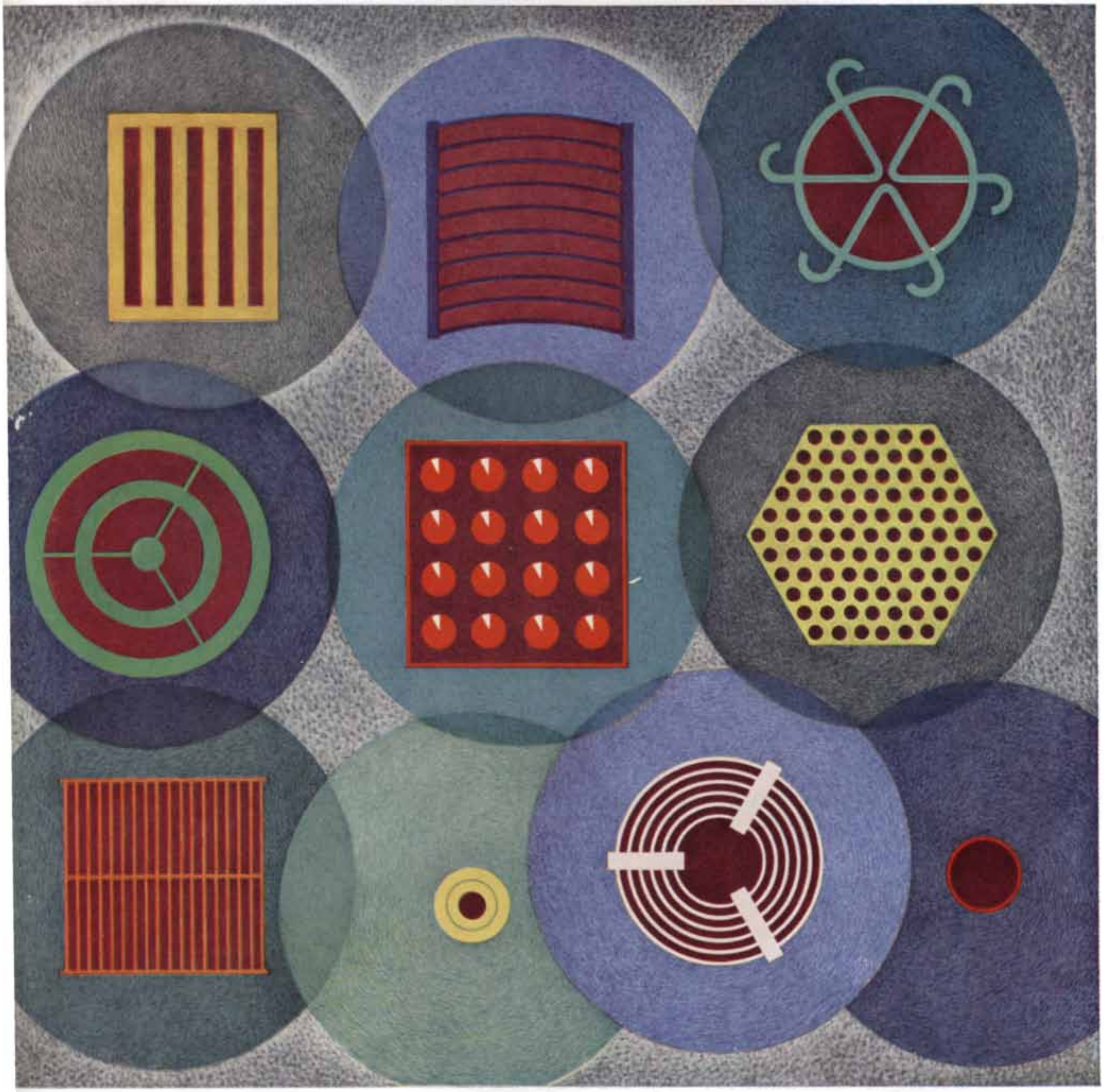
SCIENTIFIC AMERICAN



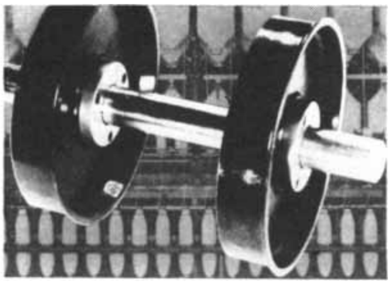
REACTOR FUEL ELEMENTS

FIFTY CENTS

February 1959

PRODUCT-DESIGN BRIEFS FROM DUREZ

- **impact strength comes down in price**
- **fast-curing phenolic cures a cost problem**
- **new idea for closures**



High impact at low cost

These big pulleys help drive huge spinning frames made by Roberts Co., Sanford, N. C., a leading manufacturer of textile machinery.

Until recently, the pulleys were made of stamped metal or heavy cast iron. Designers looked for a better material—strong, dimensionally stable, low in cost. They found it in *Durez 18683*.

This new sisal-filled phenolic solves the cost problem of high-impact parts in three ways:

1. It costs only pennies more than general-purpose wood-flour-filled phenolics.
2. It molds by simple compression or transfer methods, using standard presses, standard pressures, standard dies.
3. It cures as fast as general-purpose compounds.

Durez 18683 molds dimensionally stable parts with impact strength of 1.4 ft. lb./in. Molded parts are self-extinguishing, have excellent resistance to humidity, and can meet U/L requirements for attached electrical contacts. You'll find that *18683* opens the way to savings on hundreds of applications where higher-cost materials are used now.

Consider it for heater and air-conditioner housings, instrument panels. Specify it for gears, wheels, pulleys, electric motor end bells—wherever you need impact strength and want it at lower cost.

The sooner you investigate *Durez 18683,* the sooner you can start saving with it! For bulletin, data sheet and/or evaluation sample, mail the coupon today.

Torrid tempo

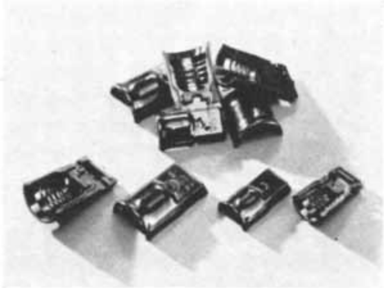
Rapid production is beating out a new rhythm of lowered costs for the makers of these small lamp sockets (center column), Noma Lites, Inc.

The key notes are smart redesign, use of multi-cavity molds, and an exceptionally fast-curing Durez phenolic.

Formerly, the manufacturer bought one-piece sockets, forced metal screw shells into them, applied pitch to protect against moisture, then laboriously soldered in the wires.

Zip! Now, threads are molded into the split sockets by the molder, Holyoke Plastics Company Inc. Wires are laid across the socket halves. A simple metal clip joins the halves and pierces the wires with contacts.

Whoosh! Socket halves are molded 80 at a time. Into the molds goes speedy *Durez 265,* general-purpose compound that cures in a few seconds. Even at this dizzy rate, its batch-to-batch uniformity assures consistent molding.



Hurry! Want to snap things up a bit? *Durez 265* can probably help you do it. To see how, dash right over to your molders. Or shoot us coupon for data on *265* and other GP molding compounds.

A cap can be pretty

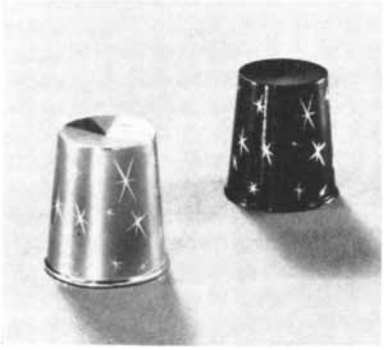
Not so long ago, you couldn't get this decorative effect in a molded plastic closure. Now you can.

It's done by wiping color into the debossed design. Debossing used to be the crux of the problem, because of the undercuts. It was impossible to make a workable mold cavity by machining, hobbing, or casting.

The solution: electroforming. The mold is built up in nickel around a soft, resilient master, which is then withdrawn from the cavity.

The process is a development of Armstrong Cork Company and Electromold Corporation. It gives the designer a new freedom—permits intricate textured effects like leather and wood grain, as well as the simpler ones you see here.

Durez is in the picture, too. Versatile phenolics, especially formulated for bottle and container caps, provide the requisite impact strength, resist chipping and cracking, and do not bleed when in contact with alcohol. If these qualities might help you uncork a closure idea or unbottle a bottleneck, we suggest you contact your molder on the use of Durez phenolics for closures.



For more information on Durez materials mentioned above, check here:

- ☐ High-impact low-cost phenolic, *Durez 18683* Bulletin and data sheet
- ☐ Evaluation sample of *Durez 18683*
- ☐ *Durez 265* (data sheet) and descriptive Bulletin 400

Clip and mail to us with your name, title, company address. *(When requesting samples, please use business letterhead.)*

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PLASTICS DIVISION

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127
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Established 1845 **SCIENTIFIC AMERICAN** February, 1959 Volume 200 Number 2

ARTICLES

DEPARTMENTS

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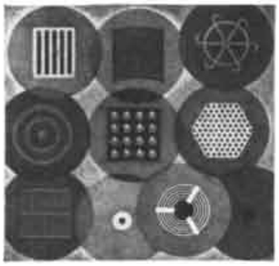

THE COVER

The fanciful design on the cover shows 10 nuclear reactor fuel elements in cross section (*see page 37*). The elements on which the painting is based are manufactured by Sylvania-Corning Nuclear Corporation.

THE ILLUSTRATIONS

Cover painting by Eric Mose

Page	Source
38-41	Irving Geis
42-43	Argonne National Laboratory (*top*), Irving Geis (*bottom*)
45-46	Bunji Tagawa
47	Katherine Esau
48	Susann and Orlin Biddulph
49	Bunji Tagawa
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72-73	Bunji Tagawa
74	Gernsheim Collection
76-78	New York Public Library
80	Bettmann Archive
88	A. R. Taylor, Research Laboratories, Parke, Davis & Company (*top*); S. S. Breese and A. Briefs, Walter Reed Armed Forces Research Institute (*bottom*)
89	C. F. T. Mattern and H. G. du Buy
90	Joseph L. Melnick and M. Benyesh
92	John Langley Howard
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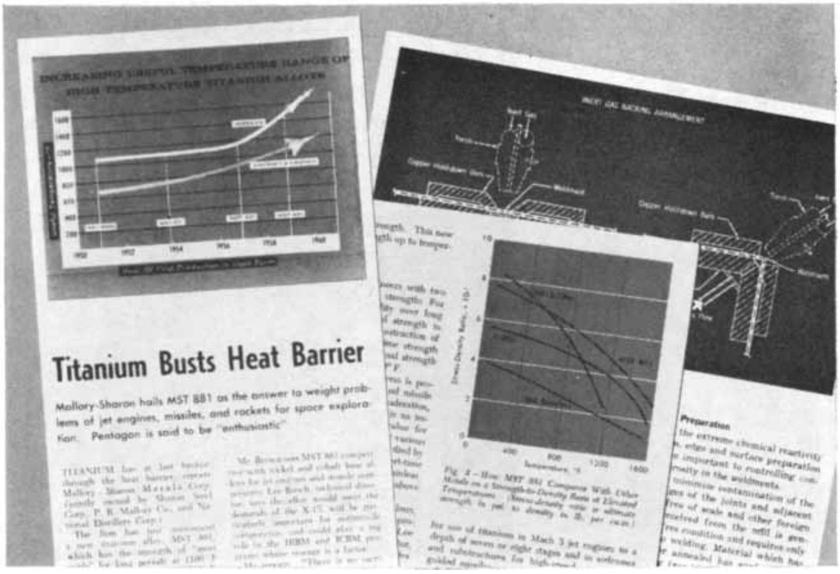


Who's MAKING NEWS *in special metals*

In aircraft and missile design, in hundreds of industrial applications, the search for new and better metals goes on constantly.

How can strength-weight problems be licked?

What new alloys promise to "break through" existing heat barriers?

Where can maintenance costs be cut by applying new metals with very high corrosion resistance?

In the field of special metals, Mallory-Sharon is the company that's *making news*. New titanium alloys, with elevated temperature properties never before achieved with this material! Reduced prices on titanium and zirconium sponge . . . savings directly reflected in lower prices of mill products! 1,000,000 lbs. of zirconium to be available for commercial use in 1959!

For technical assistance on *any* problem involving titanium, zirconium or other special metals . . . call in a Mallory-Sharon service engineer. He knows what's new in special metals.

MALLORY MS SHARON

MALLORY-SHARON METALS CORPORATION • NILES, OHIO

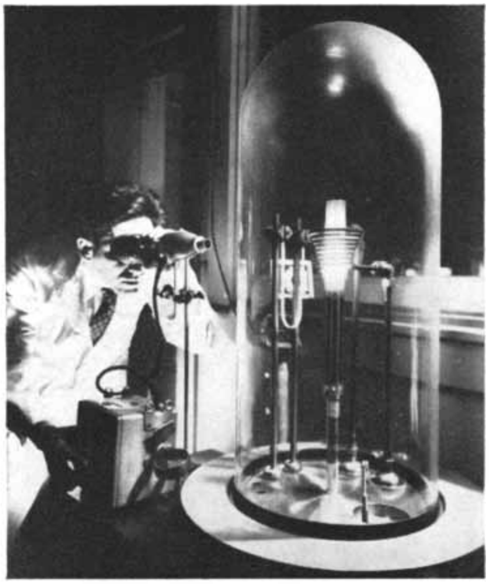
Integrated producer of Titanium • Zirconium • Special Metals

CAPABILITIES FOR DEFENSE

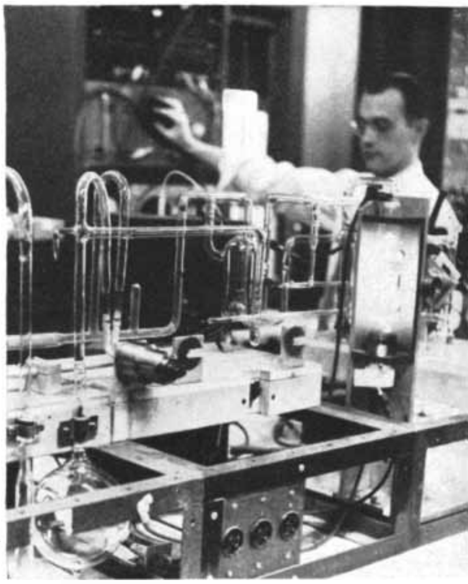
Westinghouse is spending $185 million for research and development in 1959

HERE ARE SOME CURRENT PROJECTS . . .

HIGH TEMPERATURE ELECTRICAL INSULATION. Effective for long periods at 500° C—eventual applications to 1000° C now contemplated. Demonstration motor shown above is running red hot. ***Aircraft Equipment Department, Materials Engineering Departments, and Research Laboratories***



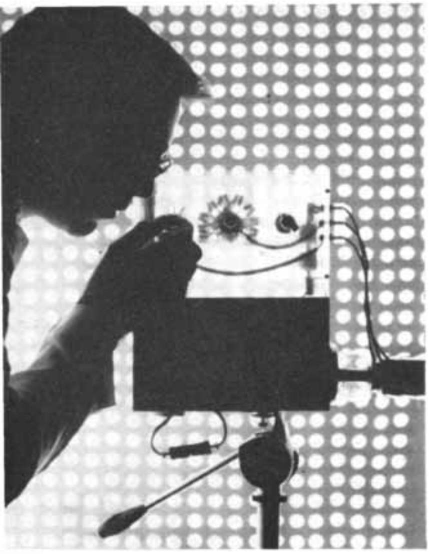
SPECIAL METALS. Westinghouse spearheads research in refractory alloys with one of the country's largest programs in special metals. Westinghouse is nation's principal supplier of a number of special defense-application metals. ***Materials Manufacturing Department, Aviation Gas Turbine Division and Lamp Division***



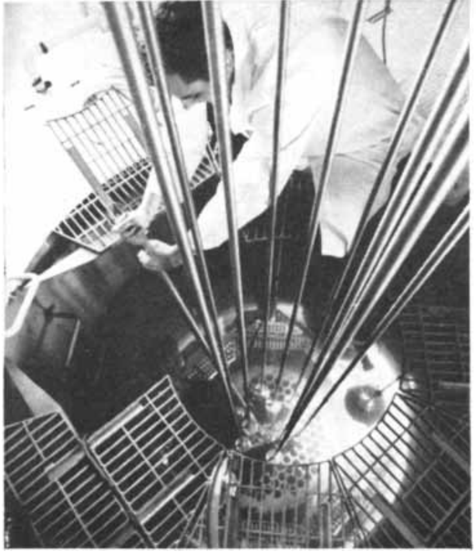
HIGH-VACUUM RESEARCH. Extensive high-vacuum research conducted since 1947. Current areas of investigation include electrical and chemical pumping in ultra high-vacuum range and component development for large high speed pumping systems. Results being applied in advanced electronic device development. ***Air Arm Division and Research Laboratories***

UNDERWATER SONICS. Current Westinghouse projects being conducted in laboratories and at sea are investigating various types of "scatterers" and their effect on the underwater transmission of sound. Also under development: acoustical torpedo controls and an acoustical mine identification system. ***Ordnance Department and Research Laboratories***

NON-ROTATING 360° RADAR ANTENNA. Only the feed point moves. Principle involved will permit economical construction of very large high gain scanning antennas. Application of inflation techniques will permit lighter-weight long-range air-transportable radar. Working models already built and evaluated. ***Electronics Division and Research Laboratories***



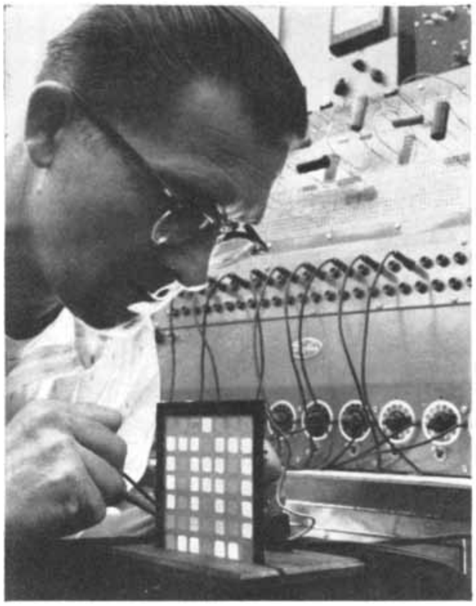
LIGHT AMPLIFICATION, through electron bombardment induced conductivity. Extremely sensitive. Principle especially useful for satellite reconnaissance devices. Efficient working models have been developed. ***Electronic Tube Division, Astronautics Institute and Research Laboratories***



NUCLEAR RESEARCH. At the Westinghouse Testing Reactor, engineers are preparing high intensity radiation tests on a wide range of materials to determine their structural, chemical, and nuclear stability. This is a necessary prelude to using these materials in certain atomic power applications now under development. ***Atomic Power Department***

INFRARED research projects include: *thermal imaging* — working models in advanced development; *ultrasensitive doped crystal detectors* — advanced test models; *photo-electric magnetic detection* — working model. ***Air Arm Division, Semi-Conductor Department, Materials Engineering Departments, and Research Laboratories***

PULSE-DOPPLER RADAR is in advanced development in three major areas of application at Westinghouse. Research is continuing to open up new potentials. Westinghouse is the acknowledged leader in this field. ***Air Arm Division***



NEW DATA DISPLAY DEVICES. Electroluminescent cells, individually controlled, form flat picture. Model has oversize cells for demonstration; latest techniques produce cells only 1/16″ across. Similar tote board display, capable of high-speed read-out of digital inputs, in production. Both devices can be erased instantly or retained and studied for long periods. ***Electronics Division, Rayescent Lamp Department and Research Laboratories***

THERMOELECTRICITY. Westinghouse recently developed the first efficient material to produce electricity directly from heat at high temperatures (1100° C). In addition, other thermoelectric material under development can be used for cooling purposes, including very light-weight applications. Forty Westinghouse scientists now on this project. ***Materials Engineering Department and Research Laboratories***

LOW-NOISE MICROWAVE AMPLIFICATION. Westinghouse scientists have developed various low-noise solid-state amplifying devices, both MASER and non-linear reactance types. Progress in recent years was speeded by prior years of research in low-temperature and solid-state physics. ***Air Arm Division and Research Laboratories***

For information on these and other research projects, write to Mr. E. W. Locke, Director, Customer Relations, Westinghouse Defense Products Group, 1000 Connecticut Avenue, N.W., Washington 6, D. C.

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YOU CAN BE SURE... IF IT'S Westinghouse

LETTERS

Sirs:

The article "Drilling for Petroleum" by Sullivan S. Marsden, Jr., [SCIENTIFIC AMERICAN, November, 1958] described a "most striking Soviet innovation" that sets aside conventional mechanical drilling methods in favor of flame drilling.

The flame drilling process which is described as in the development stage is not a Soviet innovation. Several flame processes for flame piercing and working of rock and stone were developed in the U. S. many years ago by Linde Company, Division of Union Carbide Corporation. One of these patented processes, known as Jet-Piercing, uses the same fuel combination as the Soviet "experimental" process, a mixture of kerosene and oxygen, to produce a high temperature, supersonic flame. The difference between the processes would appear to be the time of development. The American Jet-Piercing process has been in production use in the U. S. for more than 10 years.

Our country's largest domestic reserve of iron ore consists of iron-bearing formations of taconite located in the Mesabi Range of northern Minnesota and throughout northern Michigan. Known as the "meanest rock on earth," taconite has a hardness capable of scratching glass and at one time was considered impossible to mine. Thousands of blast holes were needed to get out the valuable taconite, but because of the extreme hardness of the taconite the use of con-

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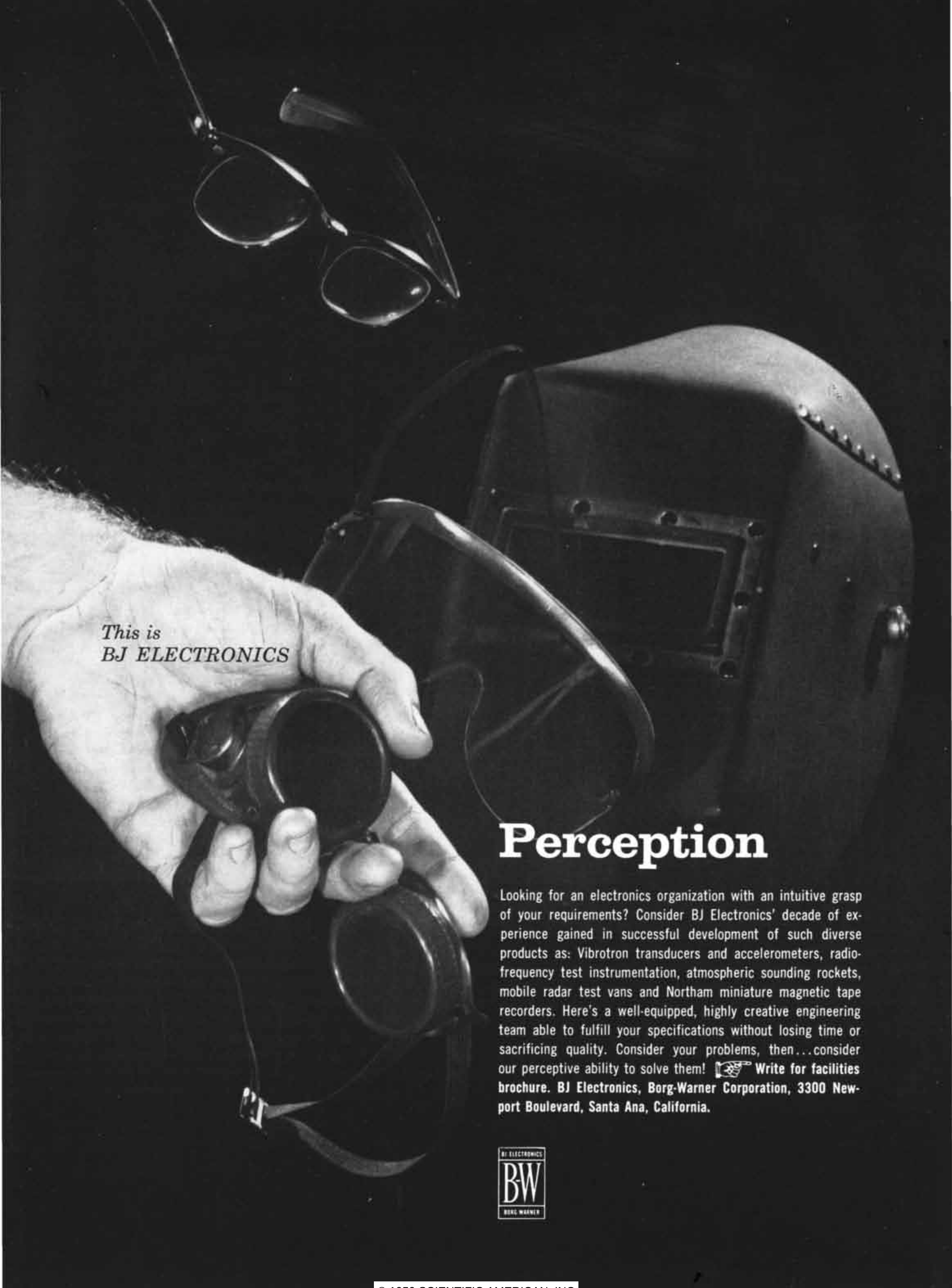
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ventional drilling methods was considered economically impossible.

The Jet-Piercing process makes possible the economical mining of the taconites and other low-grade iron ores, and produces blast holes at speeds of from 12 to 40 feet an hour.

R. B. Aitchison

Linde Company
New York, N. Y.

Sirs:

Mr. Aitchison is correct in saying that the concept and practice of flame drilling first evolved in the U. S. and not in the U.S.S.R. If my article gave another impression, I am sorry. However, I was referring to the use of the flame technique in the drilling of oil wells. Such drilling involves problems of greater magnitude than those encountered in the drilling of blast holes. I know of no published reports on the flame drilling of oil wells in the U. S., though it may very well have been tried.

Sullivan S. Marsden, Jr.

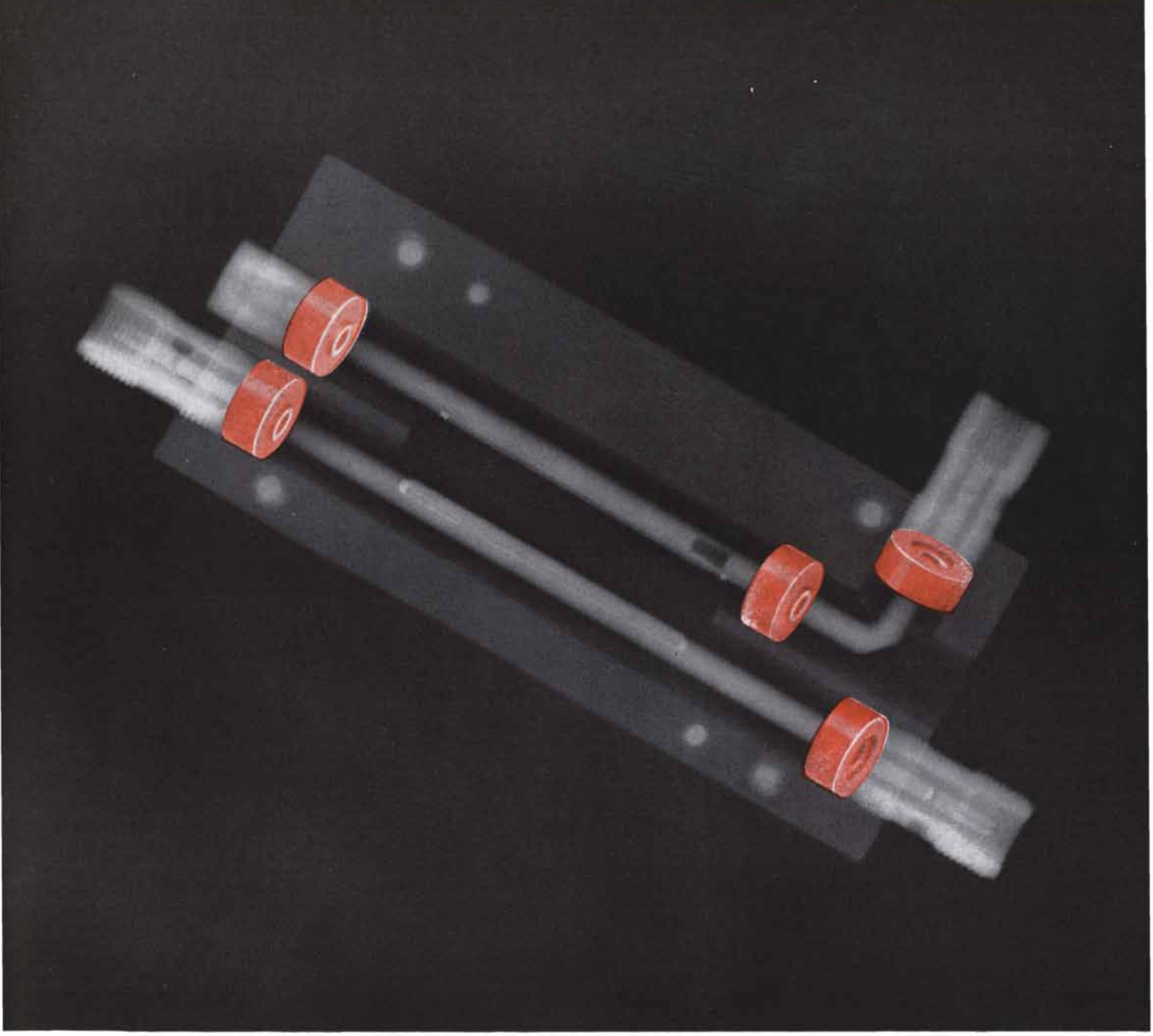
Stanford University
Stanford, Calif.

