, 489-516, 46-66, 144-164 and 193-213; March-September, 1921.

HEREDITARY LOOP-TAIL IN THE HOUSE MOUSE. L. C. Strong and W. F. Hollander in *The Journal of Heredity*, Vol. 40, No. 12, pages 329-334; December, 1949.

ATOMIC PILE CHEMISTRY

SOURCEBOOK ON ATOMIC ENERGY. Samuel Glasstone. D. Van Nostrand Company, Inc., 1950.

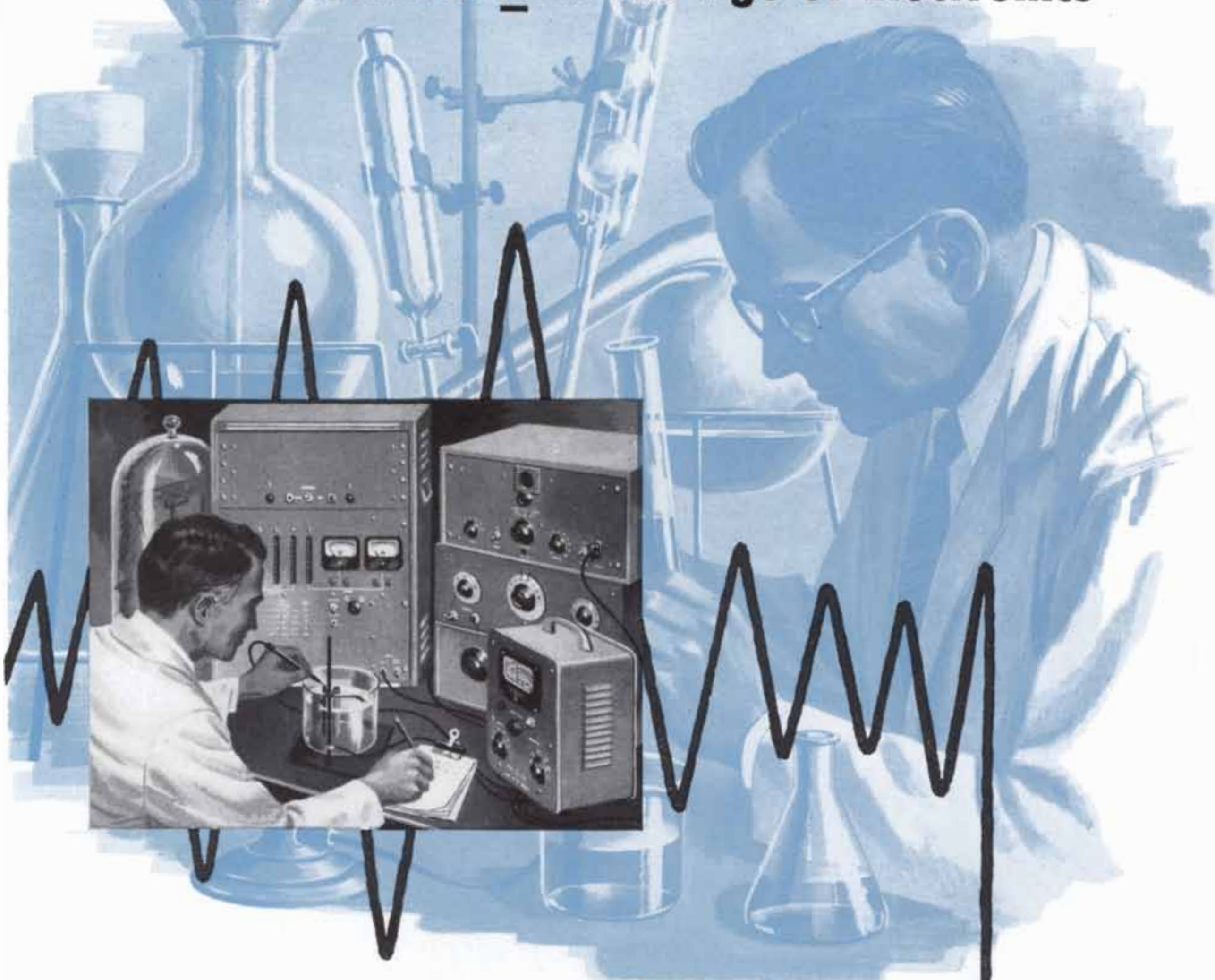
THE SCIENCE AND ENGINEERING OF NUCLEAR POWER. Clark D. Goodman. Addison-Wesley Press, Inc., 1947.

THE UMBILICAL CORD

CIRCULATION IN THE FOETUS. A. E. Barclay, M. M. L. Prichard and K. J. Franklin. Charles C. Thomas, 1947.

RESEARCHES ON PRE-NATAL LIFE, Vol. I. Sir Joseph Barcroft. Charles C. Thomas, 1948.

Your Business is in the Age of Electronics



Accurate, time-saving electronic measurements cut research and laboratory costs

Time and money spent in research are more productive when your engineers work with up-to-date electronic equipment. Many leading manufacturers find elecronics the only practical solution to today's more demanding development problems. Perhaps modern electronic equipment will help your laboratory achieve better engineering.

The Hewlett-Packard Company specializes in electronic measuring instruments. These are basic tools your engineers apply or adapt to your exact needs. They are used in research and manufacturing throughout the world and are distributed through the world's largest organization of electronic engineer-salesmen.

CATALOG 20-A *lists data and uses of over 100 major -hp- instruments. Request it on your company letterhead, please.*

HEWLETT-PACKARD COMPANY

2403-S PAGE MILL ROAD • PALO ALTO, CALIF.

Export: FRAZAR & HANSEN, LTD. San Francisco • Los Angeles • New York

hp

ELECTRONIC MEASURING INSTRUMENTS

for speed and accuracy

2403