Sirs:

In your November review of my book, *Computability & Unsolvability*, the discovery of "absolutely unsolvable problems" is attributed to Kurt Gödel and A. M. Turing. Actually unsolvable decision problems first appeared in 1936 in papers by Alonzo Church and by A. M. Turing. Gödel's important discovery, which appeared in print five years earlier, was that for any system of symbolic logic which satisfied a small number of reasonable conditions there would be a proposition about the positive integers whose truth could not be decided *within that logic*. Gödel's propositions are thus "undecidable" only relative to a given logic. The unsolvable decision problems of Church and Turing relate not to a single proposition but to an entire class of propositions. Their result is that there can be no mechanical procedure for determining whether or not a given proposition selected from this class is true or false, and this result is truly "absolute" depending on no initial choice of a system of logic.

Martin Davis

East Windsor Hill, Conn.



Insulators made of TFE-fluorocarbon resins are used in coaxial couplers which sample RF power in radar-jamming equipment. (By Narda Microwave Corporation, Mineola, New York.)

THE INSIDE STORY: parts that help misguide enemy missiles

High above the earth a missile reels in unguided flight—its radar blinded by electronic countermeasures. Insulation of TFE-fluorocarbon resins . . . in components like those shown here, and on wire and cable . . . is often vital to the performance of such instruments of defense, where *reliability* is an absolute necessity.

The insulating spacers shown here must have a low dielectric constant and low dissipation factor over an extreme range of frequencies, including the microwave region. They must withstand severe vibration without cracking. They must not absorb moisture. They must withstand high temperatures . . . and must be unaffected by aging. TEFLON TFE-resins meet all these requirements in many forms of insulation.

TFE resins are important materials not only in advanced military hardware, but also in many industrial applications. They offer the maximum in such characteristics as chemical inertness and low coefficient of friction. The combination of properties found in TFE resins adds up to better performance at a lower total cost. Send for technical data and information on uses and processing. Write to: E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room T-392, Du Pont Building, Wilmington 98, Delaware.

In Canada: Du Pont Company of Canada (1956) Limited, P.O. Box 660, Montreal, Quebec.

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TFE-FLUOROCARBON RESINS

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ANOTHER NEW USE FOR BENDIX POWER STEERING!

The pilot in the picture is looking at a power steering device that differs from the type we make for your car mainly in that it is *electronic* and hydraulic. The quickness of electronics was needed because the airplane is the new Republic F-105 Thunderchief, the Air Force's fastest, most advanced fighter-bomber. It takes off at about 180 mph, flies at nearly twice the speed of sound and

lands at speeds of up to 230 mph! The super sensitive Bendix steering mechanism gives the pilot firm control of the plane on the ground at all times.

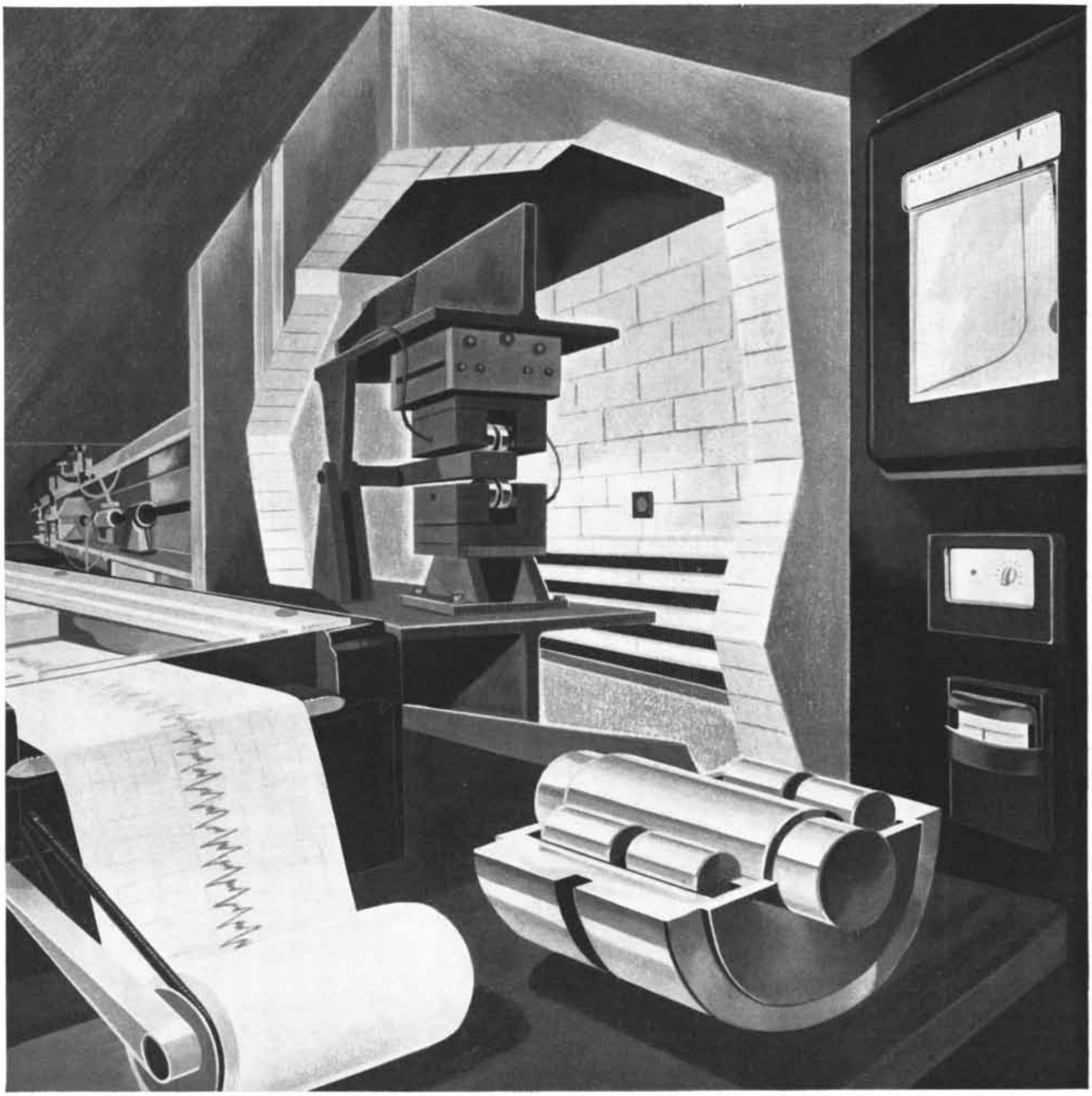
Republic gave Bendix the job of developing something special in this case because we have built power steering systems for practically every type of vehicle on or off the road, in the water or up in the air. Submarines, missiles, aircraft, cars, trucks, buses, tractors

and giant road builders all use Bendix® Power Steering.

People buy it for different reasons. Sometimes they need its brute force most, as in the case of submarines or the awesome B-58 "Hustler", the world's first supersonic heavy bomber; it flies so fast it would be impractical for man to fly without the aid of the revolutionary new Bendix Control System that "thinks" with the pilot. Other times a customer puts top priority on the extreme accuracy of our "power steering" for guiding a missile in flight, for example, or this Republic F-105 airplane on the ground.

If you are not familiar with the pleasing sensation of driving a car with Bendix Power Steering, you ought to make a special point of asking for a demonstration when you inspect the new 1959 models. It makes steering so easy we think you'll buy it if you try it.

A thousand products Bendix AVIATION CORPORATION Fisher Bldg., Detroit 2, Mich. *a million ideas*



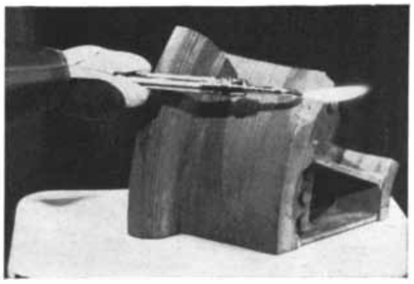
THE FACTS ABOUT MAGNESIUM AND FIRE

There are many misunderstandings about the lightest structural metal... Here are some facts everyone in manufacturing should know.

MAGNESIUM is being used today in many varied applications. Some of these uses involve normal operating temperatures while others involve elevated temperatures ranging from 500° to 700°F. and above. Such items as ladders, luggage, hand trucks, aircraft wheels and skins are all used at temperatures where ignition is improbable. Supersonic jets and missiles, however, rely on magnesium alloys for dependable performance at the elevated temperatures previously mentioned.

Yet some designers, engineers and production men hesitate to work with magnesium because they have heard that it "burns." What are the facts about this highly useful metal?

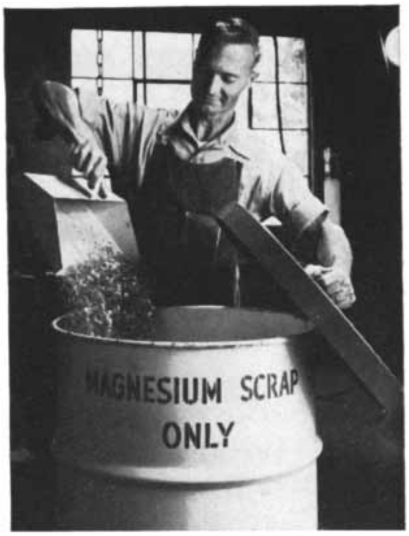
The National Fire Protection Association discusses the combustibility of magnesium as follows: "The ease of ignition of magnesium depends to a large extent upon the size and shape of the material as well as the size or intensity of the source of ignition. In the form of ribbon, shavings, or chips with thin feather-like edges, or grinding dust, a spark or the flame of a match may be sufficient to start the material burning. Heavier pieces such as ingots and thick wall castings are difficult to ignite because heat is conducted rapidly away from the source of ignition. If the entire piece of metal can be raised to the ignition temperature (about 1200°F. for pure magnesium and many of the alloys) self-sustained burning will occur."*



AN ACETYLENE TORCH fails to sustain ignition of this magnesium casting, even after prolonged contact. Heat is conducted rapidly away from the point of application.

Hundreds of foundries and metal-working fabricators work with magnesium every day. Because these firms know how to handle the metal, the incidence of fires attributed to magnesium is very small.

It is important that proper machine shop practices and rules of good housekeeping be followed. Correctly ground tools will decrease tool pressure and friction on the work, preventing temperatures high enough to reach the ignition point of the chips and turnings. A shower of hot sparks from the grinding of a steel tool bit could ignite dust left from the previous grinding of a magnesium part, but magnesium will not ignite spontaneously.



GOOD HOUSEKEEPING, proper machine shop practices keep risk of fire to a minimum.

Once ignited, a fire in magnesium can be extinguished effectively by sprinkling on a layer of a graphite base powder such as G-1. Various other proprietary powders are also available. Water, or any of the liquid, gas, or foam type extinguishers should not be used. They tend to react with the burning metal and accelerate the fire. With the correct basic knowledge and proper attention to safety precautions, anyone can handle magnesium in the shop with negligible risk.

DIRECT CONTACT with an open flame will not ignite magnesium alloy in this application. Magnesium griddles for cooking have been in use for many years.

* *Source: Chapter One (N.F.P.A.), Bulletin No. 48, STANDARDS FOR MAGNESIUM. This bulletin available on request without cost or obligation.*

FOR FURTHER DETAILS on safe handling of magnesium, contact your nearest Dow Sales Office or write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Department 1482-EQ2.

YOU CAN DEPEND ON DOW

50 AND 100 YEARS AGO

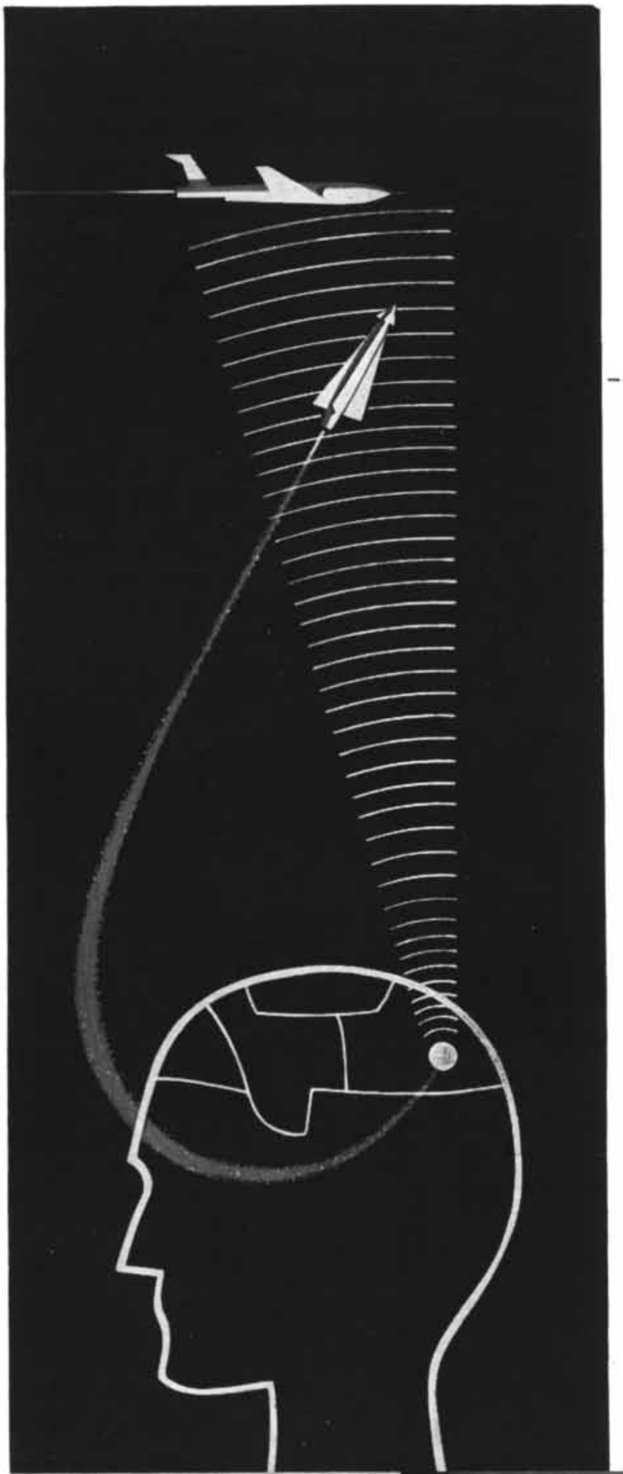
SCIENTIFIC AMERICAN

FEBRUARY, 1909: "The popular subscription for Count Von Zeppelin, the inventor of the huge German airship, was closed on December 24th after a total amount of over $1,500,000 had been raised. Since acquiring the remodeled third airship of the Count, the German Government has decided to order four new aircraft of this type for naval use. In contrast to Germany's forward-looking policy, the U. S. House of Representatives has just rejected a bill for the appropriation of $500,000 for the purchase of balloons and aeroplanes for military purposes."

"Capt. Roald Amundsen's polar expedition is now assured, for the Norwegian Storthing has voted him a subsidy of $18,000, necessary for the outfitting of Nansen's famous ship, the *Fram*."

"As a result of a lecture delivered by Sir Frederick Treves, the eminent British surgeon, in which he illustrated some practical curative results attained by the use of radium, a British Radium Institute has been founded for carrying out research operations in connection with the application of radium to surgery. In the course of his lecture Sir Frederick stated that radium can cure every form of naevus; will eradicate the terrible port-wine stain, which is probably one of the greatest disfigurements with which one can be afflicted; and will rid the patient of the pigmented mole and hairy mole."

"From Thomas A. Edison's works at Orange, N.J., have come upward of 1,310,000 phonographs during the past 20 years, with and for which there have been made and sold no less than 97,845,000 records of a musical or other character. In connection with these figures it is interesting to recall that when the first operative machine was produced, Mr. Edison packed up the instrument and came to the office of SCIENTIFIC AMERICAN. Without ceremony he placed the machine on the Editor's desk and turned the crank. The machine liter-



From Bell Telephone Laboratories...

Brainpower
for the brawny
Nike-Hercules

The Army's newest surface-to-air guided missile—the lethal Nike-Hercules—is now operational. Because it is, no unfriendly plane will be able to fly sufficiently high, fast or evasively to escape a fatal rendezvous with it.

For Hercules has a "brain"—an intellect that makes it a prodigy among today's electronic robots. Bell Telephone Laboratories developed it. Western Electric (prime contractor for the entire missile system) is producing it. Douglas Aircraft Company is giving it its body.

This "brain" is a fully integrated guidance system, almost entirely land-based. Only the vital signal-receiving apparatus is expendable within the missile itself. Other highly practical features: it defies "jamming," is completely mobile, is designed in separate "building block" units which are replaceable in seconds—and is deadly accurate.

Bell Labs scientists and engineers designed the world's largest and most intricate telephone communications network for the Bell System. They developed about half of the Armed Forces' radar equipment during World War II. And they pioneered the nation's *first* successful air defense guided missile system—Nike-Ajax.

They were eminently qualified to give Hercules the brainpower it needed.

BELL TELEPHONE LABORATORIES
World center of communications research and development

Vigilant acquisition radar for Nike-Hercules first detects approach of distant aircraft, pinpoints its location and instantly signals to battery control.

Two tracking-radar antennas, housed in radomes, take over. One feeds target azimuth, elevation, range data to computers; other tracks Hercules.

Two sets of radar data are electronically computed and plotted. Hercules is "steered" by radio signals, then detonated at precise point of interception.

ally spoke for itself. 'Good morning,' it said. 'How do you do?' And thus the Editors of SCIENTIFIC AMERICAN constituted the first public audience that ever listened to the phonograph."

"Monochromatic photographs of the sun have been made daily on Mt. Wilson since October, 1905, with the Snow telescope and the five-foot spectroheliograph. These record the phenomena of a region in the solar atmosphere higher than that previously explored, and reveal the existence of extensive vortices or cyclonic storms associated with sunspots. There can now be little doubt that what we see in the telescope as a sunspot is the mass of vapor, cooled somewhat below the temperature of the photosphere, which lies at the center of an invisible vortex. Tests made with the 30-foot spectrograph of the tower telescope show all the characteristic phenomena of the Zeeman effect in the spot spectrum, and indicate that a magnetic field is produced by the revolution of negative corpuscles in the vortices."

"For the purpose of making systematic surveys to determine the magnetic conditions on all the deep seas of the world, the Carnegie Institution is having constructed a magnetic survey vessel, designed by Henry J. Gielow, author of some of our must successful racing yachts. She will have full sail power, with a brigantine rig capable of carrying about 12,900 feet of plain sail. In order to render her practically nonmagnetic, all-metal deck fittings and metalwork on spars and rigging will be of bronze, copper and gun metal. Except for the thin, cast-iron cylinder liners and the steel cams for the valves, the engine is constructed entirely of bronze. The shaft will be of Tobin bronze and the propeller and feathering gear of manganese bronze."

"Oxybenzyl-methylenglycol-anhydride is the chemical name of a coal-tar product which is being used as an insulator. However, it goes by a trade name of bakelite after the inventor, Dr. L. H. Baekeland. It is stronger than hard rubber, withstands a higher temperature, and is unaffected by most chemicals."

"According to a consular report, Sir Oliver Lodge has recently demonstrated the efficiency of his fog-clearing apparatus in Liverpool. He succeeded in clearing a thick fog over a radius of 60 feet. The Lodge system consists in discharging electricity at high voltage from

sophisticated mission training

THE F-105-D FLIGHT SIMULATOR— BEING HUMAN ENGINEERED, DESIGNED AND BUILT BY ERCO PROVIDES COMPLETE, RELIABLE, EFFECTIVE TRAINING FOR THE ENTIRE MISSION PROFILE OF THE LATEST AIR FORCE ADVERSE WEATHER AIRCRAFT.

FEATURES:

Automatic Self-Checking System (aural-optical) provides component failure indication by general area and exact location. The simulator is operative in a matter of minutes.

Reliability—in excess of 95% utilization.

Human Engineering—complete environmental realism.

Man-Machine Task Analysis Design—maximum learning transfer for both operator and instructor.

Erco's manpower—facilities—capabilities and mission training experience help the Air Force "to fill the suit..to man the plane."

WRITE FOR ILLUSTRATED F-105-D MISSION TRAINING BROCHURE.

ERCO TRAINING—TO FILL THE SUIT ..TO MAN THE PLANE

ERCO

NUCLEAR PRODUCTS – ERCO, DIVISION OF
acf INDUSTRIES, INC., RIVERDALE, MARYLAND

AMERICAN CAR AND FOUNDRY • ADVANCED PRODUCTS • AVION • CARTER CARBURETOR • SHIPPERS CAR LINE • W-K-M a series of disks, with the result that the fog is condensed and falls to the ground. The apparatus will soon be tested in London."

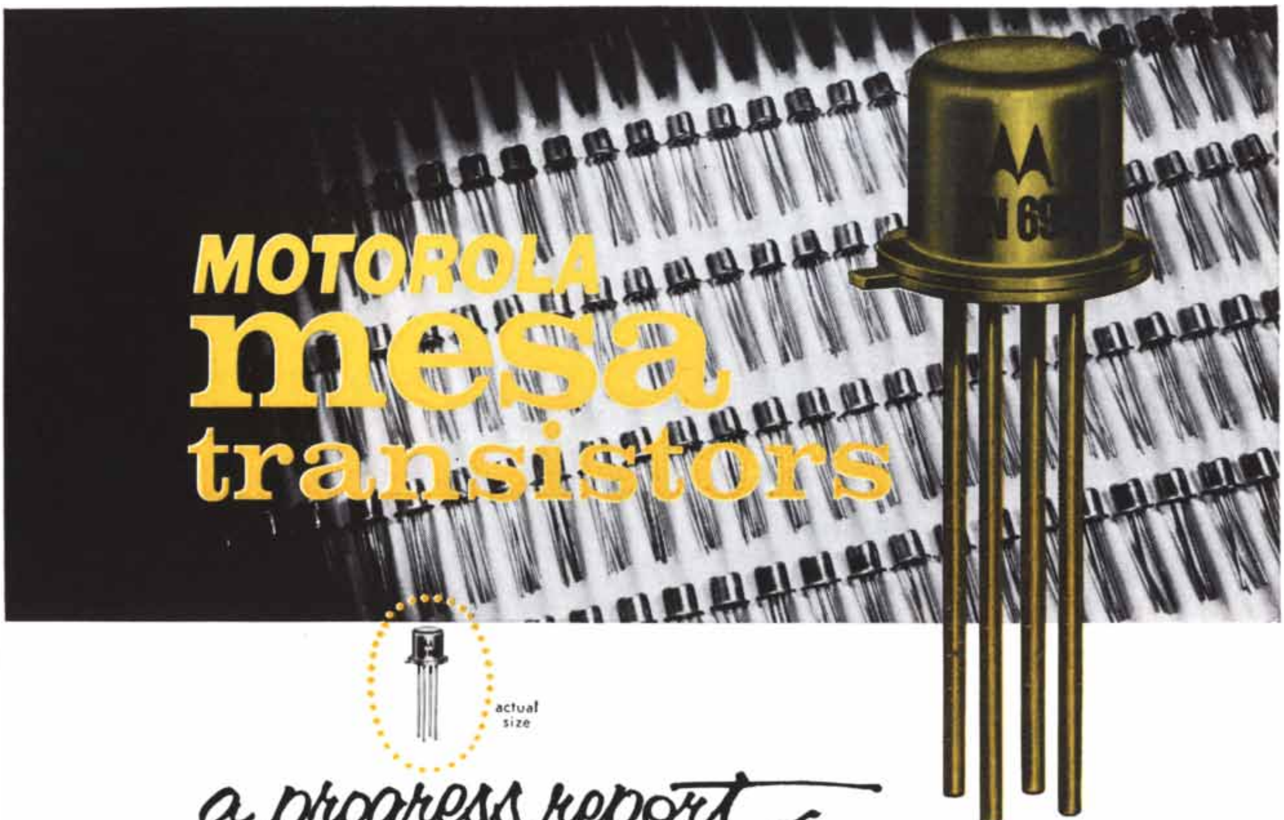
"The referee board of Consulting Scientific Experts appointed by President Roosevelt to pass finally upon the pure food decisions of Dr. Harvey W. Wiley, Chief Chemist of the Department of Agriculture, has reversed the findings of Dr. Wiley, and given it as their opinion that benzoate of soda is not harmful to health. Among the signers of the report are President Ira Remsen of the Johns Hopkins University, and Russell H. Chittenden, director of the Sheffield Scientific School of Yale University."

SCIENTIFIC AMERICAN

FEBRUARY, 1859: "M. Groux, the man with the thoracic cavity which admits of an inspection of the internal mechanism, has had an electro-magnetic machine made which, applied through the orifice, tinkles a bell with every pulsation of the heart. The machine was made by Mr. Farmer, of the Alarm Telegraph office. Recent experiments were made in connection with the exact and delicate apparatus in the Observatory at Cambridge, Mass. The operating forces were divided, one portion taking their post at the Observatory, the other in Boston. The principal agent, Mr. Groux himself, being in Boston, the heart's impulses were transmitted over the electric wires, and instantaneously recorded at the Observatory."

"The distinguished inventor of the stereoscope and of the first telegraph erected in England, Professor Wheatstone of London, has just secured a patent for a recording telegraph whose object is to use the positive and negative currents alternately, so as to obviate some of the evils of induction that prevent the rapid transmission of messages. He uses a perforated strip of paper to receive the records. This strip is placed in connection with a rheomotor (or source of electric power) which, on being set in motion, causes it to move along and act on two pins in such a manner that, when one of them is elevated, the current is transmitted in the opposite direction. The apparatus is quite complicated."

"It is really wonderful to witness the progress which some inventions have



a progress report

BY DR. C. LESTER HOGAN / *General Manager*

The first two Motorola Mesa transistors, the 2N695 switch (with a rise time less than 3 mμsec) and the 2N700 (a 200 mc amplifier), were announced in August, 1958. Our pilot line facility at that time had a capacity to produce several hundred devices per day and our plans were to move into full scale production during the first few months of 1959. We expected this capacity to be able to meet any possible demand which our customers might place on us. However, the reception of these devices surpassed all expectations and requests for samples far exceeded our pilot production. Naturally, we have been very happy with the response, but our main concern has been the integrity of our product, and we have steadfastly refused to proceed with expanded production until we satisfied ourselves that each new process would yield the extremely high quality and reliability which we intend to be synonymous with the name Motorola Mesa.

As many of you already know, the two Motorola Mesa transistors now available are unusual devices. The active region of these transistors covers an area less than that of a human hair. Yet they are manufactured by methods so precise that they do not need to be selected, as are most transistors today, but are made within extremely close tolerances to the electrical and mechanical characteristics desired. The elements which are used in their fabrication have been carefully selected so that each and every transistor can be baked out under high vacuum at 300°C before being hermetically sealed.

This is just one of the extra steps we at Motorola are taking to insure the integrity and reliability of these devices. The size of the transistor, the ultra-precise methods which we use in its fabrication, and the basic design of the Motorola Mesa itself all combine to give you the most reliable transistor the industry has yet seen. There is no doubt in our minds that the Mesa is "the" transistor of the future.

With this conviction guiding us we have been putting great emphasis on production tooling for Motorola Mesas and within a few weeks we shall swing into large scale manufacture of the Mesa transistor. At that time, we shall be in a position to accept production orders for these transistors of the future.

Even with this emphasis on production, basic research and development has not been neglected. Motorola's development team has expanded its study of the Mesas. Extensions of the design to higher power and higher frequency are ready for introduction in the very near future. Before long, we shall have a whole family of Motorola Mesas with the same integrity and reliability of these first two devices . . . a family of devices that will open up entirely new areas of transistor application.

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"DEPENDABLE QUALITY-IN QUANTITY"

MOTOROLA SEMICONDUCTORS

MOTOROLA INC., 5005 E. McDOWELL, PHOENIX, ARIZONA made, in spite of the most bitter and powerful opposition. This has been the case with gas-lighting in the city of Philadelphia. The Philadelphia *Ledger* publishes a document or remonstrance, made in 1833 by a large number of the most wealthy and distinguished citizens, against lighting the city with gas. The keenest satire which can be published on the light which then shone upon the minds of such petitioners is that one of them, Mr. John C. Cresson, is now chief engineer of the city gas works."

"Dr. Bocker, of Bonn on the Rhine, so well known for his experiments on the digestion of articles of food and aliment, has by experiment discovered that sarsaparilla has none of those wondrous purifying properties usually attributed to it, and that it is a useless and expensive hospital drug. This but confirms the opinion which has been previously expressed through our columns."

"S. K. Basset, of Galesburgh, Ill., has invented a new steam plow, in which the wheels of the track of a traction steam-engine are so arranged that the track may be readily guided and turned, and the engine rendered available for drawing a gang of plows to turn over the earth in the usual way."

"There is not an establishment in this country where stitching of any kind is required in which the sewing machine is not now employed, and there are few private families in which it is not an acknowledged article of furniture. Messrs. Wheeler & Wilson made and sold during the last three months 4,700 machines, and are now producing and selling 100 per day. Messrs. Grover & Baker manufactured and sold in 1858 14,000 sewing machines. Messrs. I. M. Singer & Co. produce and sell about 350 machines weekly. Messrs. Singer & Co., taking advantage of the fact that Howe's English patent (now owned by Thomas, of London) does not cover Scotland and Ireland, have a branch establishment in Glasgow, and in the last year they sold machines in that city to about the amount of 25,000 pounds, thus proving that in the old country, wherever 'Yankee Doodle' (as we are familiarly called) has a chance, he can make money and give value received."

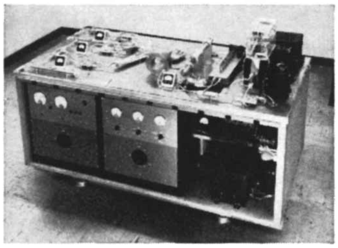
"M. Berthelot, of Paris, has succeeded in transforming marsh gas—a compound of carbon and hydrogen—into ether and alcohol, and he thinks that all the hydrocarbons may be made to produce vinous spirit by the same process."

third in a series

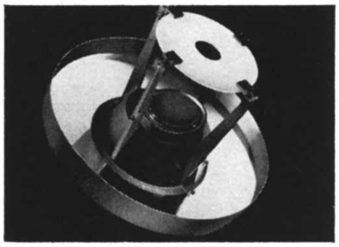
THE DIVISIONS OF THOMPSON RAMO WOOLDRIDGE INC.

RAMO-WOOLDRIDGE

The completely transistorized RW-30 airborne digital computer has a volume of 4.19 cu. ft. and weighs only 203 lbs., including power supply



Ramo-Wooldridge is responsible for advanced electronic sub-systems development for application with both current and projected missile programs



Important infrared "search and track" equipment is now being developed by Ramo-Wooldridge for applications in modern U.S. Military aircraft

R-W is one of the major participants working with the Boeing Airplane Co. Systems Management Office on the U.S. Air Force Dyna-Soar project

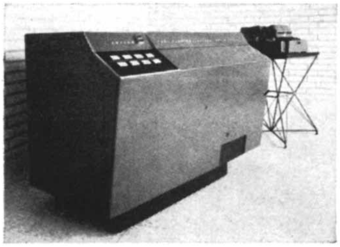
New type of radar data processing system developed by R-W materially increases the capabilities of ground defense radar

While it is now a division of **Thompson Ramo Wooldridge Inc.** instead of a separate corporation, **Ramo-Wooldridge** remains an integrated organization for research, development, and manufacture of electronic systems for military and commercial applications. R-W's military work is covered by thirty-four contracts with the Army, Navy, Air Force, and other government and industrial organizations. These support a broad technical and—in some cases—manufacturing program in such varied fields as Electronic Reconnaissance and Countermeasures; Microwave Techniques; Infrared; Analog and Digital Computers; Air Navigation and Traffic Control; Antisubmarine Warfare; Electronic Language Translation; and advanced Radio and Wireline Communication.

In the commercial field, the well-known RW-300 industrial process control computer and associated equipment—the basis of the expanding business that **The Thompson-Ramo-Wooldridge Products Company** is doing with process industries—was developed and is manufactured by the Ramo-Wooldridge division.

Men, machines, and manufacturing know-how from other TRW divisions will be added as needed to build up the growing production strength of the Ramo-Wooldridge division. In other ways, too, the availability of the special skills and facilities of the rest of the corporate family will broaden the services R-W can offer to its customers. However, R-W's major systems work will continue to be done in an organizational framework that brings the engineering and manufacturing groups into close-knit project teams in the division's own integrated development and manufacturing facilities in both Los Angeles and Denver.

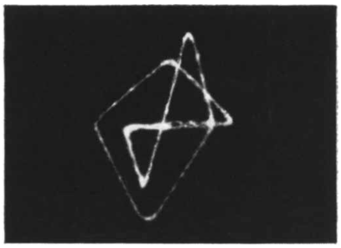
Ramo-Wooldridge is production-oriented in the sense that its end objective is the manufacture and sale of equipment. However, because of the highly technical nature of its product lines, the R-W division will continue to give unusual emphasis to maintaining a high degree of professional scientific and engineering competence.



The RW-300 digital control computer has broad applications in automatic process control, data reduction and test facility operation

Systems are being developed for the ground processing and interpretation of photographic and other data collected by aerial reconnaissance devices

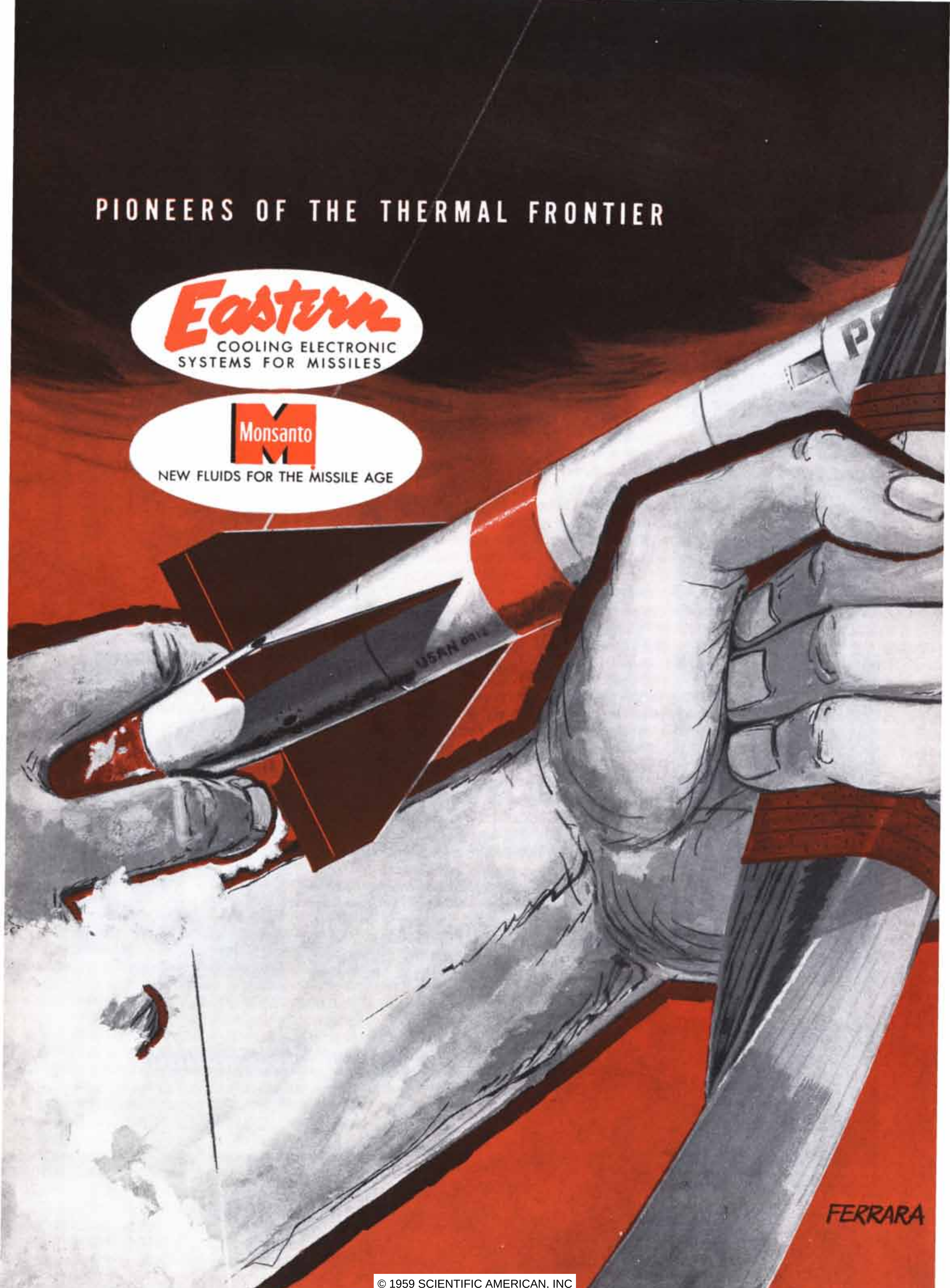
The Military and Ramo-Wooldridge are studying the use of automatic data processing techniques



In research laboratory studies at Ramo-Wooldridge, electrically-charged particles are contained and supported in a vacuum by an alternating electric field

TRW **Thompson Ramo Wooldridge Inc.**

MAIN OFFICES
CLEVELAND 17, OHIO
LOS ANGELES 45, CALIFORNIA


PIONEERS OF THE THERMAL FRONTIER
Eastern
COOLING ELECTRONIC SYSTEMS FOR MISSILES
Monsanto
NEW FLUIDS FOR THE MISSILE AGE
USAF
FERRARA

MISSILE PERFORMANCE *Boost*

with more compact, lightweight hydraulic components, cooling and refrigeration units

Smaller components pay off in higher performance . . . savings in inches and ounces add up to hundreds of additional miles per hour — or miles in range.

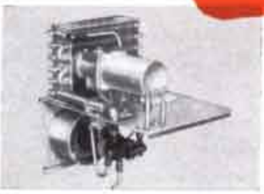
Eastern Industries' missile components and systems are miniaturized to meet the most rigorous requirements in space and weight. Through the use of Monsanto *Coolanol* 45* and miniaturization concepts, Eastern now makes it possible to design more power, more performance into less and less volume and weight.

Avionic Cooling with Coolanol 45: This Monsanto-produced fluid is the answer to heat problems associated with miniaturized electronics . . . extends operations to altitudes where air cooling is impractical. Having a high boiling point, *Coolanol* 45 permits "hotter," smaller systems than with water cooling; low foaming tendency guards against circulation troubles. Heat transfer characteristics and dielectric properties of *Coolanol* 45 are excellent over its —65° to 400°F. temperature range.

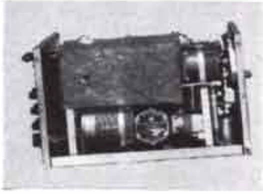
Hydraulic Pumps and Coolanol 45: Eastern puts *Coolanol* 45 to double use—as a hydraulic fluid as well as a coolant. The higher pump speeds possible (up to 24,000 rpm) mean more efficiency, result in smaller units for any given job . . . and prolonged pump life is the result of the fluid's excellent lubricity.

For deep forays into the thermal thicket — for problems in system redesign or miniaturization — for imaginative solutions — turn to Eastern Industries.

**Coolanol:* Monsanto Trademark.



HIGHER . . . Eastern electronic tube cooling units and systems permit avionic operation at altitudes which rule out air cooling. The cooling pack shown easily handles 1000 watts at altitudes to 60,000 ft.

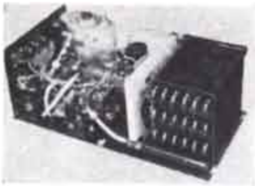


FASTER . . . sustained supersonic speeds will call for advanced refrigeration-type cooling units for temperature control within close limits. This system, which relies on Coolanol 45, protects entire electronic systems.

FARTHER . . . miniaturized pump space and weight—extends missile range. This unit, an integral part of an APU system, helps provide hydraulic power to a cruise missile.

SMALLER . . . high operating speeds of this Eastern hydraulic power unit (to 24,000 rpm) results in modest dimensions and weight: 7¾" x 2½" x 7½", 4 pounds, 12 ounces.

LONGER . . . long life and reliability is typified in this Eastern high pressure hydraulic pump. Reliable performance under extreme environmental conditions is an Eastern tradition.



HOTTER . . . this unit protects electronic components of high performance aircraft from heat — delivers Monsanto Coolanol 45 coolant at 1.3 gpm flow rate and 60 psi pressure.

COOLER . . . much cooler electronic equipment, and new performance concepts — this is the promise of Coolanol 45. For the characteristics and applications of this new Monsanto product, write for Monsanto Technical Bulletin Number AV-3.

MORE . . . much more information on these and other accessories and systems is contained in this new complete brochure. It contains latest developments in hydraulic power, cooling and pressurization. Send for your free copy of Bulletin 360 today.

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Eastern AVIATION PRODUCTS

EASTERN INDUSTRIES, INC.
100 Skiff Street
Hamden 14, Conn.

THE AUTHORS

JAMES F. SCHUMAR ("Reactor Fuel Elements") directs metallurgical engineering at the Argonne National Laboratory. His department there developed the fuel and other core components used in the Argonne's first and second experimental breeder reactors, the Argonne-duPont reactor, the Experimental Boiling Water Reactor (EBWR), the "Borax" reactors and the reactor that powers the U. S. Navy's first nuclear submarine, the *Nautilus*. Schumar came in on the ground floor of nuclear-fuel engineering. Upon graduating from Case Institute of Technology in 1939 he joined the Wolverine Tube Division of Calumet & Hecla, Inc., and there, three years later, he was put to work extruding a "special metal" (uranium) for the Manhattan Engineer District. After World War II Schumar joined the Metallurgical Laboratory at the University of Chicago, assisting in its transformation in 1946 into the Argonne National Laboratory.

SUSANN and ORLIN BIDDULPH ("The Circulatory System of Plants") are a husband-and-wife team of plant physiologists. Orlin Biddulph, a Utahan, graduated from Brigham Young University. He received a University of Chicago Ph.D. in 1934, whereupon he became head of the department of botany at the University of South Dakota. Since 1937 he has taught botany at the State College of Washington, where he holds the rank of professor. Biddulph was one of the first workers to use radioactive tracers to study the translocation of nutrients in plants. The earliest tracers were substances foreign to plants, such as lead. But by 1938 Biddulph was employing the first radioactive phosphorus made by the University of California cyclotron. Mrs. Biddulph, a taxonomist until converted to plant physiology by her husband, studied at Oklahoma State University and has a Ph.D. from the State College of Washington (she was a researcher there until a few years ago, when she ran afoul of the state nepotism laws).

HERMAN A. WITKIN ("The Perception of the Upright") pursued his undergraduate career at Cornell University and New York University, where in his senior year a course on animal behavior taught by T. C. Schneirla, the noted authority on ants, caused him to

abandon biology in favor of psychology. Witkin became a graduate student of Schneirla's, receiving his Ph.D. in 1939; after a further year of research at Swarthmore College under Wolfgang Kohler, he joined the staff of Brooklyn College, where he worked until 1952. Witkin's research at Brooklyn College was backed by grants from the National Research Council during World War II. Later he undertook a project on personality factors in perception for the Office of Naval Research and more recently for the National Institute of Mental Health. Witkin now continues his work on perception-cum-personality at the State University of New York Downstate Medical Center, where he is professor in the Department of Psychiatry and director of the psychology laboratory. He is a co-author of the book *Personality through Perception.*

LOREN C. EISELEY ("Alfred Russel Wallace") has published a number of articles in SCIENTIFIC AMERICAN; his present contribution complements his biographical account of Wallace's great contemporary Charles Darwin, which appeared in the February, 1956, issue of this magazine. Eiseley, an authority on early man, heads the anthropology department of the University of Pennsylvania. His interest in human evolution is but part of a concern for evolution as a whole. Eiseley's books, well known as models of popular exposition, include *Immense Journey* and the recent *Darwin's Century.*

JOSEPH L. MELNICK ("Enteroviruses") graduated from Wesleyan University in 1936, then commenced a 21-year career at Yale University. There he acquired a Ph.D. in biochemistry, held a National Research Council fellowship and taught preventive medicine, microbiology and epidemiology. Melnick is a well-known authority on poliomyelitis. In 1957 he resigned his Yale professorship to become chief of the Virus Laboratories at the National Institutes of Health. He has since returned to academic life as professor of virology and epidemiology at the Baylor University College of Medicine in Houston, Tex.

V. B. WIGGLESWORTH ("Metamorphosis, Polymorphism, Differentiation") has been called "the man who has perhaps done most to initiate the study of insect physiology." He has been an avid insect collector since he was five. After attending the Repton School (his two successive headmasters both became

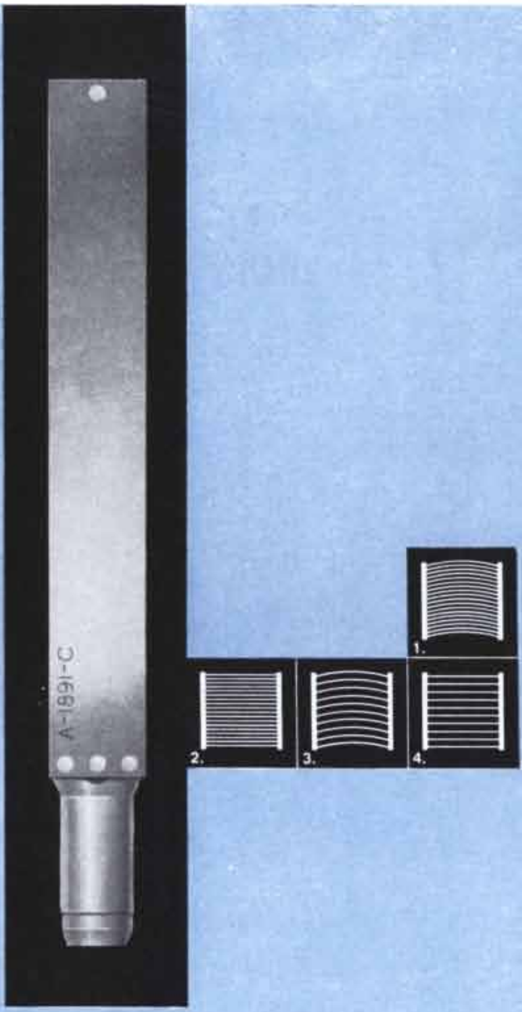
Archbishops of Canterbury), he entered Gonville and Caius College at the University of Cambridge, intending to follow in his father's footsteps as a physician; he then had no idea that entomology could be a full-scale scientific career. After studying at Cambridge under Frederick Gowland Hopkins, he received medical training at St. Thomas' Hospital. Wigglesworth was on the point of qualifying as a physician when an unexpected appointment made him lecturer in medical entomology at the newly reorganized London School of Hygiene and Tropical Medicine. There followed extensive researches in West Africa, India, Burma, Malaya, Java and Ceylon. Wigglesworth is the discoverer of the juvenile hormone of insects. He has published three standard volumes on insect physiology and metamorphosis. Since 1942 he has been director of Britain's Agricultural Research Council Unit of Insect Physiology, and he is now also Quick Professor of Biology at the University of Cambridge.

BRUCE CHALMERS ("How Water Freezes") is Gordon McKay Professor of Metallurgy at Harvard University. A Londoner, he received his training at the University of London and taught physics and mathematics there for several years. During and after World War II he headed the metallurgy departments of the Royal Aircraft Establishments and of the Atomic Energy Research Establishment at Harwell. "One of my main research interests," he says, "has been the solidification of metals and alloys—many aspects of which, I found, could more readily be studied in a transparent medium such as water. This led me to the study of ice crystals, which I still carry on in parallel with studies of metals."

ROBERT A. HALL, JR. ("Pidgin Languages") is professor of linguistics at Cornell University. A specialist on the structure of Romance languages, he graduated from Princeton University in 1931 and later acquired the degree of Dottore in Lettere from the University of Rome. At the outbreak of World War II Hall, then teaching at Brown University, undertook to prepare a textbook of Melanesian Pidgin English for the use of U. S. troops who were subsequently to land in New Guinea and the Solomon Islands; in the course of this work, he taught pidgin to armed services personnel in training programs at Columbia and Yale universities. Since then Hall has studied and prepared scientific descriptions of Chinese Pidgin English, Haitian Creole and Taki-Taki.

ANOTHER SYLCOR "FIRST"

STANDARD FUEL ELEMENTS!



You can now design your research reactor to be fueled with one of four standard SYLCOR Fuel Elements.

The SYLCOR Standard Fuel Element plan will result in substantial reduction in over-all fuel element design and manufacturing costs.

SYLCOR Standard Fuel Elements eliminate the cost of custom design, special drafting and engineering, estimating time, special tooling and testing . . . and will permit us to stock and deliver fuel elements "off the shelf". Standard control elements compatible with standard fuel elements will also be available.

If you are planning a research reactor we suggest you write now for data sheets on SYLCOR Standard Fuel Elements, including standard grid plate orifice designs.

SYLCOR will, of course, continue to produce custom fuel elements to specific designs where your needs are of a special nature.

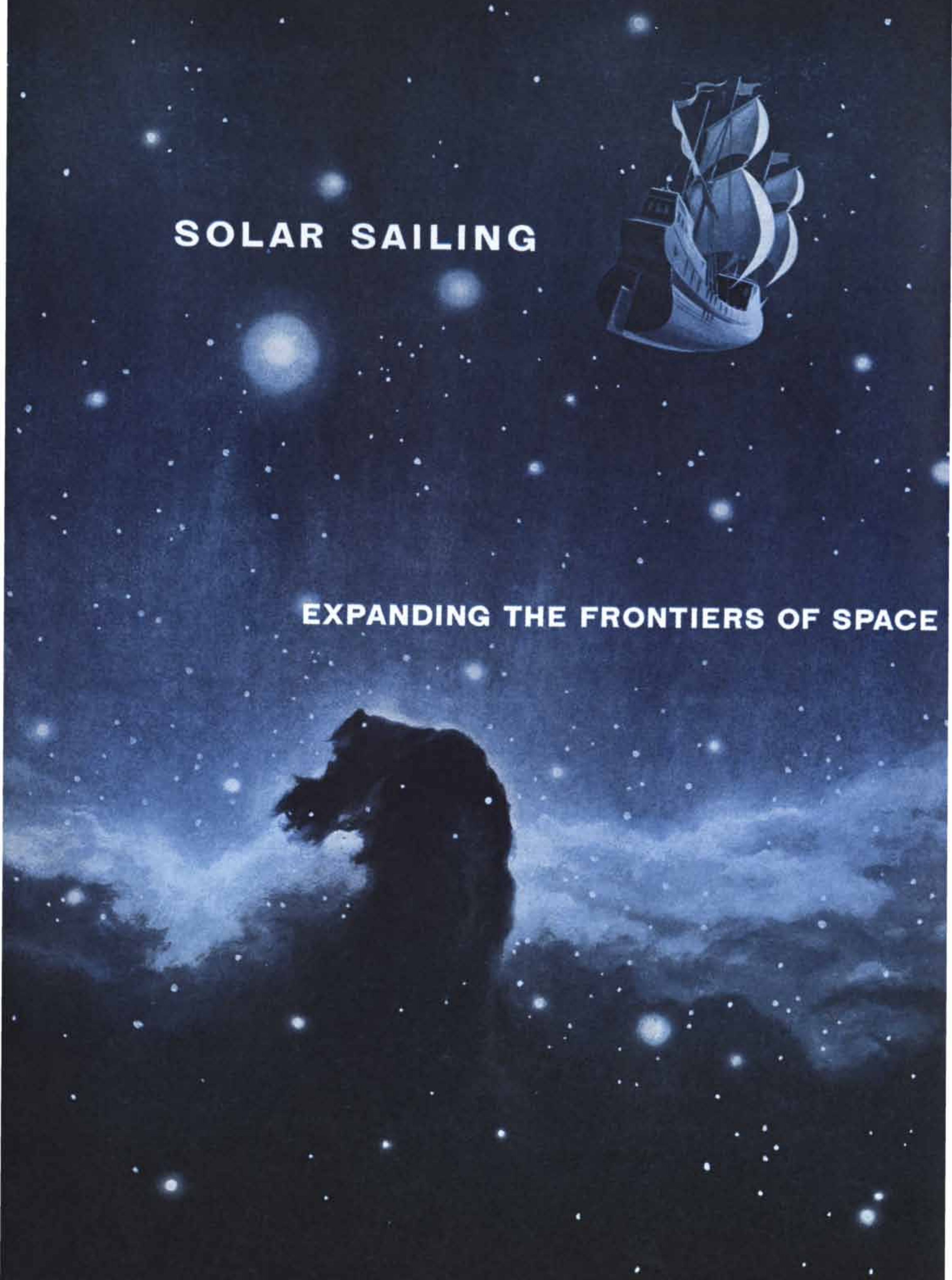
Brief Description of SYLCOR's 4 Standard Fuel Elements

1. SYLCOR A-1891-C: 18 curved plates of 90% enriched uranium. Total loading per element: 196 gms. of U^{235}
2. SYLCOR A-1891-F: 18 flat plates of 90% enriched uranium. Total loading per element: 196 gms. of U^{235}
3. SYLCOR A-1091-C: 10 curved plates of 90% enriched uranium. Total loading per element: 165 gms. of U^{235}
4. SYLCOR A-1091-F: 10 flat plates of 90% enriched uranium. Total loading per element: 165 gms. of U^{235}

Send now for Data Sheets on SYLCOR Standard Fuel Elements. Write to Sylvania-Corning Nuclear Corp., Bayside, N. Y.

SYLCOR

SYLVANIA-CORNING NUCLEAR CORP.


SOLAR SAILING
EXPANDING THE FRONTIERS OF SPACE

TECHNOLOGY

SOLAR SAILING: Space travel with the aid of solar radiation pressure — an area of advanced research at Lockheed. Vehicle would employ a sail that would be raised and lowered in flight. The artist has depicted Magellan's ship "Trinidad" to symbolize man's great voyages of discovery.

Lockheed Missile Systems Division is engaged in all fields of missile and space technology — from concept to operation. Advanced research and development programs include — manned space; space communications; electronics; ionic propulsion; nuclear and solar propulsion; magnetohydrodynamics; computer development; oceanography; flight sciences; materials and processes; human engineering; electromagnetic wave propagation and radiation; and operations research and analysis.

The successful completion of programs such as these not only encompasses the sum of man's knowledge in many fields, but requires a bold and imaginative approach in areas where only theory now exists.

The Missile Systems Division programs reach far into the future. It is a rewarding future which men of outstanding talent and inquiring mind are invited to share. Write: Research and Development Staff, Dept. B-36, 962 W. El Camino Real, Sunnyvale, California, or 7701 Woodley Avenue, Van Nuys, California. For the convenience of those living in the East or Midwest, offices are maintained at Suite 745, 405 Lexington Avenue, New York 17, and at Suite 300, 840 N. Michigan Avenue, Chicago 11.

"The organization that contributed most in the past year to the advancement of the art of missiles and astronautics."

NATIONAL MISSILE INDUSTRY CONFERENCE AWARD

Lockheed / MISSILE SYSTEMS DIVISION

SUNNYVALE, PALO ALTO, VAN NUYS, SANTA CRUZ, SANTA MARIA, CALIFORNIA
CAPE CANAVERAL, FLORIDA · ALAMOGORDO, NEW MEXICO

akimoto

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Designed for acquiring data in the energy region of one-thousand to a million-volt neutrons—a region exceedingly difficult to measure—these neutron detectors have been used for studies of both practical and theoretical interest. By determining how many neutrons scatter in what directions, they impart valuable information on the interaction between neutron and nucleus, and on the nucleus itself—and help us predict how a reactor will behave, and how effective its shielding will be. A large fraction (20%) of the scattered neutrons that enter the detectors are measured by neutron counters after they have been slowed down by oil. The massive construction is required to shield against stray neutrons. It is so effective that there are almost no background counts except for the ones produced by neutrons that are scattered by the air in the region within one foot of the scattering sample.

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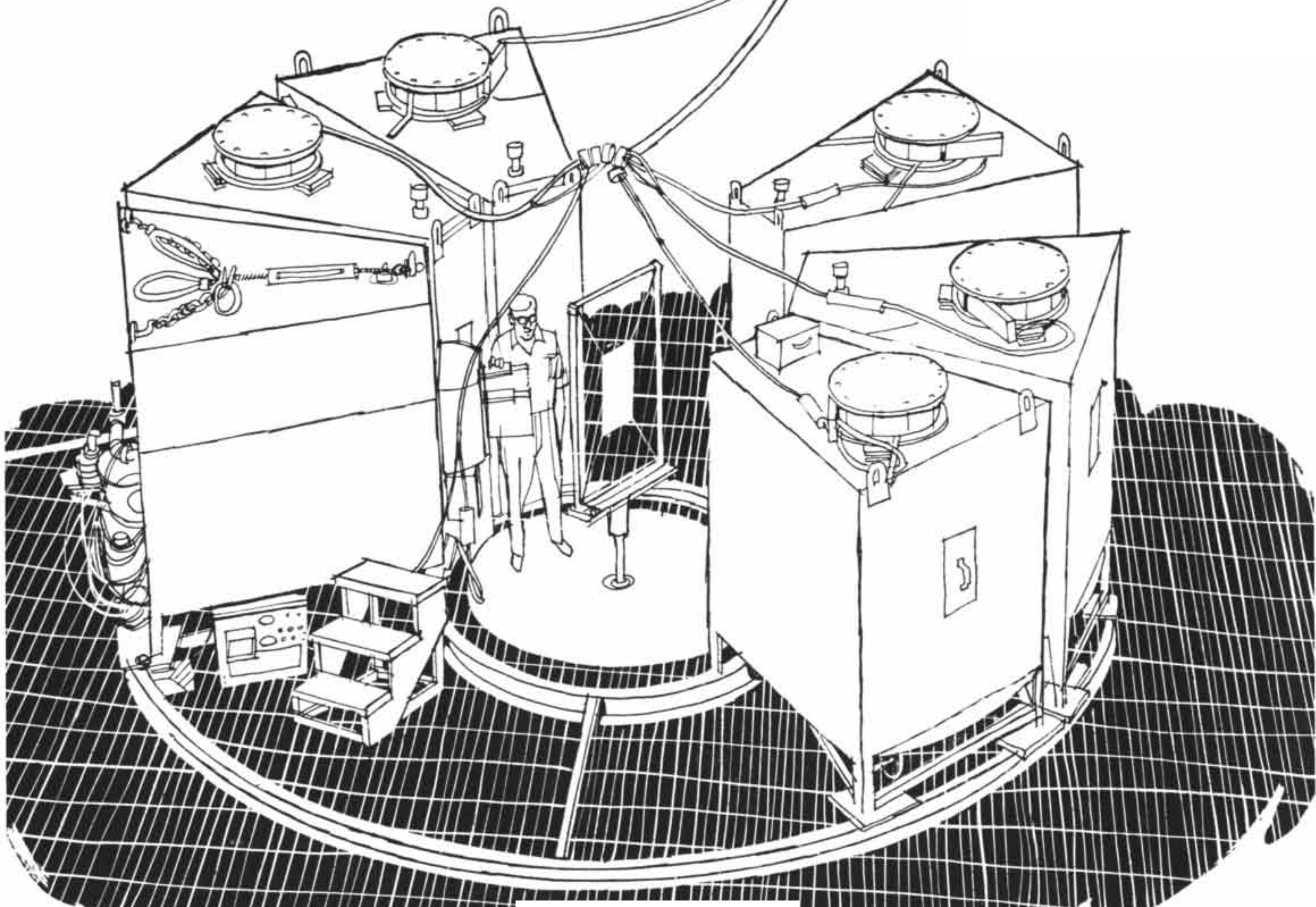

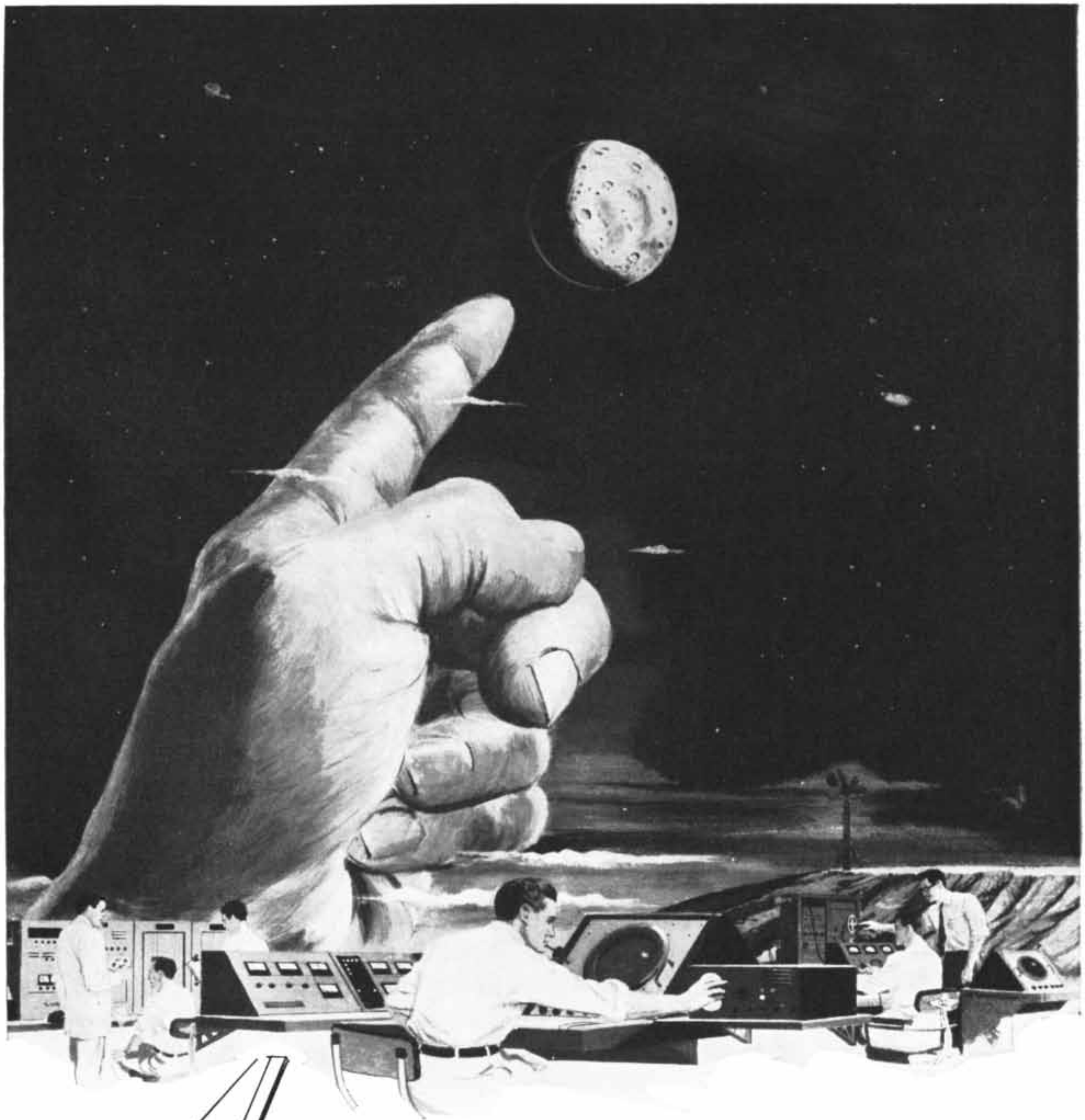

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Reactor Fuel Elements

As the evolution of nuclear reactors proceeds, their fissionable material and its protective coating assume remarkably intricate forms. These are the result of subtle technological compromises

by James F. Schumar

It is the year 4995 A.D. In view of the acute crisis caused by the impending exhaustion of uranium and thorium, power engineers find great interest in a paper entitled "On the Feasibility of Coal-Driven Power Stations." Under the heading "Fuel Elements," the author writes reassuringly:

"It is likely that these will be easier to manufacture than in the case of fission reactors. Canning is unnecessary and indeed undesirable since it would make it impossible for the oxygen to gain access to the fuel. Various lattices have been calculated, and it appears that the simplest of all—a close packing of equal spheres—is likely to be satisfactory. Computations are in progress to determine the optimum size of the spheres and the required tolerances. Coal is soft and easy to machine; so the manufacture of the spheres should present no major problem."

The 50th-century author is the 20th-century physicist O. R. Frisch, writing in a collection of humorous papers celebrating the 70th birthday of Niels Bohr [see "Jocular Physics"; Scientific American, March, 1956]. Though Frisch's words are facetious, they are a sharp comment on a central problem of nuclear technology.

The fueling of the present family of nuclear power reactors is a far cry from the stoking of a coal furnace. As Frisch's mythical author suggests, this fueling depends heavily on the design of the fuel elements. These are precisely engineered rods or plates containing the fuel jacketed or "canned" in a protective coating of metal. Their design is governed first of all by the requirements of nuclear physics. Assembled in a carefully computed lattice, the fuel elements must bring together the critical mass of fuel in which the fission reaction will begin spontaneously and sustain itself at the desired temperature with maximum utilization of the precious fuel atoms (cost: $12 to $15 per gram). This same lattice must serve as a heat exchanger, transferring heat with maximum efficiency from the interior of the fuel elements to the coolant fluid that ultimately delivers the energy to a turbine. Here the design of the fuel elements is governed by the more familiar concepts of classical physics. But the new and the old physics make a strange synthesis. The fission reaction transforms the elemental nature of the fuel and changes its chemical and structural characteristics. In the flux of nuclear particles at the core of the reactor, conventional materials of construction also develop weird and unpredictable properties. Under the circumstances, fuel-element design must be heavily conditioned by the need for safety. In addition, it must take account of the fact that the fuel elements will have to be reprocessed periodically to decontaminate them of fission products and recover unburned fuel. In sum, the design of a reactor and its fuel elements embodies the compromise of the competing claims of nuclear physics, thermodynamics, structural and materials engineering, nuclear chemistry, safety and economics. The compromise is often difficult to make.

At the state of the art now attained, each new reactor suggests modifications and improvements in the next. There is no such thing as a "standard" fuel element. The host of possible compromises is suggested by the cross section of fuel elements that inspired the geometrical abstraction on the cover of this issue of Scientific American.

However individual in design, all nuclear reactors depend upon the same natural process. That is the disintegration of atoms of the four unstable isotopes of two of the heaviest elements, uranium 235 and 233 (U-235 and U-233) and plutonium 239 and 240 (Pu-239 and Pu-240). Upon being struck by a neutron the nucleus of these atoms fissions; some of its mass is converted to energy and the balance to atoms of smaller mass plus, on the average, more than two neutrons. It is the extra neutrons that generate the chain reaction, as they fly off to upset the nuclear stability of other atoms. Conversely, the lighter elements (the fission products) produced in the disintegration of the fuel atoms tend to suppress the chain reaction; they have a large cross section for neutrons of low velocity, that is, they capture them with high probability.

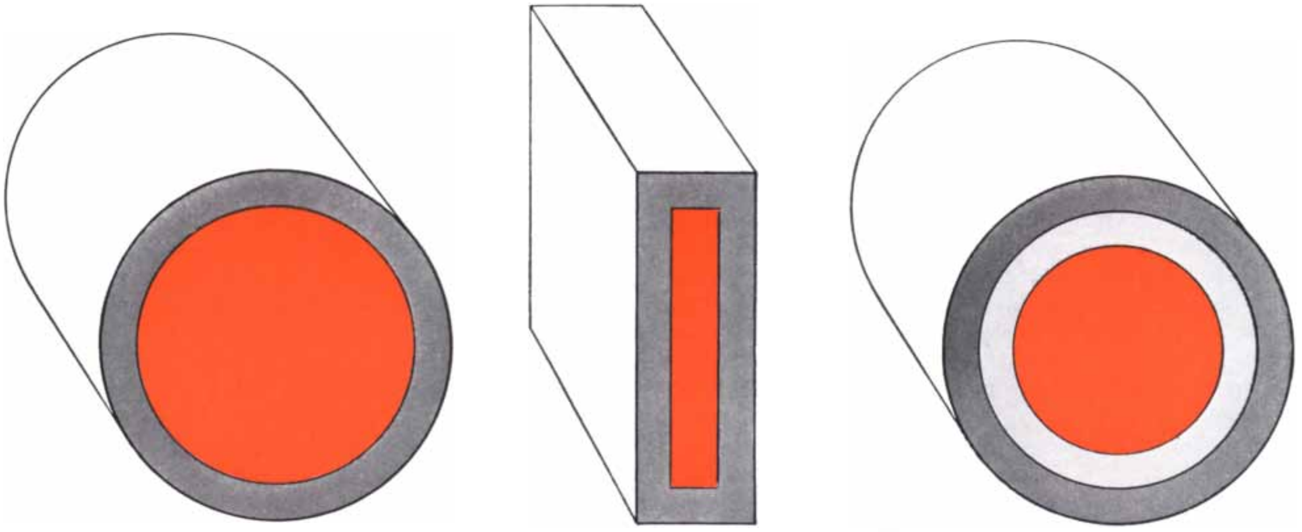
Of the four fuel isotopes U-235 is the only one that occurs in nature. The plutonium isotopes are synthesized when surplus neutrons in a chain reaction collide with atoms of U-238, the stable and much more abundant isotope of uranium; U-233 is the product of similar transformation of thorium 232. In the past the "synthetic" fuel isotopes have largely been produced in reactors designed for this purpose. Current power reactor design, however, seeks to extend the life of the fuel elements by converting stable uranium and thorium isotopes ("fertile" material) to fissionable isotopes (fissile material) to be consumed as the chain reaction proceeds. In addition, some power reactors are being designed as "breeders," to produce more fissile material than they consume.

Control of the reaction speed is a critical factor in reactor design. "Thermal" reactors employ a moderator substance such as graphite to slow down the velocity of the neutrons to energies on the order of .01 electron volt. On the other hand, "fast" power reactors employ no moderator and operate with a neutron flux in the 100,000-electron-volt energy range.

The critical mass of a thermal reactor occupies a larger volume of space which it shares with the moderating substance; it yields heat at a lower rate, well within the range of conventional power-engineering practice. The fast reactor, with its high temperatures generated in a relatively small volume of space, raises entirely new problems in heat-transfer technique. In either case nuclear physics dictates the primary premises of design. The desired reaction rate and temperature establish the quantity of fuel atoms required per unit volume and the ratio of fuel atoms to other atoms—structure, coolant and, if any, moderator—in the reactor core. In the choice of materials for these secondary purposes, neutron cross section may play a restrictive role; atoms that absorb neutrons too readily can damp the chain reaction. Since nuclear physics also dictates the spatial distribution of fuel atoms in the core, it determines to the first approximation the shape and arrangement of the fuel elements.

From this point on, heat-transfer technology fixes the ruling design considerations. As the million-degree temperatures of an uncontrolled chain reaction suggest, the problem is not so much how to generate the heat, but how to get it out of the reactor. A nuclear fuel element is an extremely compact heat source; it generates many watts of energy per gram. How much heat it can be allowed to generate is limited by the rate at which heat can be transferred to the coolant, the heat flux being expressed in calories per unit surface area. The element is of course hottest at the center and coolest at the surface which is in contact with the coolant. The larger the temperature difference, the greater the heat flow and the more efficient the fuel element. Across a narrow cross section of material, a mere fraction of an inch, the temperature gradient may fall several hundred degrees. The maximum temperature difference is set, in the first instance, by the thermal properties of the fuel and jacket materials; to ensure heat transfer between these materials, they are usually closely bonded to one another. The heat flux is dependent next upon the thermal properties of the coolant and its rate of flow. Hotter elements require more rapid circulation of the coolant, which means higher pumping costs, or a larger ratio of coolant to fuel, which tends to damp the reaction. Taken together, these variables fix the square footage of heat-transfer surface required per unit volume, the dimensions of the fuel elements, the thickness of the jacket or "cladding," the spacing of the elements to provide coolant channels and the general configuration of the reactor assembly.

The ideal specifications which emerge from the compromise thus far arranged between nuclear physics and thermodynamics must now face further compromise with the realities of structural design and the physical properties of materials of construction. In the first place the sharp temperature drop between the center and the surface of the element sets up enormous stresses because of unequal expansion. The most elaborate system for circulating the coolant cannot maintain uniform pressure over the entire surface of a fuel element; inequalities in pressure may warp individual fuel elements. Turbulence may aggravate these pressure differences and produce destructive "flutter" in the plates or rods. If the coolant is a boiling liquid, such as water, uneven boiling adds further strains and also complicates the heat-transfer problem, since gases (*e.g.*, steam) conduct heat far more slowly than liquids. A thicker fuel element will withstand greater stresses, but reduction of the ratio of its surface to its volume will reduce its heat-transfer efficiency. Since the fuel materials are

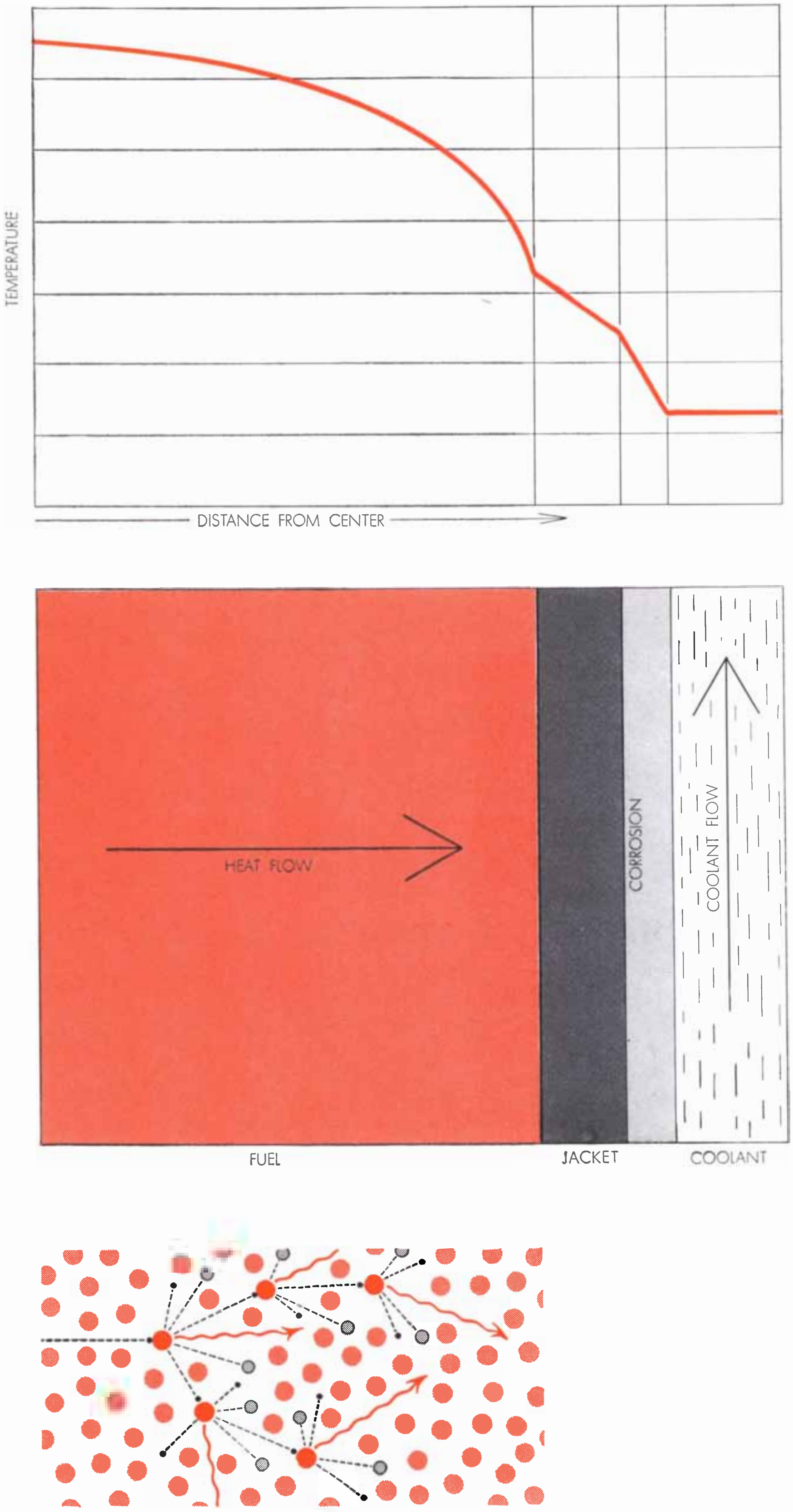


CROSS SECTIONS OF FUEL ELEMENTS, shown here schematically, reveal their essential components: cylinders or plates of fuel (*color*) enclosed in jacketing (*dark gray*). For ease in fabricating, jackets are sometimes designed to fit loosely (*right*). For efficient heat transfer they must then be bonded to the fuel by adding other material such as lead or liquid sodium (*light gray*).

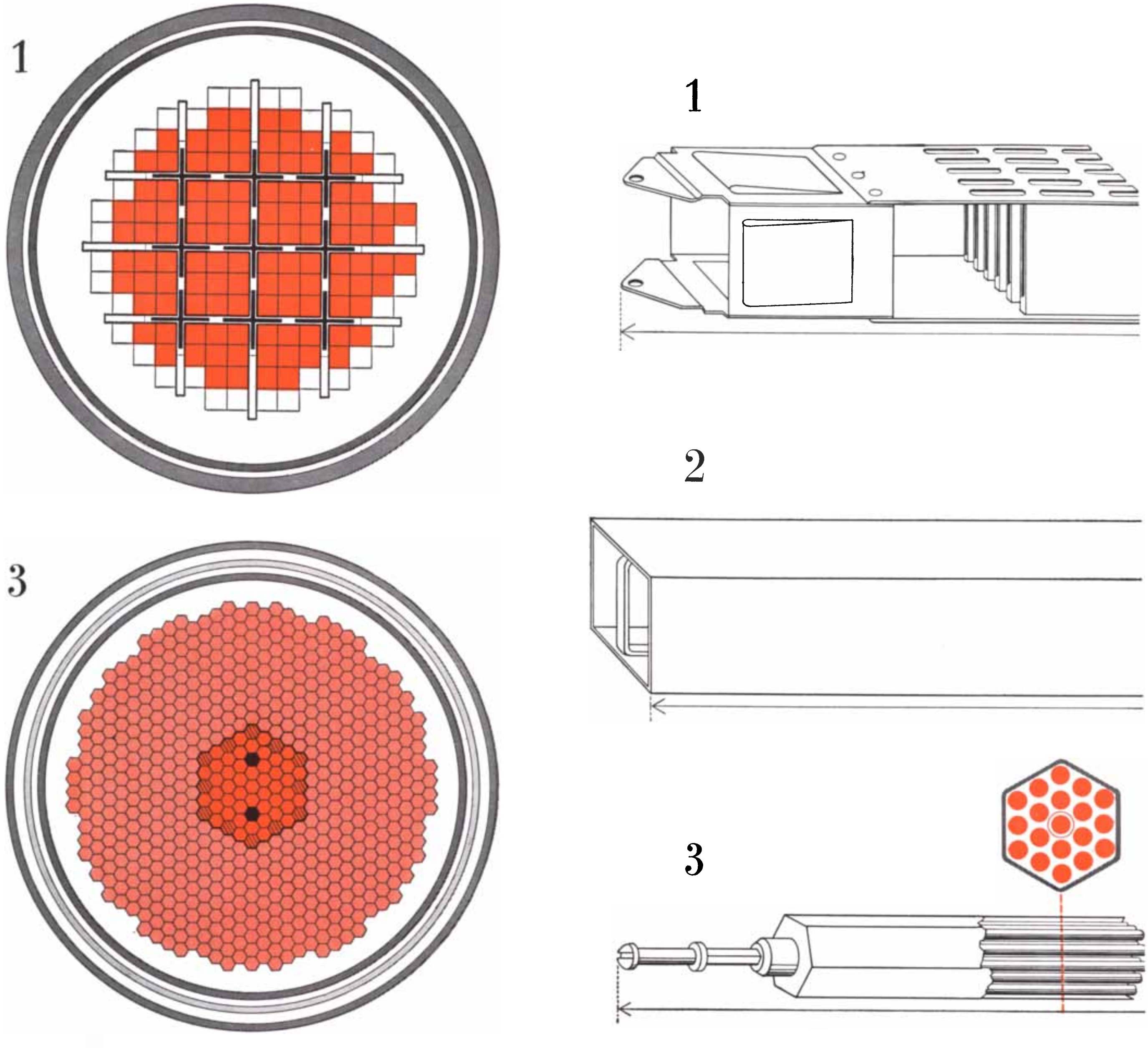
themselves integral with the structure of the reactor, there is little in the conventional engineering handbooks to guide the designer. The metallurgy of uranium is still less than 20 years old, and plutonium did not even exist in quantity before 1943. Thus while metallurgists long ago observed that some substances expand or shrink when subjected to repeated cycles of heating and cooling, pure uranium turns out to possess this property to a unique degree. In one experiment a bar of rolled uranium, heated and cooled 3,000 times, increased in length by 600 per cent. Fortunately the alloying of the fuel metal with metals such as molybdenum and zirconium, plus heat-treating, can almost eliminate this problem; diluting the uranium with a large proportion of zirconium or aluminum provides an alternative solution.

But there are other problems more confounding and more serious. Fission plays havoc with the crystalline structure of the fuel material. The accumulating fission products have a greater volume than the atoms which produced them, and so weaken, distort and crack the fuel element. Among the fission products are the inert gases krypton and xenon. Unable to enter into chemical combination with other elements, they remain in gaseous form. The pressure of these gases, building up as their parent atoms fission, is built up further by high temperatures, and may cause the fuel material to swell until it ruptures its jacket. Short of this extreme, the gases reduce the density and thus the thermal conductivity of the fuel element. A major objective in reactor metallurgy is to develop fuel alloys that can retain these gases without changing size or shape.

It is, of course, the function of the jacket to help retain the fission products, especially the radioactive ones which could do grave damage to the rest of the plant and endanger the lives of personnel if they were to be carried off from the reactor core in the coolant. The jacket has the additional function of protecting the fuel from corrosion by the coolant. But the bonding of uranium and plutonium to more familiar metals is a new art. The first breeder reactor, at Arco, Idaho, provides a costly example of the pitfalls. The fuel elements in this reactor consist of rods of uranium metal encased in stainless steel. Separately, each of these metals withstands temperatures well above 1,000 degrees centigrade, several hundred degrees above the operating temperature of the reactor. Together, however, they form an alloy which melts at about 725 de-



NUCLEAR AND THERMAL PROCESSES are shown in a portion of a fuel element enlarged some 30 times (*center*). Bottom drawing shows chain reaction in fuel, produced by neutrons (*black dots*), which yields energy (*wavy arrows*) and fission products (*gray circles*); energy flows from fuel to coolant. Maximum temperature is at the center of the element, minimum at its surface, as suggested by the curve at top. The sharp temperature drop over a short distance sets up severe stresses between different parts of the element.

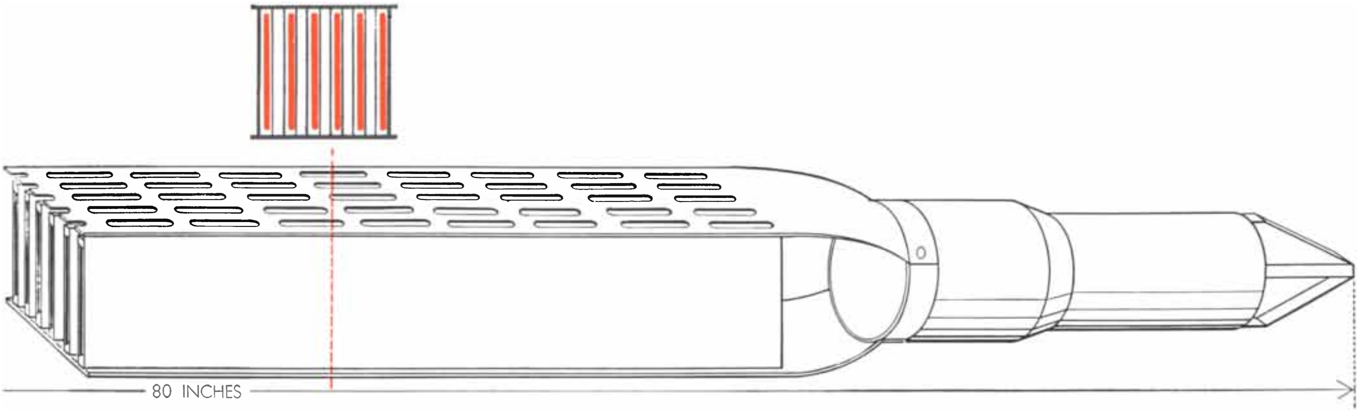


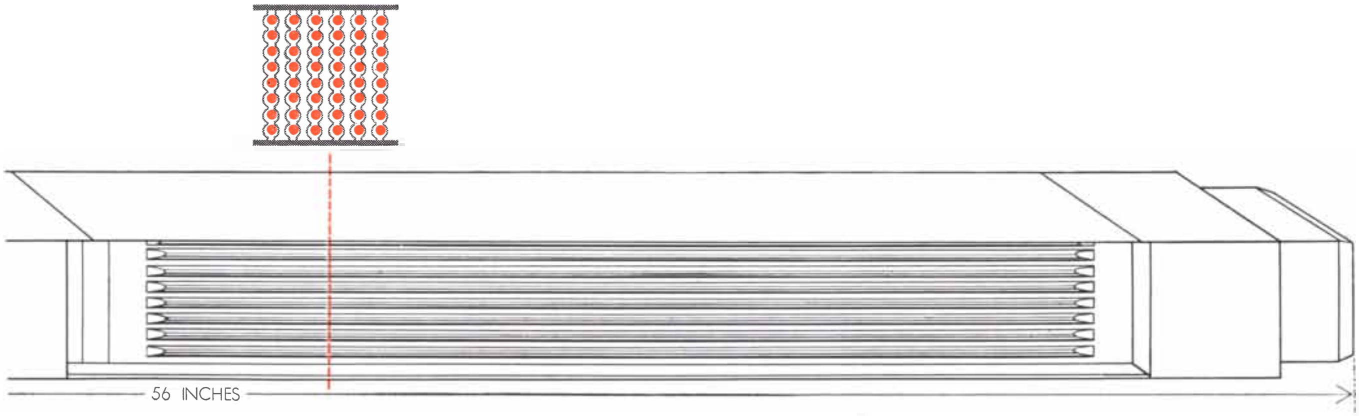
FUEL ELEMENT ASSEMBLIES for three reactors are shown in drawings and schematic cross sections (*right*). Cross sections of two reactors (*left*) show how the assemblies are fitted together. Elements of the Experimental Boiling Water Reactor (*1*) are plates of enriched uranium clad in zirconium. Black crosses in the reactor are control rods. Borax-IV elements (*2*) are aluminum tubes containing ceramic pellets of uranium and thorium oxides; the reactor itself resembles the EBWR. The Experimental Breeder Reactor II (*3*) has three-part assemblies. Center section consists of thin, stainless-steel tubes (*not shown in cross section*) containing

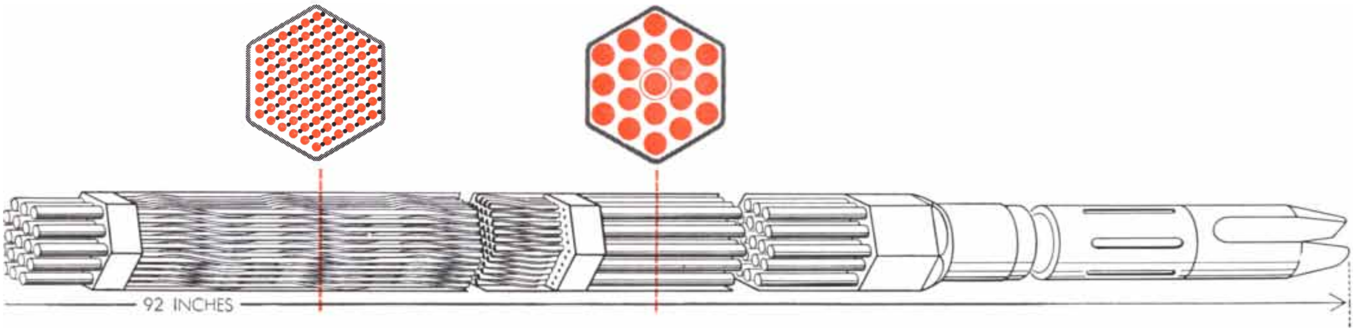
grees. A local "hot spot" in the reactor, probably caused by a warped element which obstructed the flow of coolant, raised the temperature of one element past this critical figure, and the jacket simply melted away. The disintegrating jacket blocked more coolant channels, producing more hot spots which melted more jackets. Before the reactor could be shut down most of the fuel elements had fused into a lump.

If the physical and chemical stresses of operation do not put a fuel element out of action, then the steady accumulation of fission products may damp the output of the element when only a tiny percentage of its fissile material has been consumed. The reprocessing of the fuel, to remove the fission products and return the unburned fuel to the reactor, is a major factor in the economics of nuclear power. The cost of this operation provided a special incentive for the recent development of fuel elements that generate and consume additional fissile material as the reaction proceeds, and thus last longer between reprocessings.

The Experimental Boiling Water Reactor now in operation at the Argonne National Laboratory provides a successful working example of the compromises that enter into fuel-element design. A pilot industrial power reactor, designed to produce 20,000 kilowatts of heat, EBWR operates in the thermal range, with its neutron flux moderated to very low velocities. As its name suggests, its moderator—water—doubles as its coolant; moreover, steam from the water that bathes the reactor core goes directly to a turbine, instead of giving up its heat to some intermediate heat-exchange fluid. The fuel elements therefore had to be designed for high mechanical stability and corrosion resistance. Failure of an







slender "pins" of uranium-plutonium fuel. A helical rib on each tube preserves spacing and prevents warping. At either end are thicker "blanket" elements containing nonfissionable uranium 238, which changes into fissionable plutonium as it absorbs neutrons emitted by the fuel. In the reactor these three-part assemblies are surrounded by blanket assemblies containing only U-238. The black hexagons are safety rods; hatched hexagons are fuel assemblies which can be lifted or lowered to control the level of the reaction. The variously shaped fittings at the ends of the assemblies serve to position them in the reactor, and to facilitate handling.

element would not only force a shutdown of the reactor but also would contaminate the turbine and condenser with fission products, making maintenance work on these machines hazardous to personnel. Since the reactor is pressurized to raise its steam temperature to around 250 degrees C., the removal of a fuel element for reprocessing requires that the reactor be shut down completely. Long operating life was thus set as an important criterion for fuel-element design. Finally, since most metals readily absorb slow neutrons, the choice of materials for the jacketing and for other auxiliary purposes was sharply restricted.

To fuel this reactor, our group at Argonne chose uranium metal enriched so that it contained 1.5 per cent of fissionable U-235. Enriched uranium is much cheaper than pure U-235, and we could count on the conversion of U-238 to plutonium. The high density of the metal makes for a higher concentration of fissile atoms in a given volume of fuel and improves heat conductivity, thus enabling us to hold down the size of the reactor and the massive pressure tank in which it is enclosed. To improve the corrosion and irradiation resistance of the elements, we alloyed the uranium with small quantities of zirconium and niobium.

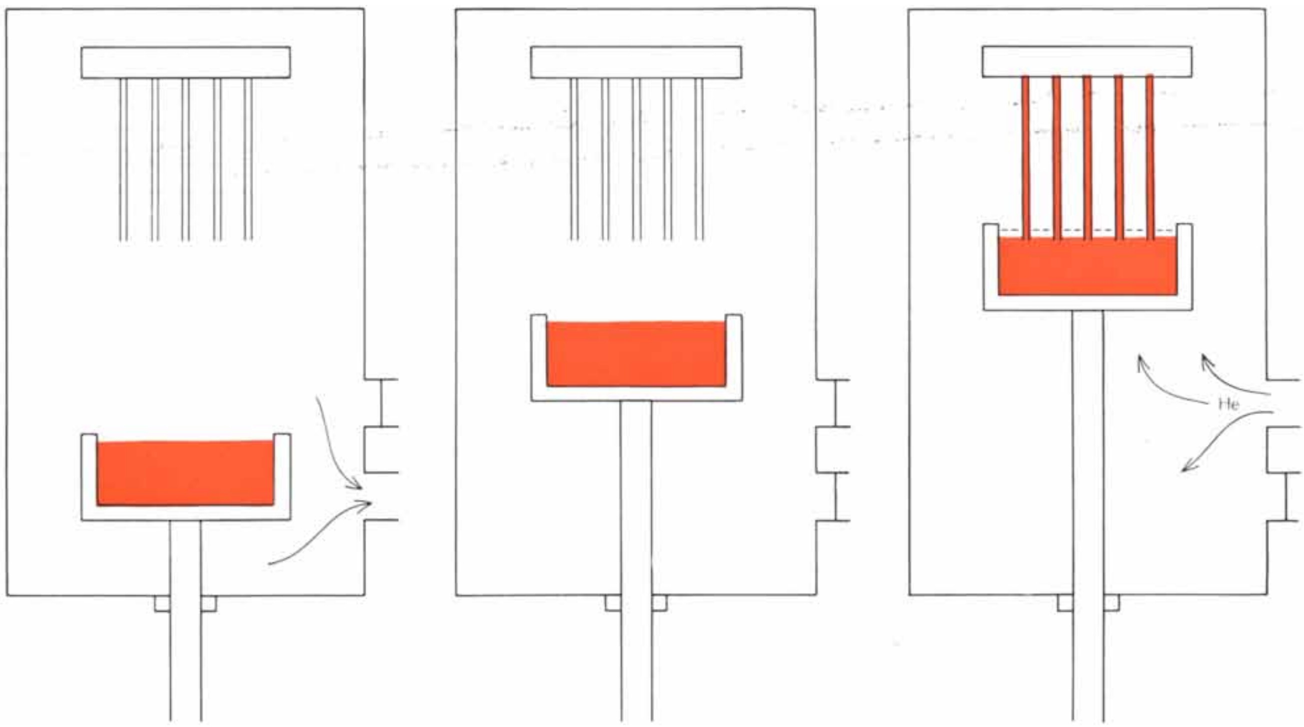
Of the possible jacketing and structural materials, only magnesium, aluminum and zirconium possess a low neutron cross section. We settled for zirconium, despite its higher cost, because it offered much greater mechanical strength at high temperatures as well as superior corrosion resistance. The working properties of the zirconium and the uranium alloys are so similar, however, that we were able to fabricate the fuel elements by means of a simple rolling technique. The elements are long, narrow plates containing a layer of uranium sandwiched between and bonded to two layers of zirconium. Six parallel plates, separated by channels for the coolant and welded to perforated zirconium side plates, make up the long, boxlike assemblies [*see illustration on preceding two pages*]. We estimate that these elements will have an effective life of five to 10 years. They have already functioned satisfactorily for more than two, participating in that time in the production of more than 30 million kilowatt hours of electricity.

DAMAGE TO NUCLEAR FUELS, due to irradiation and the accumulation of fission products, shortens the life of fuel elements and makes frequent reprocessing necessary. Chiefly responsible are the inert gases produced by fission, such as krypton and xenon.

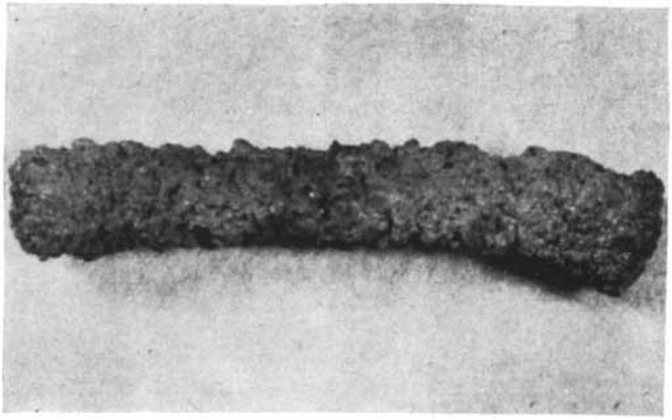
Borax-IV, another boiling water reactor at Argonne, illustrates some new departures that may have an important place in future fuel-element technology. It was built not for power, but for research into the possibilities of ceramic fuels, that is, kiln-fired oxides of uranium, plutonium or thorium. Ceramic fuels could largely eliminate the corrosion hazard, since they are themselves products of a kind of corrosion: oxidation. Moreover, ceramics have extraordinarily good resistance to both heat and irradiation.

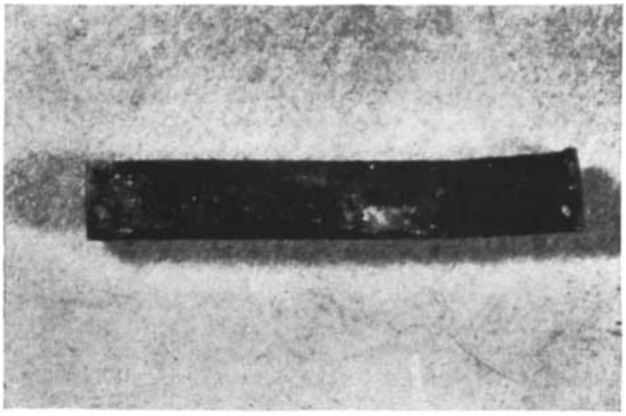
Unfortunately uranium oxide is nearly twice as bulky as uranium metal. The increased bulk slows the chain reaction for a given concentration of fissile atoms, and lowers heat conductivity. Thorium oxide, however, is not much more bulky than thorium metal, and there is reason to believe that a boiling water reactor may convert thorium to U-233 more efficiently than it converts U-238 to plutonium. For our experimental fuel we therefore chose thorium oxide mixed with 6 per cent U-235 oxide, baked into cylindrical pellets about a quarter-inch in diameter. Since Borax-IV is designed to operate intermittently at lower temperature we were able to economize by using aluminum rather than zirconium as the jacketing material.

The jackets are made of aluminum extrusions, each consisting of eight tubes integral in a ridged plate. For economy in fabrication we did not try to get a close fit between the tubes and the fuel pellets; the space between them is filled with lead, which has a low cross section for neutrons. The assemblies, which resemble those of EBWR, consist of six tube-plates with cooling channels between them, welded to side plates.



REMOTE-CONTROL CASTING of fuel pins for the Experimental Breeder Reactor II is shown in these drawings. Fuel elements for this reactor must be reprocessed every few months to remove some of the accumulated fission products. Partially purified uranium-plutonium alloy is melted in a vacuum (*left*). The liquid metal is then lifted (*center*) toward an array of hardened glass molds. Helium admitted to the apparatus (*right*) forces the metal into the molds, which can be easily broken away from the solidified pins.





The large volume of their atoms causes the fuel to swell and eventually disintegrate. The photograph at left shows the remains of a rolled uranium bar after only .73 per cent of its atoms had fissioned. The heat-treated bar in center shows much less damage at 1 per cent "burn-up." The casting at right, made of uranium alloyed with zirconium, is almost undamaged even at 1.6 per cent burn-up.

In the Experimental Breeder Reactor II (EBR-II), now under construction, our group has had to deal with a very different set of problems. EBR-II is an unmoderated "fast" reactor, with a heat output rated at 60,000 kilowatts. In addition, this reactor is to breed more fuel than it consumes by converting U-238 into plutonium.

For efficient breeding the reactor must conserve neutrons to the utmost. EBR-II therefore has a very small core of concentrated metallic fuel, about 20 per cent fissionable material as against 1.5 per cent for EBWR and 6 per cent for Borax-IV. The fuel in this concentrated core "burns" relatively rapidly to produce temperatures around 600 degrees C. at the surface of the fuel elements. The radiation damage, aggravated by the high temperatures, limits the life of the elements to months rather than years. The need for frequent reprocessing accordingly emerged as the decisive factor in their design.

A fuel element withdrawn from a reactor must be handled throughout the entire reprocessing by remote control machinery in a "hot cell." The EBR-II fuel elements are designed to minimize the difficulties of this operation. The fuel metal is fabricated in slender cylinders, or "pins," which fit loosely in the long, thin-walled tube of the stainless-steel jacket; the space between fuel and jacket is filled with metallic sodium. Since sodium has a melting point of 98 degrees C., it is easy to melt out the sodium and decant the fuel pins from the jackets. The fuel pins now go to the refining process, and the jackets, contaminated with radioactivity, are scrapped. With the jacket out of the way, the refining process is considerably simplified. It is simplified further because there is no need to get rid of all the heavier fission products, which do not absorb fast neutrons. Reprocessing involves simple melting techniques and is designed primarily to get rid of the troublesome gases. An automatic casting machine then casts the reprocessed fuel into pins in hardened glass molds, which are broken away when the pins solidify. Still other machines insert the pins into new jackets, fill the annular space between pin and jacket with sodium and fit the completed fuel elements together in an assembly unit, ready for reinstallation in the reactor. The entire process takes less than 24 hours. Since only one assembly is reprocessed at a time, the reactor will operate at a high level without interruption.

The reactor does not need to be pressurized, because the boiling point of its coolant, liquid sodium, is 880 degrees, well above the operating temperature. Sodium, however, presents problems of its own. It rapidly picks up impurities, and impure sodium is extremely corrosive. Fortunately we did not have to consider nuclear properties in our choice of materials to withstand corrosion, since few substances absorb fast neutrons. We chose stainless steel because of its resistance to heat and corrosion and because its low cost makes it expendable during reprocessing. The peculiar behavior of uranium and stainless-steel alloy that was demonstrated at Arco, however, limits the surface temperatures of the fuel elements. Jackets of vanadium, zirconium, molybdenum or niobium would have permitted higher temperature, but these metals are costly and difficult to fabricate.

The fuel elements are long and slender; a helical rib spirals around the outside of each tube. When the tubes are arrayed in the fuel assembly, these ribs separate them from one another and create the channels through which the sodium coolant circulates. This arrangement safeguards the rather flexible individual tubes against the warping which caused so much trouble in the first breeder reactor.

The assemblies are hexagonal tubes of stainless steel about 8½ feet in length. A bundle of 91 fuel-element tubes occupies roughly the middle third of this length. Above and below them are similar elements containing pure U-238, which the neutrons released by the fuel elements will gradually convert into plutonium. These "blanket" elements produce much less heat than the fuel elements and are therefore about twice as thick, with enough stiffness to make the helical ribs unnecessary. About 90 of these assemblies make up the core of the reactor. Surrounding them is a thick layer of blanket assemblies containing only U-238. Thus the small core of fuel is blanketed at both ends and all around by breeding material. The blanketing sections will produce more than enough fuel to replace what the fuel sections consume.

The now well-advanced art of fuel-element design may be made obsolete with the arrival of the so-called homogeneous reactor. In such a reactor the fuel and the moderator are intimately mixed, instead of being engineered as separate entities, as in the "heterogeneous" reactors discussed in this article. One homogeneous reactor has already been built, but for experimental purposes rather than power production. The design of these reactors raises problems which are proving as challenging as the design of fuel elements.

The Circulatory System of Plants

Substances required in the metabolism of plant cells not only travel up from the roots but also move about in other ways. This circulation has recently been clarified by experiments using radioactive tracers

by Susann and Orlin Biddulph

It is a familiar fact that the sap of a plant travels upward through its stem. It is not so familiar that the vital activities of the plant require the extensive circulation of a wide variety of substances. Water moves from the roots to the leaves, where it may participate in the process of photosynthesis. Sugar manufactured by this process travels from the leaves to cells that are not photosynthetic, or to regions of the plant where it is stored. Some of the sugar that descends to the roots reacts with minerals to form amino acids and other complex substances which then ascend the stem. Other minerals travel upward to the leaves, fruits and flowers, and the excess not utilized by the metabolism of these parts is free to move on. Growth hormones manufactured in the tips of shoots, and vitamins synthesized in newly matured leaves, similarly travel through the plant to participate in the activities of other tissues.

All this ebb and flow is called translocation. How is translocation accomplished? This is a fundamental question of plant physiology, and also a practical one. For example, many new substances that are used in agriculture depend for their effects on translocation: systemic compounds which combat pests, the fertilizers and herbicides which can be sprayed on leaves, and growth substances which regulate flowering and fruit drop.

Translocation occurs in two tissues, the conduits of which extend throughout the plant. The conduits in the woody tissue, or xylem, consist of thick-walled tubes of dead cells. Through these tubes water travels from the roots to the leaves, where it is utilized by living cells or evaporates from the leaf surface. Because the cells of the tubes are dead, the process is thought to be a purely physical one [see "The Rise of Water in Plants," by Victor A. Greulach; Scientific American, October, 1952].

In contrast, the conduits through which foods and minerals travel from the leaves to the roots and to the shoot tips consist of living cells. These cells are joined end to end, and their ends are perforated by minute pores, so that their contents are interconnected. Because the pore areas resemble tiny sieves, the conduits are called sieve tubes. The sieve tubes are supported by fibers which give certain plants (*e.g.*, flax, jute, hemp) their economic importance. Associated with these tubes are other cells that store food; the whole tissue is called the phloem. In woody plants the phloem is located in that part of the bark which is next to the wood; in herbaceous plants it is associated with the xylem in the veins.

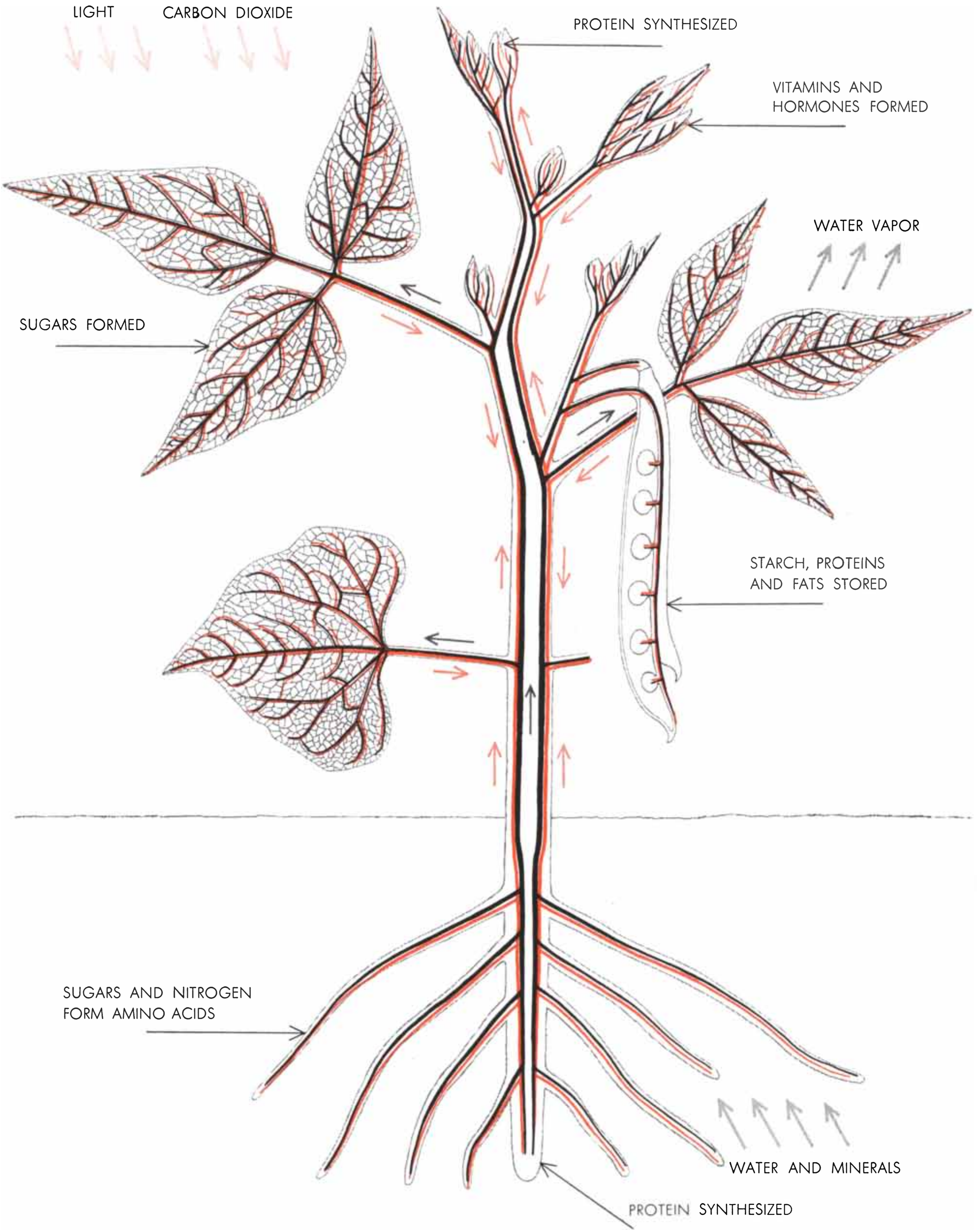
Until the 1920s it was thought that all food substances traveled upward through the dead tubes of the xylem and downward through the living tubes of the phloem. Then it was calculated that food substances moved from the leaf at the rate of 20 inches per hour—a rate then considered too high to be explained by movement through living cells. At the same time it was observed that the concentration of sugar in the xylem sap was too dilute to account for the amount of sugar moved upward from leaves to fruits and used at the tips of shoots by growing tissue. Moreover, it was discovered that food substances moved from the leaves to the fruits not only in the xylem sap but also through the phloem. Thus the whole problem of translocation was reopened.

Perhaps the earliest experimental approach to the study of how food substances move through plants involved "girdling" a tree by removing a ring of bark from its trunk. Girdling blocks the movement of food substances down the trunk; sometimes the accumulation is sufficient to cause a swelling above the ring. In time the roots die of starvation. Such an experiment, performed some 400 years ago by the Italian anatomist Marcello Malpighi, demonstrated the movement of substances backward from the leaves.

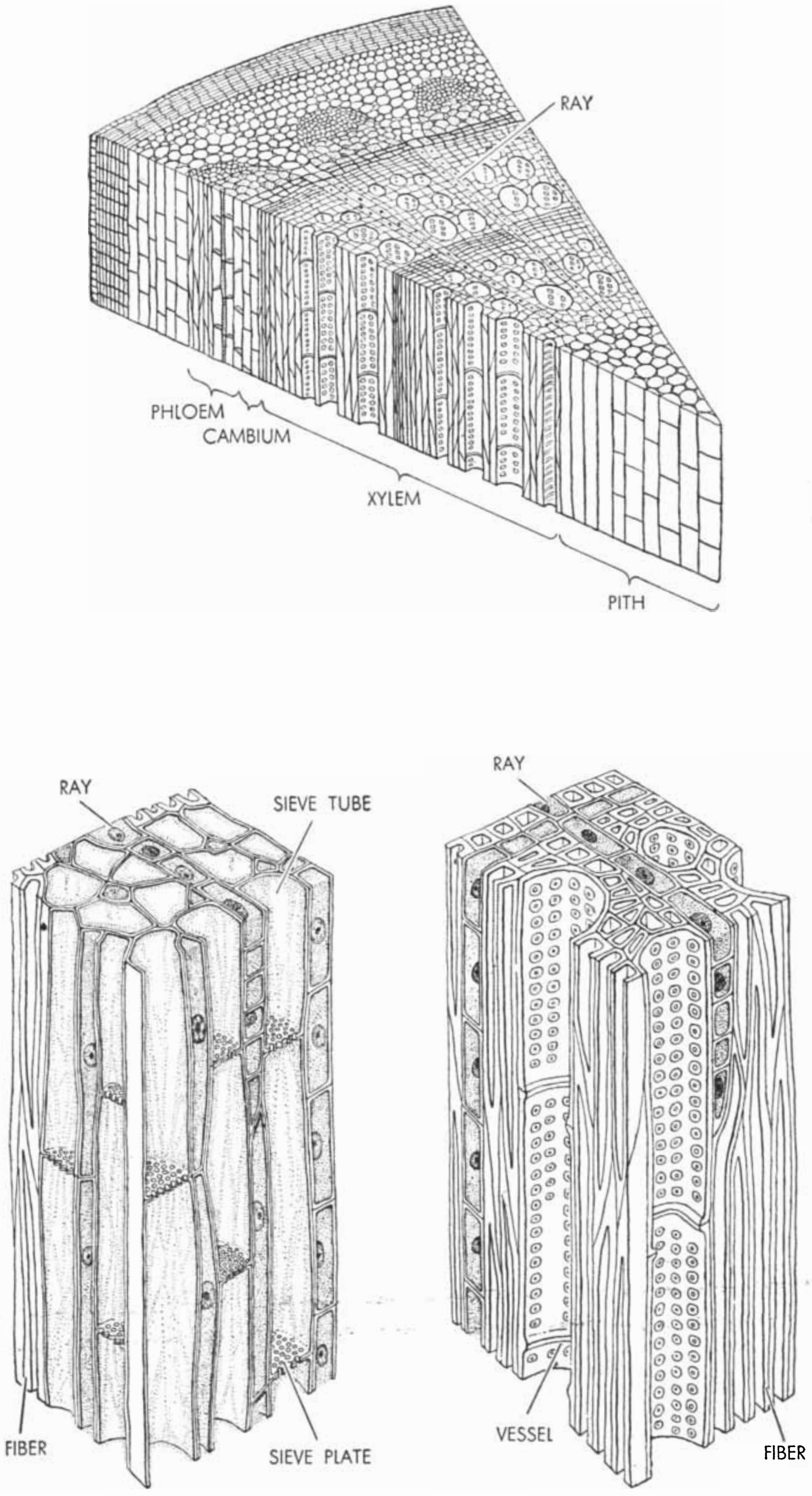
Today radioactive isotopes provide a more refined means of tracing the same movements. For example, a plant can be grown in an atmosphere containing carbon dioxide in which the carbon is radioactive. In the process of photosynthesis the plant uses the radioactive carbon to make food substances which can then be followed as they move from the leaves. By this means it has been demonstrated that the food manufactured in photosynthesis travels both upward and downward from the leaf. In a number of plants the form in which this substance is translocated has been identified as the simple sugar sucrose.

It has also been demonstrated that the sucrose travels through living tissue. If a segment of stem is killed with hot wax, the sugar cannot pass through the dead section. In our laboratory at the State College of Washington we have visually demonstrated that the living tissue through which the sugar passes is phloem. This was done by cutting a thin section of stem from a plant which had been growing in an atmosphere containing radioactive carbon dioxide, and placing the section in contact with photographic film. The radioactivity of the sugar made from the radioactive carbon exposed the film only in the area of the phloem.

Radioactivity has been useful not only in tracing the movement of sugar, but also in calculating the rate of movement. Before the advent of radioactive tracer



CIRCULATION OF A PLANT is outlined. Water and minerals travel up the stem in vessels composed of dead cells. Sugars formed in the mature leaves by the process of photosynthesis move both up and down the stem in tubes of living cells. Some of the sugars react with nitrogen in the roots to form amino acids. Vitamins and hormones formed in the immature leaves travel to other parts of the plant. Starch, proteins and fats are stored in the fruits. Proteins are synthesized at the growing tips of the stem and of the root.



TWO KINDS OF CONDUITS mediate the circulation of a plant. At top is a section of the stem of a woody plant. The tubes of dead cells through which water and minerals rise from the roots are in the xylem. The tubes of living cells through which various substances move in various ways are in the phloem. At bottom left is an enlarged section showing the tubes of phloem. At bottom right is a similar section showing the vessels of the xylem.

techniques the rates were estimated simply on the basis of the gain in the dry weight of fruits. Such measurements indicated that in the pumpkin and the squash, food moved from the leaves at a rate of 22 to 64 inches per hour. By tracing the movement of radioactive carbon in the bean plant, we have established the more precise figure of 40 inches per hour for the translocation from leaves to roots of substances manufactured by photosynthesis.

Food substances from the leaf not only move to the root—they make a circuit. The Soviet plant physiologist A. L. Kursanov has recently demonstrated this in the young pumpkin plant. He found that the passage from leaf to root took 30 minutes, and that the new mixture formed there returned to the top of the plant in about three hours.

In perennial plants food must be mobilized from stored reserves as the buds break dormancy in the spring. While some of the food may be carried up from the roots by the sap, the concentration of sugar in the sap is seldom very high. It has been found that the food and minerals required for the growth of leaves in the early spring come not from the roots but from storage regions near the leaf buds.

The water rising through the xylem provides the leaves with their original supply of minerals from the soil. When the supply is more than adequate, however, the excess minerals are translocated down toward the roots again, or up to younger leaves and growing tips, or to fruits and flowers. This circulation of minerals in the stem was demonstrated by a unique experiment in which the root system of a corn plant was divided into two parts. Each part was then placed in a separate nutrient solution. When radioactive phosphorus was added to one solution, it ascended the stem of the plant, but within six hours it had come down the stem and entered the roots in the other solution.

Some of the essential minerals are redistributed in plant tissues with remarkable facility. In deciduous trees as much as 90 per cent of certain minerals is removed from leaves before they fall. In most plants mobile elements are transferred to new leaves at the expense of old ones. Sometimes minerals are similarly withdrawn from the petals of flowers and delivered to the young fruit.

Such redistribution is particularly significant in the reproductive processes of the plant. In corn, for example, 60 per cent of the nitrogen required for the formation of the grain comes from various parts of the plant rather than directly from the soil. The commercial practice of "topping" tobacco plants prevents the plants from flowering, thus allowing the nitrogen that would normally go into the formation of flowers to increase the size of the upper leaves.

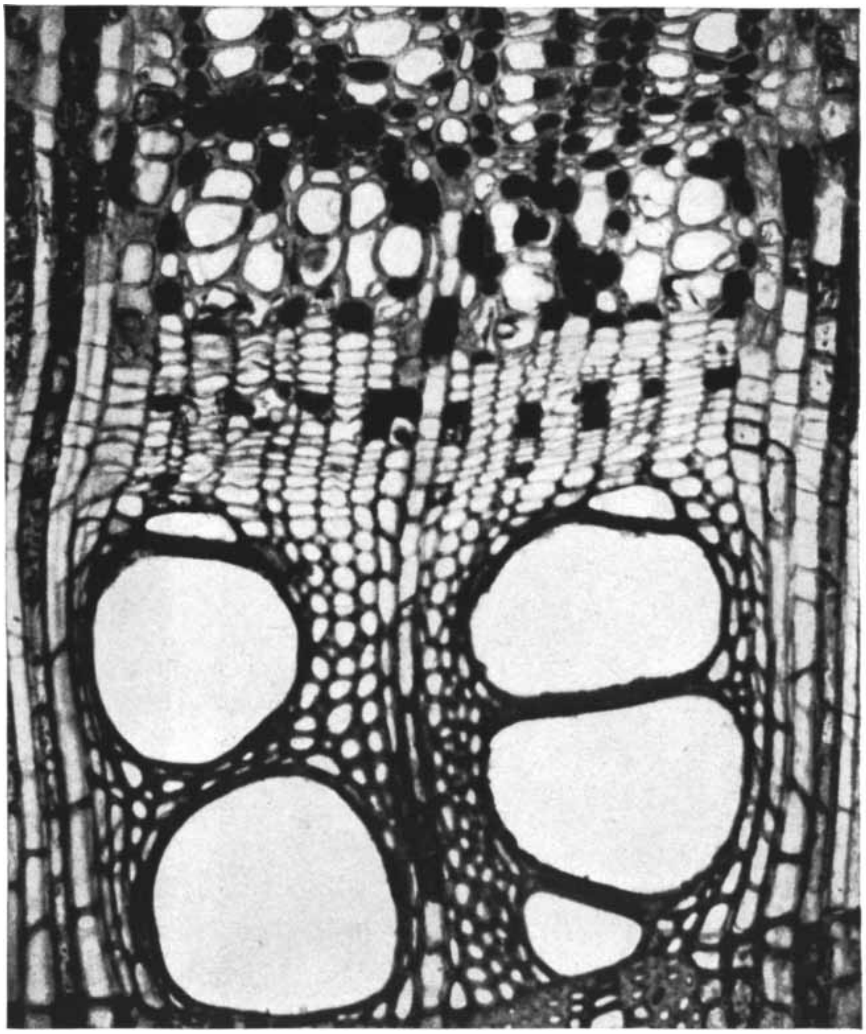
The pattern of movement and the degree of mobility vary with the mineral. The translocation of minerals from the leaf has been investigated by spraying the leaf with the mineral in radioactive form. In this way it has been demonstrated that phosphorus moves with great ease both upward and downward from the leaf. Radioautographs indicate that, like sugar, phosphorus moves down the stem from the leaf through the phloem. Part of the phosphorus, however, diffuses from the phloem into the tubes of the xylem, where it can once again ascend the stem. Much more phosphorus is translocated by day than by night, and the element moves predominantly to metabolically active tissues such as buds and young leaves. However, some phosphorus also travels from the leaves to the roots, even when the roots are immersed in a nutrient solution containing an adequate supply of the element.

Sulfur is also remarkably mobile in plants. In areas where industrial operations discharge sulfur into the air, the element enters the plant through the leaves and is not only used in their metabolism but also is translocated to other tissues. Calcium translocation has an entirely different pattern. This element does not travel from the leaf because it is not mobile in the phloem. Once it is delivered through the tubes of the xylem it is not further translocated; thus the new growth of a plant that is not steadily supplied with calcium soon becomes deficient in it. From these findings it can be seen that it is quite practical to administer phosphorus and sulfur to plants in intermittent sprays. A calcium spray, on the other hand, would not meet the needs of plants.

Phosphorus and calcium represent the extremes of mobility in plants. This has been demonstrated by radioautographs of the bean plant. A group of bean plants is grown for a short time in a nutrient solution containing one of these minerals in radioactive form. After this initial period some of the plants are removed from the solution, pressed, dried and exposed to photographic film. The resulting radioautograph will show the tissues into which the radioactive tracer moved during this period. The rest of the plants are placed in a fresh nutrient solution that contains no radioactive mineral; there they are allowed to grow for an additional period. When radioautographs of the second set of plants are compared with those of the first, they will show the behavior of the mineral during the additional period of growth.

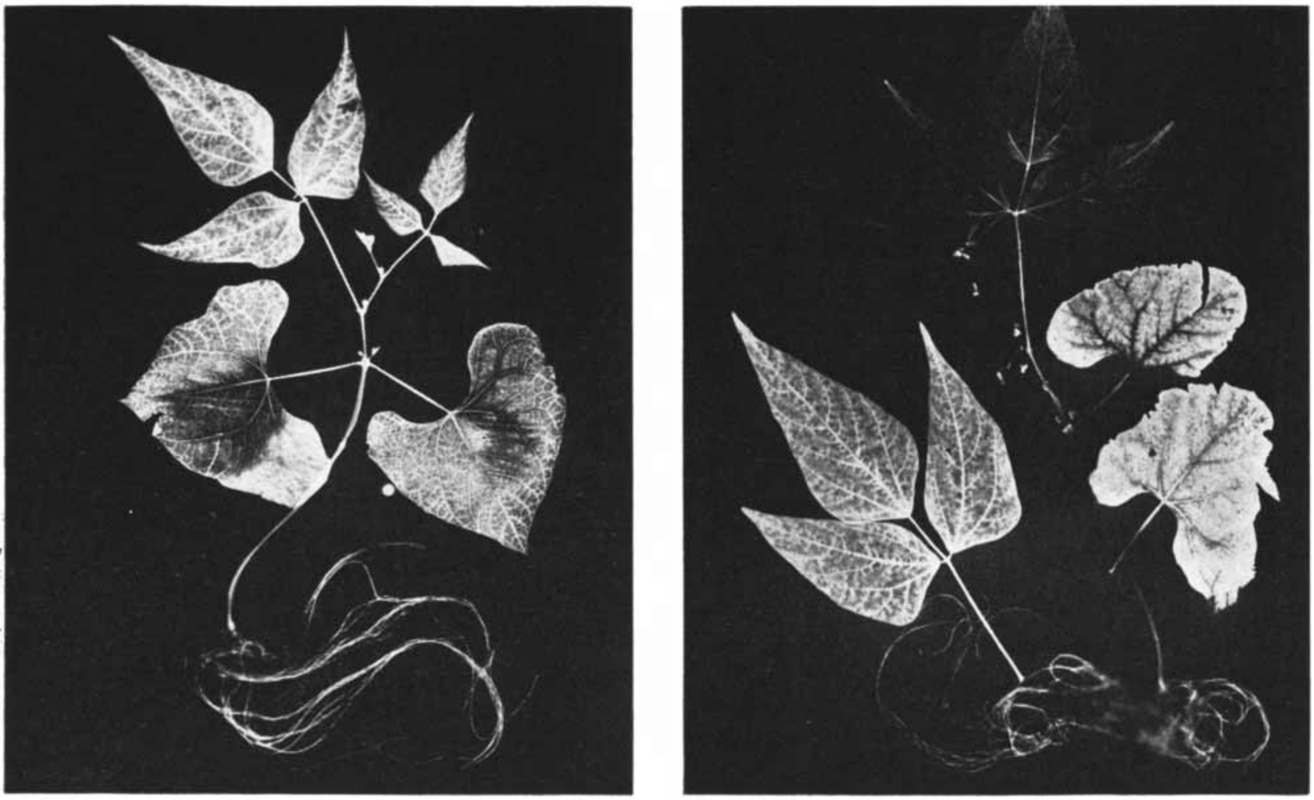
The pair of radioautographs at the top of the next page reveals the characteristic behavior in the bean plant of phosphorus. The plant at left was grown for a short period in a solution containing radioactive phosphorus; it is apparent that the mineral was delivered to all parts of the plant. The plant at right, grown in the same solution for the same period, was then removed and grown in nonradioactive solution. It can be seen that phosphorus has been withdrawn from the older tissues and translocated to the new leaves and the bud. Some of the phosphorus in the younger tissues could have come from the roots, which are still heavily loaded with the original radioactive mineral. If all of it had come from the roots, however, the oldest leaves would be the most radioactive. The fact that the new leaves and the bud are more radioactive demonstrates that another kind of circulation has occurred.

The totally different behavior of calcium is indicated by the pair of radioautographs at the bottom of the next page. Here the plant at left was briefly grown in a solution containing radioactive calcium; the mineral has been distributed to various tissues. The plant at right, like the second plant in the phosphorus experiment, was removed from the radioactive solution and grown for



PHLOEM AND XYLEM appear in this photomicrograph of a section of grapevine. The large openings at bottom are the vessels of the xylem, seen at right angles to their long axes. The smaller openings at top are the sieve tubes of the phloem. Between the two is the cambium. The photomicrograph was made by Katherine Esau of the University of California.

MOVEMENT OF PHOSPHORUS is traced in these radioautographs of two bean plants. The plant at left was grown for a short period in a solution containing radioactive phosphorus; the phosphorus is distributed throughout the plant. The plant at right was grown in the same solution, then removed and grown in nonradioactive solution; the phosphorus is concentrated in younger leaves.



MOVEMENT OF CALCIUM is similarly traced. The plant at left was grown in a solution containing radioactive calcium. The plant at right was grown in the same solution, then in nonradioactive solution; calcium has not traveled from the older leaves to the younger.

four days in a normal solution. The new leaves and the bud of the plant show very little radioactivity, which indicates that their calcium came not from older tissue but from the supply in the non-radioactive solution.

Some elements have an intermediate degree of mobility, that is, they are conditionally mobile. The movement of iron or zinc, for example, is influenced by a combination of circumstances, including the concentration of the element in the plant, the presence or absence of other elements and the acidity of the nutrient medium. If there is not too much phosphorus present, and if the medium is on the acid side, iron will be distributed evenly throughout the leaf in a form which will stimulate the development of chlorophyll. When these conditions are not met, the iron will not be accessible for chlorophyll development; the leaves will be yellow and unable to conduct photosynthesis. This disturbance, known as iron chlorosis, ranks high among those factors responsible for the decreased yield of economically important plants. Because it would be too big an undertaking to make iron available by changing the acidity of the soil, agriculturists have recently dealt with iron chlorosis in another way. They apply to the soil iron chelates: organic compounds that supply iron in a form which can be utilized by plants. It is possible that the chelates also serve to translocate iron in the plant.

In recent years the interest of investigators in translocation has been stimulated by the development of new plant-growth regulators. U. S. Department of Agriculture investigators at Beltsville, Md., have studied one growth regulator (alpha-methoxyphenylacetic acid) that is capable of moving from the leaf of a plant to the roots, then out of the roots into the soil. There it can be absorbed by the roots of an untreated plant, ascend to its leaves and alter their shape. This substance can move between a number of species of broad-leaved plants such as cotton. It does not, however, move from corn, which is a grass. The well-known specificity of 2,4-D for broad-leaved plants may be based not only on differences in the metabolism of these plants and of grasses, but also on differences in translocation. Such biological specificity has led to the study of the relationship between the molecular structure of certain substances and the capacity of the plant to absorb and translocate them. It has been found that the character of certain side chains attached to the molecule influences the ability of the compound to be translocated. It has also been discovered that the pattern in which one compound is translocated is affected by the application of another compound.

Despite all these investigations, we still do not understand the fundamental mechanism of translocation in the living cells of the phloem. Three theories are presently postulated. One theory supposes that phloem transport results from an osmotic-pressure gradient in the sieve tubes. Such a system might work as follows.

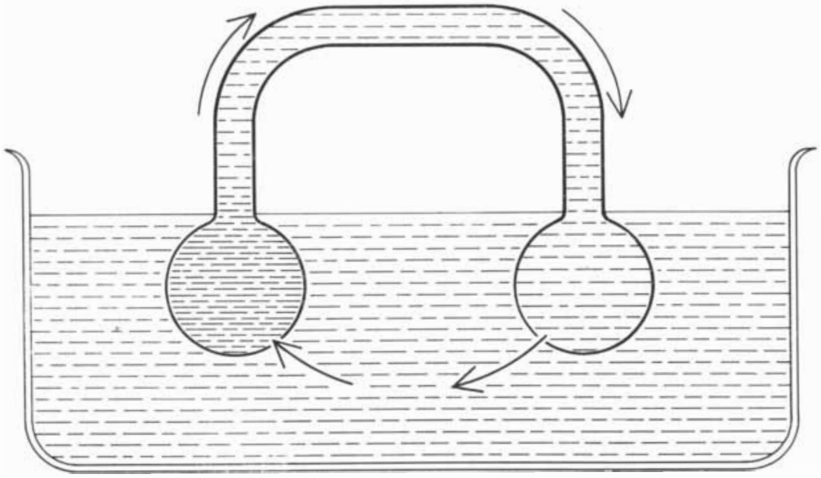
Consider two cells which have membranes permeable only to water, which are connected by a tube, and which are immersed in water [*see illustration below*]. One cell contains a solution of high osmotic pressure, such as a solution of sugar; the other contains only water. The osmotic pressure of the sugar solution will cause water to move into the first cell from the external solution. This will exert a pressure in the system and cause water to move out of the second cell. Moreover, solution will flow from the first cell through the tube into the second cell. In order for the flow to continue, however, sugar would have to be removed from the second cell and be replenished in the first.

In a living plant the first cell represents the sugar-manufacturing cells of the leaf, the second cell represents growing tissues where sugars are used (or storage organs where sugars are converted into starch), and the tube between the cells represents the sieve tubes of the phloem. The principle of the mechanism is sound, but it encounters two difficulties when it is applied to a plant. First, the forces required to move solution through the small pores in the sieve tubes at rates known to occur are greater than the pressure actually observed in plants. Second, it is difficult to see, within the limitations of what we presently know about the phloem, how the mechanism could account for the simultaneous upward and downward movement of various materials in the sieve tubes.

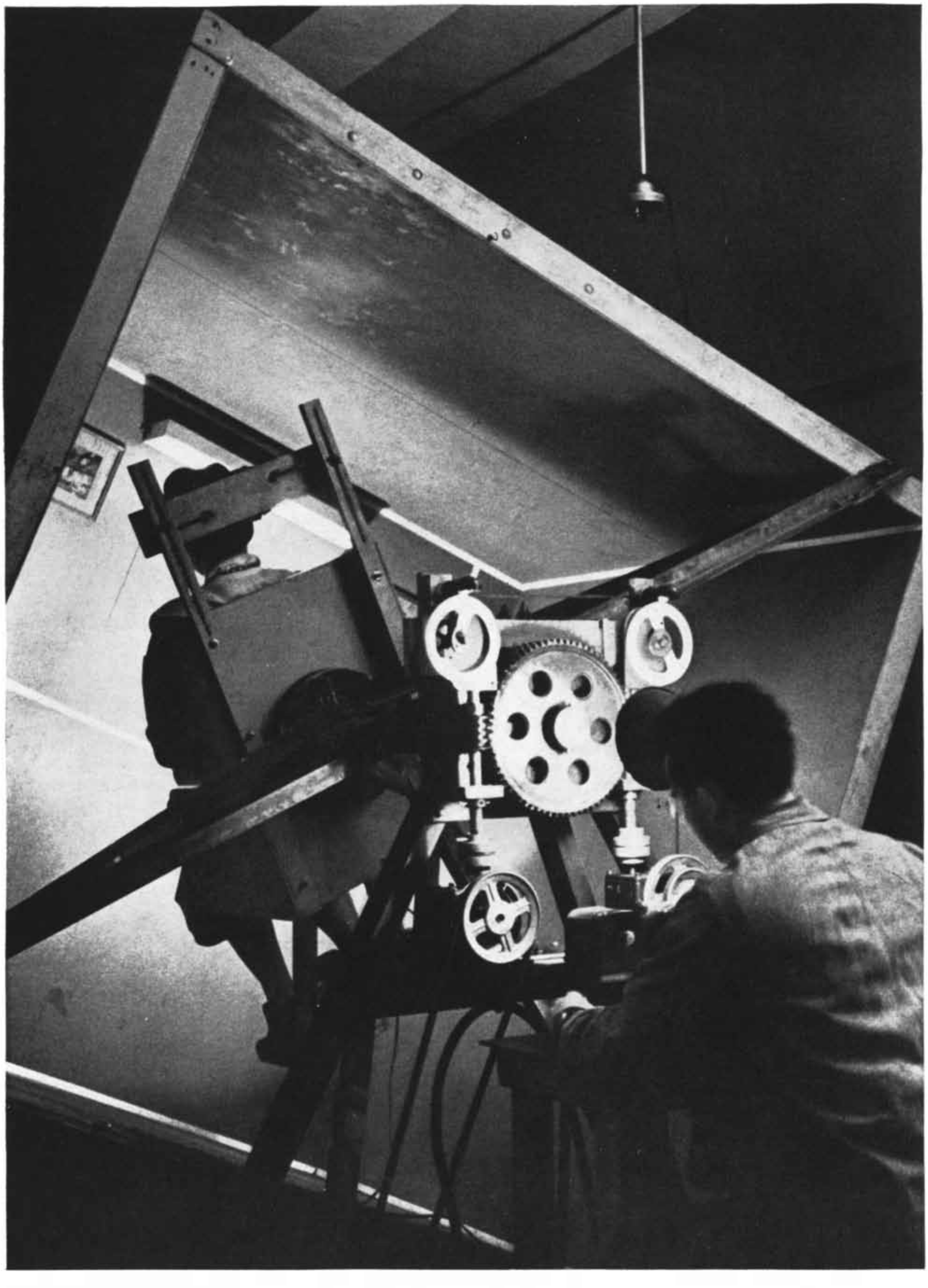
A second theory suggests that substances move through the sieve tubes by diffusion. Simple diffusion, however, would be much too slow to account for the observed rates of translocation. Accordingly it has been proposed that the diffusing molecules are somehow activated so that they are more readily transported, or offer less resistance to diffusion. Unfortunately such activation has not been demonstrated.

A third theory is that substances are carried in the phloem by actively moving or streaming protoplasm. Such streaming has been observed in many plant cells, but not in functioning sieve tubes. Recently, however, workers at the University of California have shown that the contents of a sieve tube surge from one end of the cell to the other.

Perhaps the explanation of translocation lies in a combination of these and other mechanisms. Possibly different substances move by different means. It is certain that any explanation must await a more complete understanding of the sieve tube itself. Unique among plant cells, the sieve tube continues to defy attempts to understand it because it is so readily injured by manipulation. It would seem that botanists must find more clever ways or new tools to unravel the mystery of how it functions.



ONE THEORY of how substances move through the sieve tubes of the phloem is illustrated. The cell at left contains sugar solution; the cell at right, water. The osmotic pressure of the sugar solution draws water through the cell membrane, exerting pressure in the system.



TILTING-ROOM-TILTING-CHAIR experiment engenders a conflict between the standards used in perception of the upright. With the vertical indicated by the room in disagreement with gravity, the subject is challenged to adjust her chair to the upright.

THE PERCEPTION OF THE UPRIGHT

How do we know which way is up? An investigation of this question has become a study of personality, because the way in which we perceive is related to what we are like

by Herman A. Witkin

All of us normally have a quick, automatic and correct sense of how we are located in space. We can tell without hesitation whether our bodies are upright or tilted, how much they are tilted and in what direction. This ready ability to orient ourselves to the vertical and horizontal axes of space has two bases. First, our bodies are acted upon by the force of gravity, the direction of which corresponds to the true upright. We apprehend the direction of gravity through the continuous postural adjustments we make to its pull. In addition to "feeling" our bodies, we see them against our surroundings. The "visual field," filled with prominent verticals and horizontals, provides our second basis for determining whether or not we are upright.

With equal ease and accuracy we can determine the positions of other objects. In hanging a picture on the wall, for example, we make it straight by comparison with our own bodies, as well as with the axes of the surrounding walls, ceiling and floor.

Ordinarily the two standards available for determining the upright coincide in direction. It is therefore impossible to tell at any given moment whether an individual is establishing his position on the basis of how his body feels, how well it "fits" its surroundings, or both. Nor can we know whether, in hanging a picture, he is guided predominantly by the conspicuous lines of the surrounding room or by the position of his own body.

The question with which we began our studies was orthodox enough: What is the relative importance of the two standards used in the perception of the upright? More than 15 years ago our laboratory, then at Brooklyn College, began a study of this problem. Today, at the Downstate Medical Center of the State University of New York, we are investigating personality development in children. These areas of research seem very far apart, yet the present work grew out of the original studies. (Our collaborators at various stages in the development of the research have been S. E. Asch, H. B. Lewis, M. Hertzman, K. Machover, P. B. Meissner, S. Wapner, H. F. Faterson, R. B. Dyk, D. R. Goodenough and S. A. Karp.)

The transitions in our work reflect a general change that has been taking place in the psychologist's approach to perception, the process by which we form impressions about ourselves and our environment. Earlier studies had been focused primarily on characteristics of the stimulus and on sense-organ and neural functioning. Today many investigations are concerned in addition with the personality of the perceiver: his motivations, emotions and defenses. Research stimulated by this more comprehensive approach has disclosed significant connections between perception and personality. Such findings have had an important impact on our theoretical notions. Moreover, because perception can be studied under manageable laboratory conditions, proof of its close association with personality has opened up a promising experimental route to personality investigation.

In our first experiment we set out to "separate" the gravitational standard of the upright from the standard provided by the visual field, with the aim of evaluating the importance of each. Among the several situations we devised for this purpose, two proved especially productive. The apparatus for one consists of a small room that the experimenter can tilt to any degree to the left or right, and a chair for the subject that also can be tilted to the left or right [*see illustration on opposite page and on next two pages*]. The structure and "interior decoration" of the room provide many clearly defined lines that accentuate its vertical and horizontal axes. With room and chair tilted by set amounts, the experimenter moves the chair at the subject's direction until the subject reports himself to be upright. The room—the limited world we have created for him—remains meanwhile in its initial tilted position. The conditions of the test thus separate the subject's two standards for judging the upright: the pull of gravity on his body and the direction of the tilted visual field are in disagreement. If, when he finally believes that he is "straight," the chair is close to the true upright, we may reasonably infer that he perceives body position primarily on the basis of sensations from within. On the other hand, if the chair is tipped far over toward the axes of the tilted room, he is determining body position mainly by reference to the visual field. His way of perceiving can thus be quantified, because he is required to carry out a measurable action that reflects his perception. The measure is the number of degrees he is tilted when he reports himself straight.

The second test enabled us to study individuals' perception of the "straightness" of objects apart from their own bodies. The subject sits in complete darkness, facing a luminous rod in a luminous frame; the rod and frame can be moved independently of each other [*see illustration on page 54*]. He sees them first in tilted positions. Then, while the frame remains tilted, he directs the experimenter to move the rod until it appears upright. In some trials the subject sits erect, and in others his chair is tilted to one side.

Here again the visual field and the subject's bodily sensations are in disagreement, each indicating a different vertical. If he reports that the rod is straight when objectively it is tipped far toward the tilt of the frame, he is relying primarily on the visual field. If, on the other hand, he adjusts it close to the true upright, he is relying mainly on body position, and is relatively independent of the visual field. When the subject sits erect, it is of course easier for him to utilize body position as a standard of reference. The degree of tilt of the rod gives us a measure of the subject's way of perceiving.

These and other experiments at first suggested that the visual field tends to play the more important role. Very soon, however, a most striking and unexpected finding began to emerge from our studies. We found that people differed considerably in their manner of perceiving the upright. So great was the range of individual variation that it was impossible to derive any general conclusion about the perception of the upright that would hold true for all members of an experimental group.

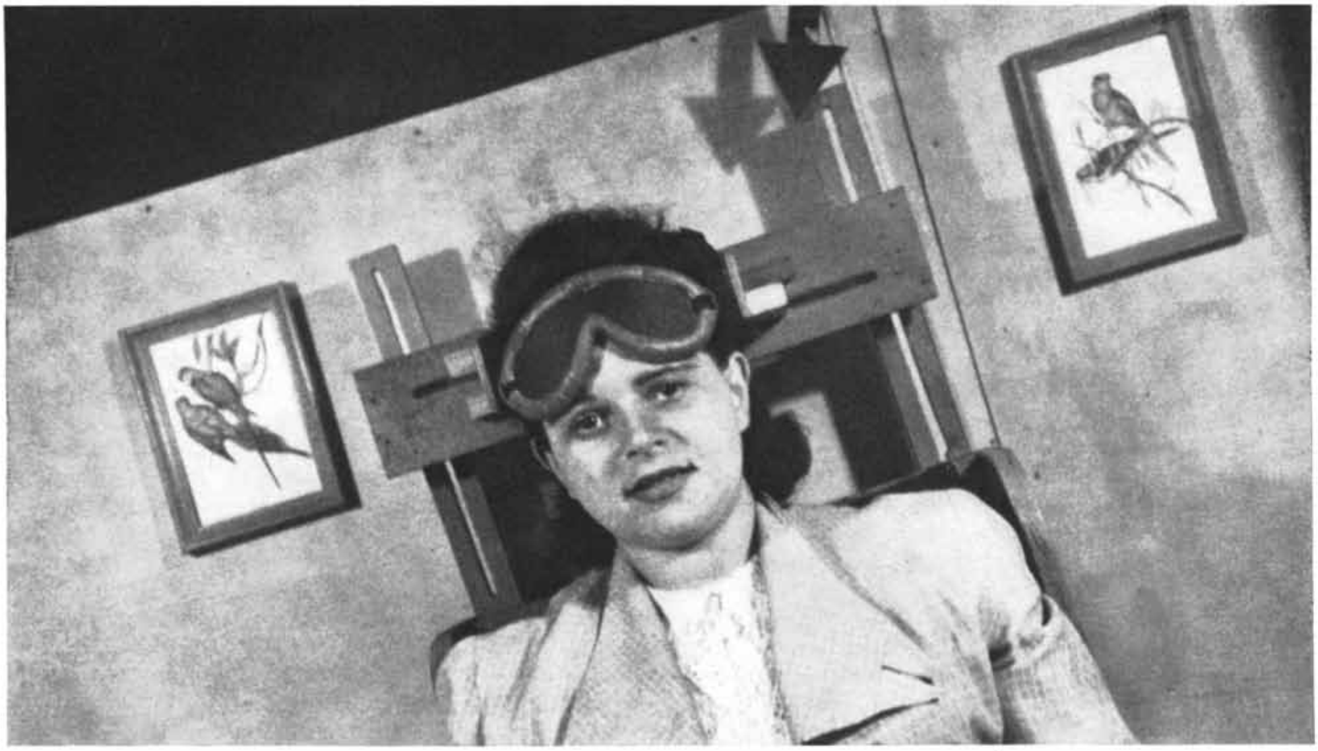
In the search for an upright body position some people were always able to bring the chair close to vertical no matter how much the room was tilted. Obviously their orientation depended to a high degree on bodily sensations, and was influenced hardly at all by the position of the visual field. At the other extreme, some people had to be more or less aligned with the tilted room before they could perceive themselves as upright. Tilted as much as 35 degrees (in one extreme case 52 degrees), they answered "Yes" when asked: "Is this the way you sit when you eat your dinner?" The impression of uprightness, though mistaken, was immediate and automatic. However, when such people closed their eyes ,they at once felt quite tilted. With their eyes still closed, they were able to bring themselves very close to the true upright. In this situation, providing the eyes are closed, anyone can adjust his body to the upright with little or no error. The marked differences among individuals manifested themselves only when the visual field had a chance to exert its influence.

Again, in establishing the position of the rod, some people were invariably able to bring the rod close to the true upright despite the extreme tilt of the frame. Other subjects saw the rod as straight only when it was aligned with the tilted frame and so was objectively far out of plumb.

We had set out to discover which of the two standards utilized in perception of the upright is the more important under various conditions, and we had found that our question was unanswerable. Instead we had encountered, under essentially identical conditions of stimulation, marked individual differences in spatial orientation. Such variation, it seemed clear, must stem basically from differences in characteristics of the perceivers, a possibility that had received little or no attention in traditional theories of perception. We decided to focus our subsequent investigations on a systematic study of the nature and origin of individual differences in perception.

Immediately we were confronted with the question: Does a person tend to determine the upright in the same way under various circumstances? We tested the same group of subjects in our series of orientation tests, and found them to be highly consistent in performance. Those who in the rod-and-frame test were able to adjust the rod close to the true upright by reference to body position were also able to make their bodies straight in the tilting-room-tilting-chair test. Others, consistently guided by the visual framework, tended to align the rod with the tilted frame and their own bodies with the tilted room. It is striking that the person perceives his own body and "neutral" external objects in a similar fashion.

Does a tendency toward one or the other of these ways of functioning characterize all of the individual's perception, and not his spatial orientation alone? To answer this question we tested the same group of subjects in a series of perceptual situations that in no way involve body position or orientation toward the upright, but do resemble the orientation



DEPENDENCE ON VISUAL FIELD is suggested by the angle of error between this subject's estimate of the upright, which is indicated by the position to which she has brought her chair, and the true upright, indicated by the vertical arrow above her head.

tests in requiring the separation of an item from its surrounding field.

One of these is the "embedded-figures" test, in which the subject is asked to locate a simple figure "hidden" within a large complex figure [*see illustration on page 55*]. People who tend to see the complex figure passively, in accordance with its dominant pattern, will of course have difficulty in locating the simple figure within it. We found that those who took a long time to discover the hidden figures were the same people who had tended to align their own bodies with the axes of the tilted room and to align the rod with the tilted frame.

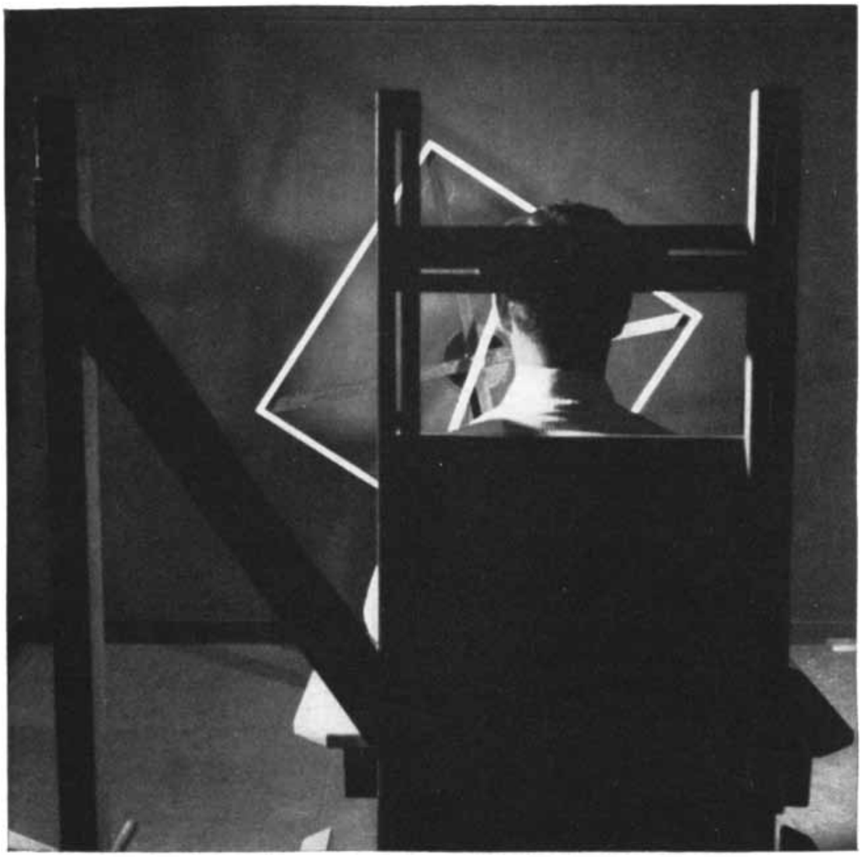
The finding of significant relationships between performance in the orientation tests and performance in the embedded-figures test (and other non-orientation tests) helped us define more precisely the nature of the individual differences we had observed. With only the results of the orientation tests available, we had characterized perception in terms of primary reliance on either bodily sensations or the visual field. Now we had a broader basis of classification. In each case our experimental situations required the individual to separate some item—be it his own body, a rod or a simple geometric figure—from its background or context; to "break up" and deal analytically with a given situation; to maintain an active "set" against the influence of the surrounding field. We designated as "field-independent" those who showed a capacity to differentiate objects from their backgrounds. Conversely, the "field-dependent" subjects were those whose performance reflected relatively passive submission to the domination of the background, and inability to keep an item separate from its surroundings. In the general population perceptual performances reflecting the extent of field-dependence or field-independence are ranged in a continuum rather than constituting two distinct types.

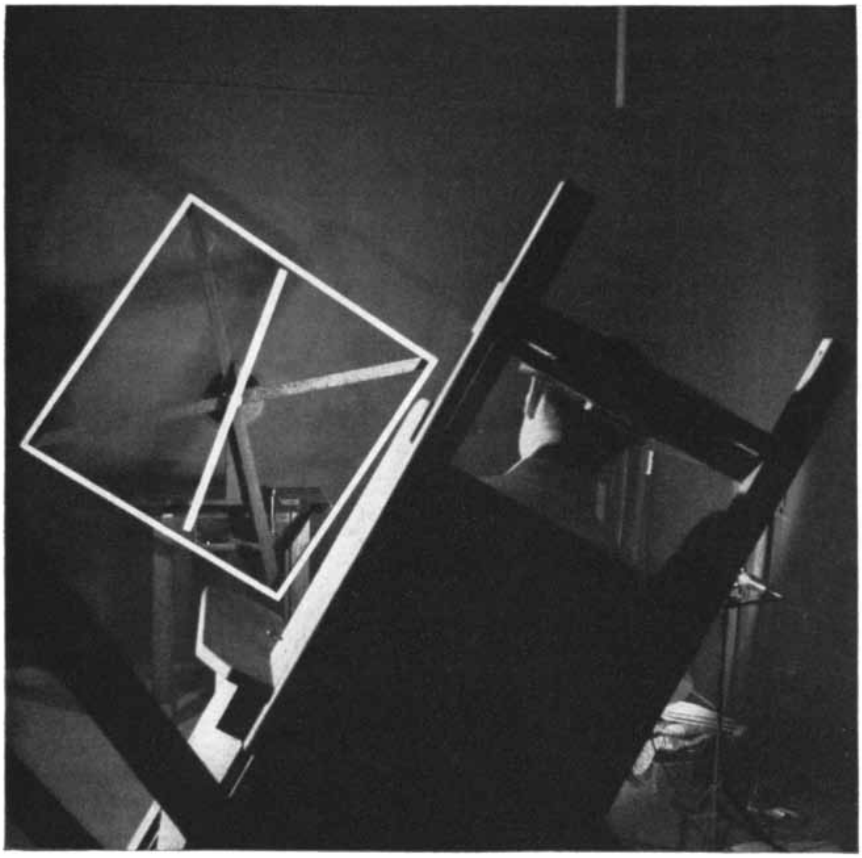
On the basis of this more comprehensive definition, we learned much more about characteristic styles of perceiving. We found a significant difference in perception between the sexes. Women as a group are likely to tip their bodies farther toward the axes of the tilted room, and the rod farther toward the axes of the tilted frame; and it takes them longer to discover the simple figures hidden in the complex designs of the embedded-figures test.

Investigations by ourselves and others have also shown that the way in which the individual perceives is an expression of a more general aspect of his functioning. Field-independent people, for example, excel at problems that require the isolation of essential components from a context and the recombination of these components in new relationships. Since our standard intelligence tests emphasize this kind of "analytical competence," field-independent children tend to achieve significantly higher I.Q.'s. We have been able to show that the higher I.Q.'s of such children result specifically from their relatively superior performance on those parts of intelligence tests that require such ability; they do not score significantly better than field-dependent children in questions concerned with vocabulary, information and comprehension. In the realm of social behavior various studies have shown that field-independent people are in general less dependent on others. They have greater ability to hold themselves apart from the pressures of their social environment, sometimes even to the point of isolation from other people. Ability to orient one's own body independently of the surrounding visual field, or to keep any object separate from its background, thus seems directly associated with capacity to function with relative autonomy of the social milieu in everyday life.

Our orientation tests had evidently tapped a source of important, deep-seated psychological differences among people. We determined next to investigate the origin and development of these differences. We began by studying changes in perception during growth. For this purpose we gave our battery of perceptual tests to separate groups of boys and girls of various ages between 8 and 20 years. At intervals over a period

INDEPENDENCE OF VISUAL FIELD, achieved by blindfolding the subject, here resulted in closer alignment of the body to the true upright. In adjusting the chair the subject could rely on the pull of gravity undistracted by conflicting visual field.





ROD-AND-FRAME experiment challenges the subject to bring the rod to the true upright despite the tilted position of the frame. The experiment is performed in the dark, with only the luminous frame and rod visible, and with the chair upright (*top*) or tilted (*bottom*).

of years we tested one group from the time they were 8 until they had reached 13, and another group from age 10 to age 17. These studies all led to the same conclusion: Children tend to be field-dependent early in their perceptual development and to become field-independent as they grow up [*see charts on page 56*]. The ability to determine the position of the body apart from the tilted room, to perceive the position of a rod independently of the tilted frame, to pick out a simple figure obscured by a complex context—all improve, on the whole, as the children become older. The change was particularly marked in the 8-to-13-year period. After this there was a tendency to level off, and even a slight tendency to regress.

Within these average trends the children showed marked differences at every age level. At the same time, all of the children we were able to follow over a seven-year period showed high stability of performance. They tended to maintain their same relative positions within the group as they grew older, even though averages for the group changed with age. These findings suggested that the child's perceptual style tends to be established early in life, and to remain relatively stable.

The field-dependent mode of perception is thus identified with earlier stages of growth and in this sense is more primitive. We were led by this finding to the general hypothesis that children who remain field-dependent, in comparison with most children their own age, may have made less progress in their general psychological development. Extensive personality studies confirmed this hypothesis.

Each child was evaluated by an interview and a series of projective tests (the Rorschach, Figure Drawing and Thematic Apperception tests, and a miniature-toy play situation). The psychologists knew nothing about how the children had performed in the perceptual situations. Guided by the general hypothesis of the study, however, they devised from these tests a series of "indicators" of relevant personality characteristics. The correlations found between these indicators and performance on the perception tests were checked by repeating the study with a new group of children.

In general these studies show that the organization of the personality of the field-independent child is more complex. He usually has a more definite sense of his role and status in the family. He tends to be more aware of his own needs and attributes and also of the needs and attributes of others. In terms of his age group he is usually able to function with greater independence in a variety of situations. The defenses and controls he has available to channel his impulses and direct his actions are generally better developed. More often than his field-dependent contemporaries he shows a desire and a capacity for active striving in dealing with his environment. His interests tend to be both wider and better developed.

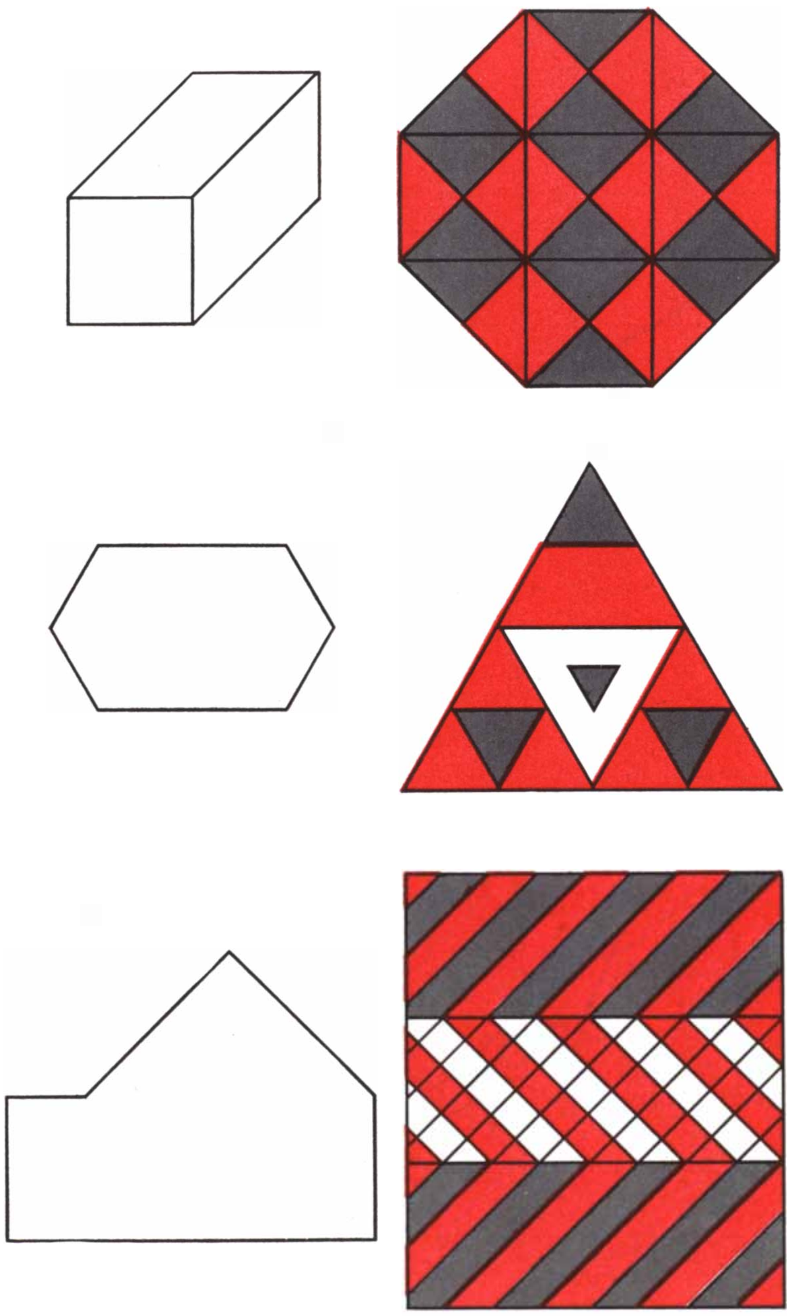
It would be a mistake to infer that these traits necessarily imply better adaptation to life situations, or absence of pathology. Maladjusted children are found in both the field-independent and field-dependent groups. Personality disturbances in field-dependent children, however, tend to be of the kind that stem from relatively primitive, amorphous, chaotic personality structure. In field-independent children personality disturbance is more likely to take such forms as over-control, over-intellectualization and isolation from reality. Perceptual style does not by itself indicate whether a child will have a "healthy" personality; it may, however, suggest the form that pathological developments may take.

Searching deeper for the source of these basic differences among children, we asked ourselves: To what extent may constitutional characteristics of children contribute to the differences? To what extent are the differences determined by the life experiences of children, both in the family and in society, in the course of growing up? To answer these questions a broad program of research is clearly required. We considered the study of mother-child relationships to be a particularly good starting point. We based the undertaking on the hypothesis that children with a field-dependent style of perceiving are likely to have been hampered in their opportunity for psychological growth.

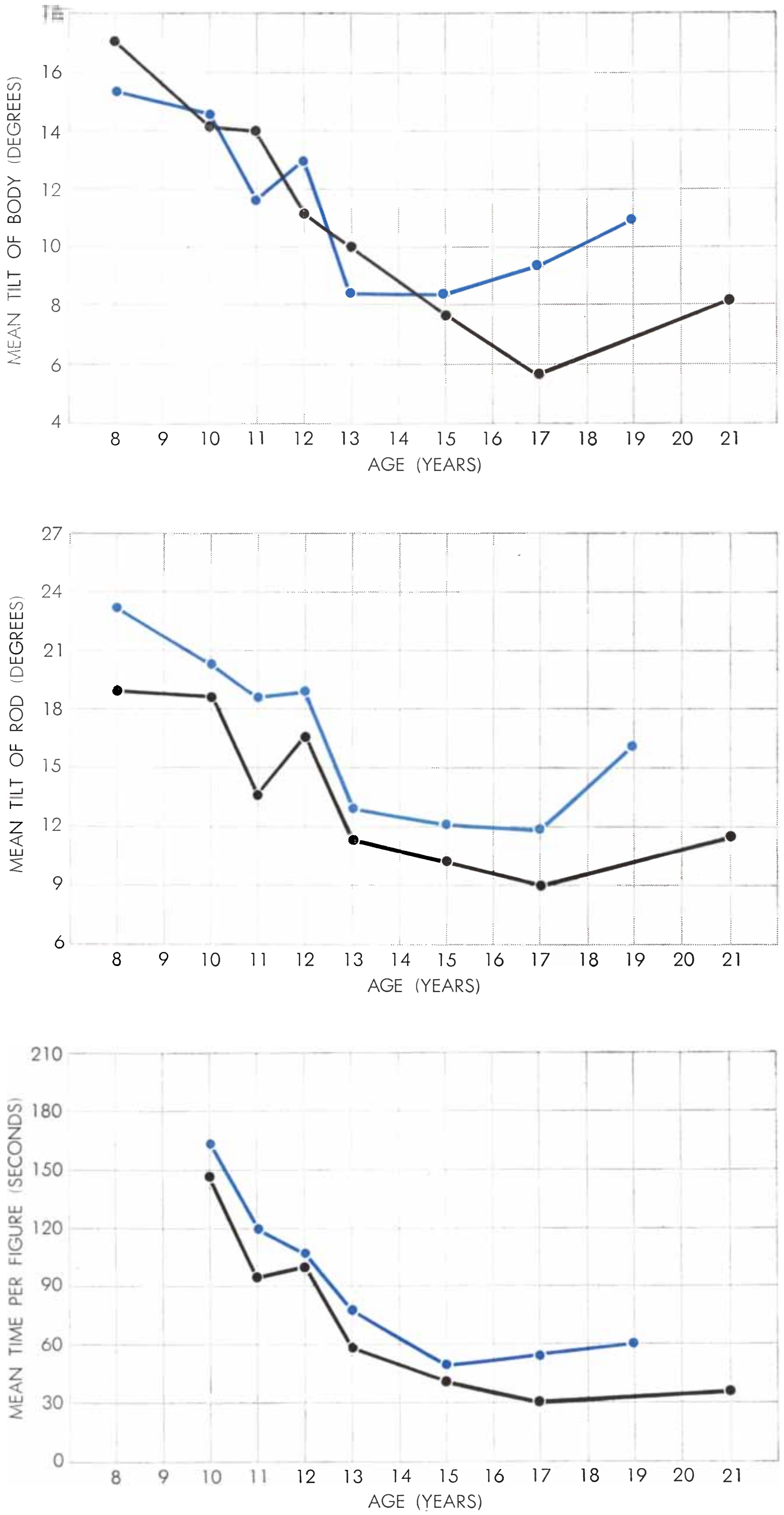
A group of 10-year-old boys whose perception, intelligence and personality we had already studied intensively were the subjects for this attempt. Each boy's mother was interviewed at home by an interviewer who did not know the child or the child's test results. The interviewer evaluated each mother's role in relation to her son in terms of whether it was predominantly "growth-constricting" or "growth-fostering." The method of evaluation may be better appreciated in the light of a few of the criteria by which a mother would be judged as growth-constricting: Because of fears and anxieties about her child, or especially strong ties to him, she markedly restricts the child's activities; her dominance and control are not in the direction of helping the child achieve increasing responsibility; her physical care of the child seems inappropriate to his age; she limits the child's curiosity and stresses conformity.

The classification of the mothers turned out to be significantly related to the children's perceptual performance. Boys with a field-dependent style of perceiving more commonly had mothers who were characterized as growth-constricting; field-independent boys more often had mothers characterized as growth-fostering.

Of course differences in early-life experiences do not tell the whole story. Constitutional differences among children may also be extremely impor-



EMBEDDED-FIGURES experiment challenges the subject to find the patterns shown at left in the more complex patterns at right, and thereby tests his ability to perceive the visual field analytically. Facility at this task is correlated with ability to establish the upright independently of the visual field in the tilting-room and rod-and-frame experiments.



AGE CURVES for boys (*black*) and girls (*colored*) in tilting-room (*top*), rod-and-frame (*middle*) and embedded-figures (*bottom*) experiments show progressive development in the direction of "field-independence" (that is, increasing capacity to overcome the influence of the surrounding field) as children grew older. Boys tend to be more "field-independent" than girls, and both sexes show a slight shift toward "field-dependence" in late teens.

tant. Hence, parallel to our investigations of mother-child relationships, we have recently begun studies that may shed light on the possible connection between characteristics observed in infancy and the kinds of pervasive differences we found in later development.

The question of how we perceive the upright, with which we began, can now be seen as woven into the total fabric of an individual's adaptations and as related to the complex of experiences that have shaped this development. The finding of connections among areas of psychological functioning formerly considered quite unrelated suggests that even circumscribed perceptual processes need to be studied in the context of the individual's general psychological characteristics. The characteristics of the perceiver, however, do not constitute the sole determinants of perception. It would indeed be a mistake to conclude that each of us experiences a world of his own making. Our perceptions are basically anchored to "what is there," and they are significantly dependent on the particular kinds of sensory and neural equipment we possess. At the same time people have well-established, preferred ways of perceiving, attributable to variations in individual psychological organization and making for individual differences in perception under essentially the same conditions of stimulation. These preferred ways of perceiving are an integral, ever-present part of the individual's psychological make-up. Under some conditions, when the situation is vague and contains conflicting elements, they may play a large role in determining the perceptual outcome. Under other circumstances, as when the situation is clear and compelling, they may have no more than minimal expression.

The intimate linkage between perception and personality makes available a very useful approach to the experimental study of personality. Since the individual's responses in diverse situations all reflect a common core of personal attributes, his characteristic way of functioning can be identified by study of any one area of activity. Moreover, as we have seen in our work, perception lends itself to objective study under conditions that permit ready manipulation and control. This is not to suggest that such procedures should replace the methods devised by the clinical psychologist. With the further development and integration of both experimental and clinical methods, great forward strides are in prospect for the study of human psychology.

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To the suavity customary in those who model men's wear, our three gentlemen above add authenticity. Alan Bell (left, Ph.D., McGill University, 1937) and Charles Kibler (center, Ph.D., University of Virginia, 1939) directed the first synthesis of the *Kodel* polymer in the laboratories of Tennessee Eastman Company—a true linear polyester containing a chemical group not previously present in polyesters. Emmett V. Martin (right, Ph.D., University of California, 1932), now a physicist, once wrote a paper (*Plant Physiol., 10*, 613-636) entitled "Effect of Artificial Wind on Growth and Transpiration in Helianthus Annuus." (That's the common sunflower.) He led the way to the unique physical structure of the *Kodel* fiber.

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

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Later other scientists in turn covered themselves with glory by discovering that for photographic exposure this was not strictly true, and still others won Ph.D.'s by explaining why not. Intensity and duration slip the shackles of reciprocity a little. Over the broad spectrum of durations from millimicroseconds to months, a certain optimum rate of feeding energy to a silver halide emulsion is encountered. The manufacturer can roll the optimum somewhat one way or the other.

Calls for shifting it to favor the effectiveness of very dim light come from astronomers, among others. From an observatory director's viewpoint, cutting hours off exposures is like having more telescopes.

Business is brisker, though, on the other end of the scale. To more and more users of photography a hundred-thousandth of a second sounds like a terribly long time. Well-read types, they fear the deviation from reciprocity. To allay those fears, we offer them something new to read, a free pamphlet bearing the title "Kodak Films for Short Exposure-Time Applications."

It is obtainable from Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.

Months to seconds

A *Cine-Kodak Special Camera* made most of the movies you have ever seen of a bean developing into a bean plant or a cow pasture developing into a steel plant. The *Cine-Kodak K-100 Camera*, which lists from $299, can likewise be adapted for this technique. No great resources in mechanical skills or facilities are demanded.

Mr. Fred O'Brien, Eastman Kodak Company, 400 Plymouth Avenue North, Rochester 4, N. Y., can tell you how to go about it.

Prices shown are subject to change without notice.

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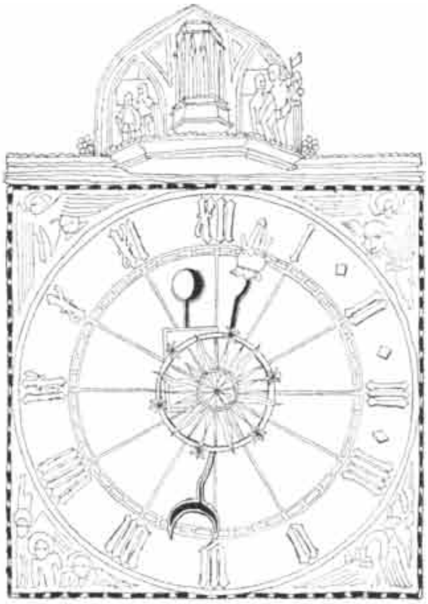
SCIENCE AND



Escape from the Earth

The Soviet rocket now in orbit around the sun represents man's second qualitative step into space. By achieving a speed of seven miles per second, the rocket was freed from the gravitational field of the earth. The rockets that had launched the artificial earth satellites needed only to reach a speed of somewhat less than five miles per second. With speeds of 7½ to 8½ miles per second, rockets will be able to coast to any part of the solar system.

The orbit of the Soviet solar rocket is roughly the same as that of the earth, though more elliptical. The distance of the earth from the sun varies between 91,500,000 and 94,500,000 miles. The rocket will approach to within 91,500,000 miles of the sun and recede to 123,250,000 miles. Its "year" will be about 15 months. Thus as it travels around the sun the rocket will fall behind the earth. The earth will catch up with it about 920 days after launching. It is unlikely, however, that the rocket will ever come to earth again, because of perturbations introduced into its orbit by other planets.

The solar rocket, weighing 3,245.2 pounds, was the ninth vehicle successfully placed in orbit. The roster of the other eight:

Sputnik I (1957 Alpha). Launched October 4, 1957. Payload (weight of satellite proper) 184.3 pounds; total weight in orbit about 1,100 pounds; first apogee 560 miles; first perigee 156 miles; orbital period 96 minutes. Burn-up of rocket early December, 1957; of satellite, early January, 1958.

Sputnik II (1957 Beta). Launched November 3, 1957. Payload 1,120 pounds; total weight in orbit about 7,000 pounds; first apogee 1,056 miles; first perigee 145 miles; orbital period 103.7 minutes. Burn-up April 13, 1958.

Explorer I (1958 Alpha). Launched January 31, 1958. Payload 18.1 pounds; total weight in orbit 30.8 pounds; first apogee 1,575 miles; first perigee 219 miles; orbital period 115 minutes. Expected lifetime: several years.

Vanguard I (1958 Beta). Launched March 17, 1958. Payload 3.25 pounds; total weight in orbit 29 pounds; first apogee 2,513 miles; first perigee 220 miles; orbital period 135 minutes. Expected lifetime: 200 years.

Explorer III (1958 Gamma). Launched March 26, 1958. Payload 18.1 pounds; total weight in orbit 30.8 pounds; first apogee 2,100 miles; first perigee 120 miles; orbital period 121 minutes. Burn-up June 27, 1958.

Sputnik III (1958 Delta). Launched May 15, 1958. Payload 2,925 pounds; total weight in orbit 7,000 to 9,000 pounds; first apogee 1,160 miles; first perigee 123 miles; orbital period 106 minutes. Burn-up of rocket December, 1958; burn-up of satellite expected February or March, 1959.

Explorer IV (1958 Epsilon). Launched July 26, 1958. Payload 25.7 pounds; total weight in orbit 38.4 pounds; first apogee 1,368 miles; first perigee 178 miles; orbital period 110 minutes. Expected lifetime: some years.

Atlas (1958 Zeta). Launched December 18, 1958. Payload about 150 pounds; total weight in orbit 8,800 pounds; first apogee 925 miles; first perigee 114 miles; orbital period 101 minutes. Expected lifetime: eight weeks.

Organized Knowledge

A plan to make the swelling flood of scientific information more readily accessible to the nation's scientists and engineers has been proposed by the Science Advisory Committee and approved by President Eisenhower. No new agency will be created; the National Science Foundation will carry out the program.

The task is stupendous, points out James R. Killian, Jr., chairman of the Science Advisory Committee. There are now published throughout the world each year 55,000 journals containing some 1,200,000 significant articles in the physical and life sciences. In addition, more than 60,000 scientific books and approximately 100,000 isolated research reports are published annually. The problem is to provide answers to the man who asks: What is being published now? Where can I find it? How can I get it?

Rather than have the National Science Foundation establish a national translation and abstracting center, as the U.S.S.R. has done, the Science Advisory Committee wants to coordinate and bolster the information services that already exist in the U. S. Under this plan the Science Foundation would help finance the publication of journals and monographs. It would sponsor the preparation of world-wide lists of scientific publications, classified by subject and indexed. It would encourage the translation of papers from Russian, Japanese and other languages that few U. S. scientists read. And, looking to the future, it would support research on better methods of storing, indexing and retrieving information.

Research Headquarters

The U. S. Government will coordinate its support of scientific research and development through a new agency, the Federal Council for Science and Technology. Agencies already involved in research and development will contribute members to the council. The chairman will be James R. Killian, Jr., who is also head of the President's Science Advisory Committee [*see above*].

I. G. Y.: The Summing up Begins

The International Geophysical Year, which officially ended at midnight on December 31, has left an enormous heritage of observations that are still being accumulated at three world data-centers. While these facts will be studied for years, they have already changed man's concept of the earth. Some of the most important findings are described in two recent issues of *Science* by Hugh Odishaw, executive director of the U. S. committee for the I.G.Y.

Odishaw estimates that 20,000 to 30,000 scientists, engineers and technicians, representing 66 nations, were involved in I.G.Y. There was perhaps an equal number of volunteer observers. Original plans called for fewer than 2,500 research stations; actually there were about 4,000, not including temporary stations. The U. S. alone spent about $100 million, excluding the cost of logistic support. Including logistic support, the total world-wide cost may have amounted to $7.5 billion.

As had been anticipated, solar activity reached a peak during the 18-month I.G.Y. period. Not since 1778 had sunspots been so numerous. Throughout the period there were about 40 world-wide alerts, during which investigators were able to synchronize on a grand scale their observations of the terrestrial effects of solar activity.

Some of the findings that Odishaw picks for special mention are as follows:

The magnetic fields associated with sunspots are much stronger than had been suspected. They are about 8,000 times as powerful as the field at the earth's equator.

There seems to be a cosmic-ray cycle that lags somewhat behind the sunspot cycle. When sunspots are at a peak, cosmic-ray intensity is low.

Clouds of charged particles ejected by the sun apparently give rise to strong magnetic fields in space, that deflect westward the cosmic rays that approach the earth.

The existence of an earth-girdling electric current—the equatorial electrojet—has been confirmed. There are two other electrojets, one in the upper atmosphere near each pole.

The ozone layer and the other layers of the ionosphere that affect radio communication persist through the long Arctic and Antarctic nights, despite the absence of the solar radiation that causes the ionization.

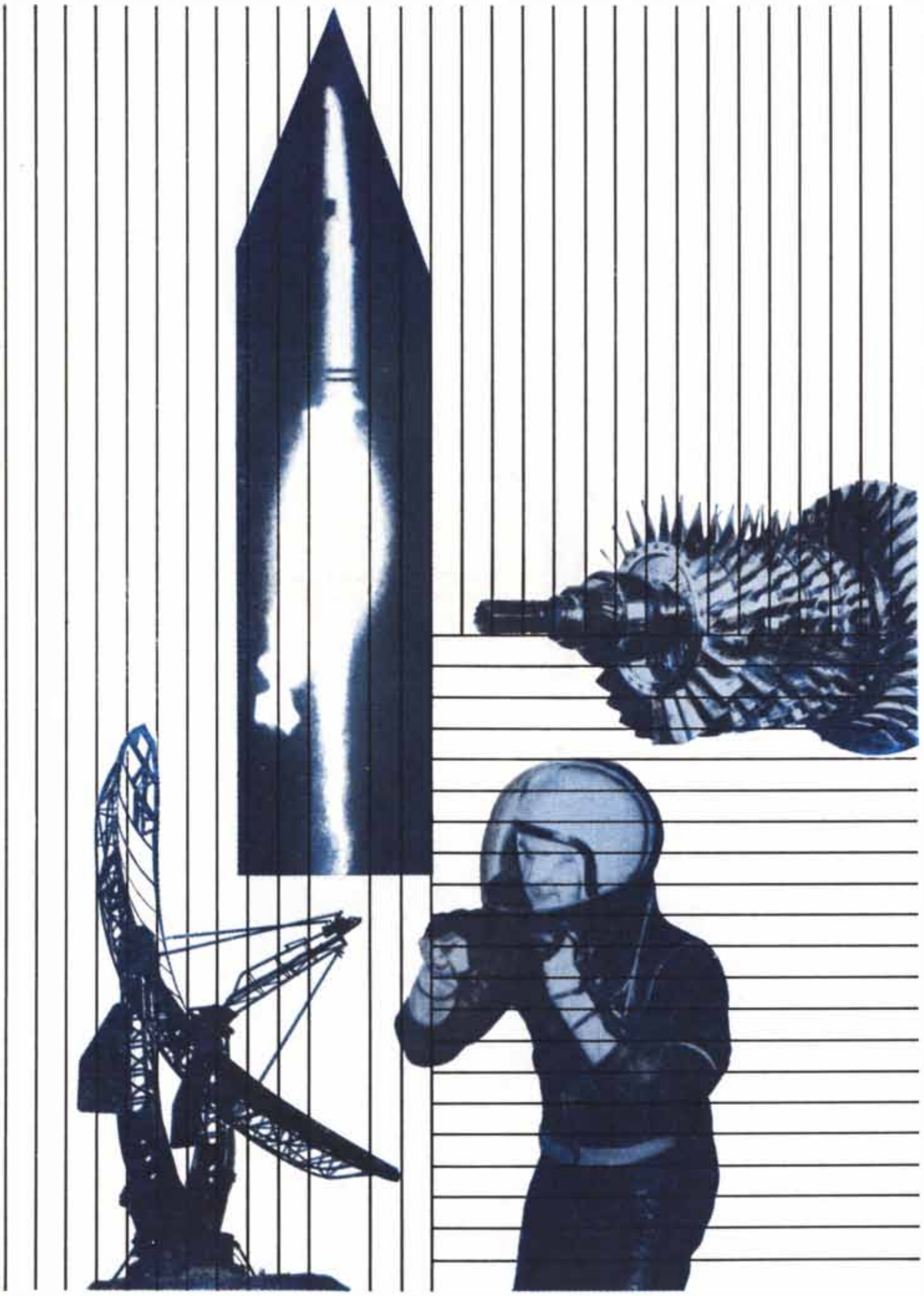
A record low temperature of at least 124 degrees below zero Fahrenheit was recorded by Soviet meteorologists 400 miles from the South Pole.

The polar regions, however, seem to be getting warmer. The mean annual temperature has risen five degrees at Little America and 10 degrees at Spitsbergen during the last half-century.

A newly discovered undersea mountain range in the Arctic Basin helps to explain why Arctic waters mix very little with neighboring seas.

Measurements in the Antarctic indicate that there is a total of some 4.5 million cubic miles of ice on earth, 40 per cent more than had previously been estimated.

There is a strong possibility that Antarctica may be two continents separated



by water. Scientists have found one undersea trough extending inland from Ellsworth Station which may connect with another that starts inland from the Ross Sea.

Science Teaching in the U.S.S.R.

The debate over the teaching of science in the U. S. is apparently paralleled by a similar debate in the U.S.S.R. When Premier Khrushchev recently called upon Soviet educators to strengthen ties between the schools and "life," Ia. Zel'dovich and A. Sakharov wrote a long letter to *Pravda* on the training of scientists-to-be at the secondary-school level.

Zel'dovich and Sakharov make a suggestion that has been independently discussed in the U. S., namely, that gifted students be enrolled in special science-mathematics schools for accelerated training. Their thesis is that boys and girls with mathematical or scientific talent spend too many years in ordinary schools in view of the fact that mathematicians and theoretical physicists are often most productive in their early twenties. They recommend the segregation of such students at 14 or 15 in schools that emphasize mathematics, physics and chemistry, perhaps to the virtual exclusion of humanities.

Whether or not such special schools are set up, Zel'dovich and Sakharov urge that the high-school mathematics curriculum be drastically revised. Their recommendations parallel efforts now under way in the U. S. to modernize the high-school mathematics course [see "The Teaching of Elementary Mathematics," by E. P. Rosenbaum; SCIENTIFIC AMERICAN, May, 1958]. Zel'dovich and Sakharov criticize Soviet secondary schools for the mathematics they teach and also for what they fail to teach. Algebra, they say, is taught in a very cumbersome way, with much time spent on special problems, while probability theory is not even introduced in an elementary way. Euclid is treated thoroughly, but not analytic geometry. There is too much emphasis on some aspects of trigonometry, and no mention of vector analysis.

They also point out that secondary-school students can grasp some important concepts of higher mathematics. Students can be taught some calculus, including differentiation, integration and the solution of simple differential equations. They would like to have students made familiar with electronic computers.

Physics is taught somewhat better than mathematics in the Soviet Union,

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according to Zel'dovich and Sakharov, but there is room for improvement. Quantum physics should, for example, be introduced at the high-school level by laboratory demonstrations followed by "chalk physics."

The Biggest Accelerator

An atom-smashing machine that will accelerate protons to the unprecedented energy of 25 billion electron volts (bev) is nearing completion at Brookhaven National Laboratory on Long Island. When it is finished next year, it will be by far the most powerful accelerator in the world, although physicists in the U.S.S.R. have announced that they are planning a 50-bev machine of similar design.

The Brookhaven accelerator, called an alternating-gradient synchrotron, will be the first machine to use the strong-focusing principle. A ring of 240 magnets will alternately pinch and spread the stream of protons, producing as a net effect a sharply focused beam. The strong-focusing design is economical of magnets: the new machine will use only 4,000 tons of magnet steel. In contrast, the 10-bev synchrophasotron in the U.S.S.R. uses 36,000 tons; the 6.2-bev bevatron at the University of California, 10,000 tons.

The Brookhaven accelerator will nonetheless be immense. The circular vacuum chamber in which the protons will be accelerated looks more like a subway tunnel than part of a scientific instrument. It is 18 feet high, 18 feet wide and half a mile in circumference. It is buried under a layer of earth that serves as a radiation shield and also helps an air-conditioning system keep the temperature within a range of four degrees Fahrenheit.

Protons will be whirled 260,000 times around this circular course, a total distance of 130,000 miles. When they have attained an energy of 25 bev, they will be deflected from the tunnel into an experimental area backed up by a thick dike of earth.

The design and construction of the machine were described in a recent issue of *Science* by R. A. Beth and C. Lasky of the Brookhaven accelerator development department.

The Ultraviolet Sky

If the human eye were sensitive only to ultraviolet radiation, and if the earth had an atmosphere transparent to such radiation, what would the sky look like? This picture is now being painted in detail by Aerobee rockets bearing

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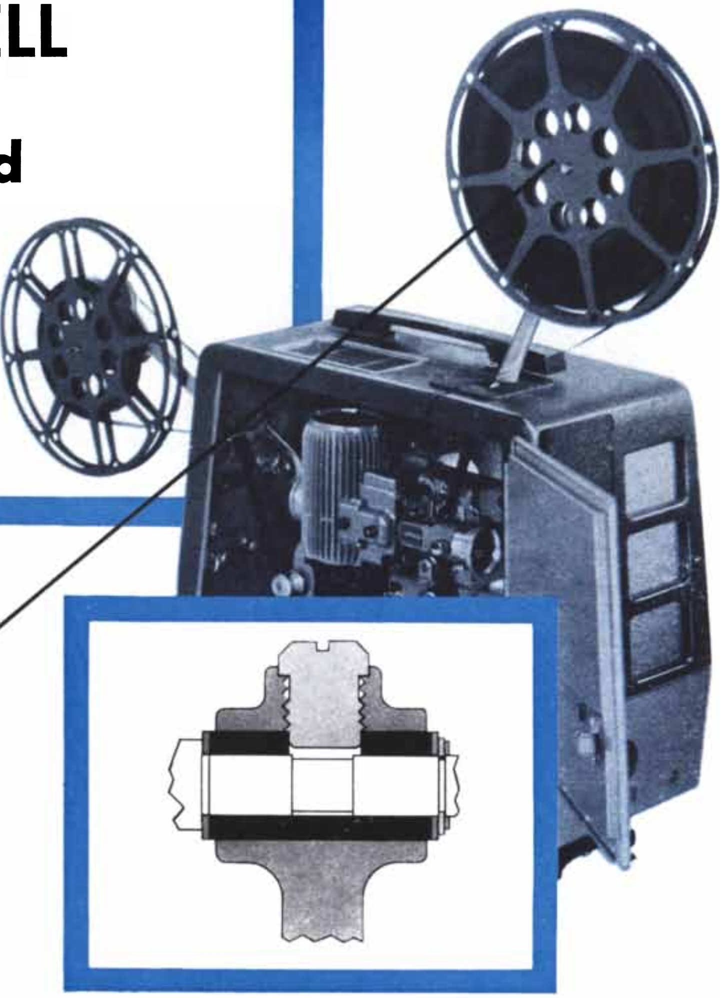

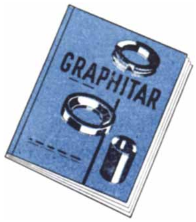

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GRAPHITAR® CARBON-GRAPHITE • GRAMIX® POWDERED METAL PARTS • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES aloft photon counters sensitive to the ultraviolet waves between 1,225 and 1,350 angstrom units in length. It is described in *The Astrophysical Journal* by James E. Kupperian, Jr., Albert Boggess III and James E. Milligan of the Naval Research Laboratory.

The most striking features of the ultraviolet sky are several brilliant regions that emit little, if any, visible light. Most seem to be clouds centered on certain extremely hot bluish stars, but the stars themselves apparently do not emit much ultraviolet. One of the most interesting features is a circular region around the star Alpha Virginis, or Spica. Kupperian, Boggess and Milligan point out that the classical theory of gaseous nebulae cannot explain the glow of this region. They eliminate the possibility that the ultraviolet radiation could result from the recombination of ions. More likely it is caused by the collision of fast-moving particles ejected from the star.

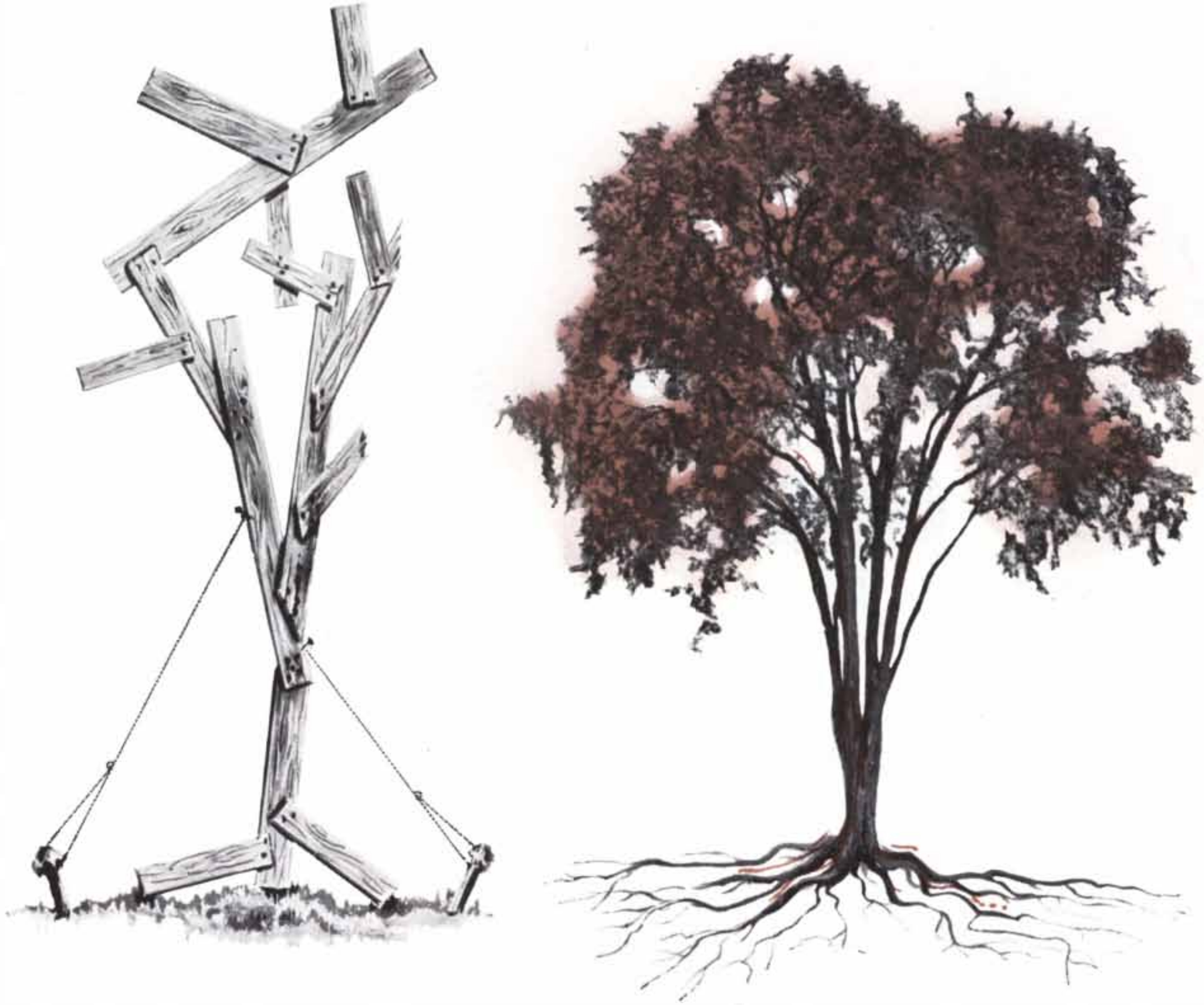
Plutonium Saga

The complete story of the discovery of the synthetic element plutonium and the hectic wartime effort to manufacture it as a nuclear explosive is told for the first time in a new book, *The Transuranium Elements*. The author is Glenn T. Seaborg, who won a Nobel prize largely for the part he played in the work.

The investigation of plutonium was cloaked in secrecy from the very beginning, even before the Government started to support it. At the end of 1940 Seaborg, A. C. Wahl and J. W. Kennedy made the first trace amounts of the metal by bombarding uranium oxide with deuterons in the University of California's 60-inch cyclotron. The results, submitted for publication to *The Physical Review*, were locked up by the editors and not published until 1946. Seaborg and his associates also imposed secrecy. Throughout 1941 they referred to the new element by the code name "copper." Some confusion arose when they had to use real copper in their experiments. For a while they had to distinguish between "copper" (*i.e.*, plutonium) and "honest-to-God copper" (*i.e.*, copper).

Early in 1942 the problem of producing plutonium in quantity was turned over to the newly organized Metallurgical Laboratory, forerunner of the Argonne National Laboratory. The task seemed almost insuperable; all that was known about plutonium chemistry was based on secondary evidence from tracer experiments.

By December, 1943, scientists at the



Metallurgical Laboratory and chemical engineers of E. I. du Pont de Nemours & Co. had finished development work on the purification process for the Hanford plutonium factory. They built a pilot plant on a microscopic scale, for at that time the total amount of plutonium available weighed less than two milligrams. The scale-up from pilot plant to full production was a billion to one, surely the greatest in technological history.

Seaborg recalls that when his group was first precipitating pure salts of plutonium they had a constant stream of visitors eager to see the new element. Not being able to afford to immobilize any of their scant supply, the scientists colored some bits of aluminum hydroxide with green ink and exhibited them, remarking: "This *represents* a sample of plutonium hydroxide." The impressed visitors naturally interpreted the remark as: "This *is* a sample of plutonium hydroxide." The investigators made an exception when Brigadier General Leslie R. Groves, head of the Manhattan Engineer District, paid them a visit. They collected all their plutonium and put it under a microscope. Groves looked through the microscope and said: "I don't see anything."

The Physics of Whips

Men were creating supersonic shock waves millennia before their projectiles and aircraft broke through the sound barrier. It seems that the crack of a whip occurs when its tip exceeds the speed of sound, and not when leather slaps against leather. This fact is revealed by an experimental and theoretical study of bullwhip dynamics made by three physicists at the Naval Research Laboratory in Washington, D.C.

With the cooperation of a team of theatrical whip-crackers, they photographed the tip of a 12-foot leather bullwhip. High-speed photographs made at 4,000 frames per second demonstrated that the tip moved at about 1,400 feet per second: some 25 per cent faster than sound. Shadow pictures clearly showed shock waves flowing from the tip.

The physicists explain that the cracking process starts with a sharp loop formed near the handle of the whip. As the whip-wielder's hand bears down on the handle, adding energy, the loop is propagated as a wave toward the tip. It moves faster and faster until finally the energy is concentrated near the tip.

The authors of the report, B. Bernstein, D. A. Hall and H. M. Trent, published their findings in *The Journal of the Acoustical Society of America.*

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Alfred Russel Wallace

This great 19th-century naturalist and Charles Darwin simultaneously announced the theory of evolution by means of natural selection. He later went beyond Darwin in applying the theory to human evolution

by Loren C. Eiseley

The year was 1852. Alfred Russel Wallace stood in a leaking longboat of the brig *Helen* over 1,000 miles from the port of Pará and watched almost everything he had collected or thought about through four years in the depths of the Amazon jungle burning before him. Flames leaped from shroud to shroud of the abandoned vessel. Monkeys screamed and ran into the heart of the fire. Fire roared in his collections below decks, and ate at the masts until they fell. Only a single parrot, clinging to a burning rope on the bowsprit, dropped into the sea and was saved.

In the boats the men watched through the night, hoping that the pillar of flame would swing a passing ship out of her course to pick them up. The dawn came, charred and vacant. They were alone on the heaving sea with a limited supply of water and food.

Wallace watched while the captain set a course for Bermuda. The naturalist who was destined to take his place, seven years later, by the side of Charles Darwin as one of the great scientists of all time, ate a biscuit numbly and helped the others bail the leaking boat. If he survived, he would return to England as poor as when he had journeyed out to South America four years before.

He had lost his younger brother Herbert to yellow fever. It might have been better to have stayed and rotted with the other eccentrics in the fever ports of the tropics. There was a luck in these things. It had been with him on the great river and in the camps of half-wild savages, but now, if there should be a storm, if they should be becalmed until the water ran out. . . . Ten days later, on short rations and still 200 miles from Bermuda, the entire crew was picked up by a passing vessel bound for London.

Wallace was, after all, coming home. His luck still held, but it was poor man's luck. He was 29 and the forests and islands of the Malay seas were still ahead of him. There was, perhaps, only one gain: in his long, difficult traverses over the watershed of the world's greatest river, he had come to realize the enormous diversity of life, and how that diversity seemed related to geographic barriers often represented by the confluent fingers of the huge river.

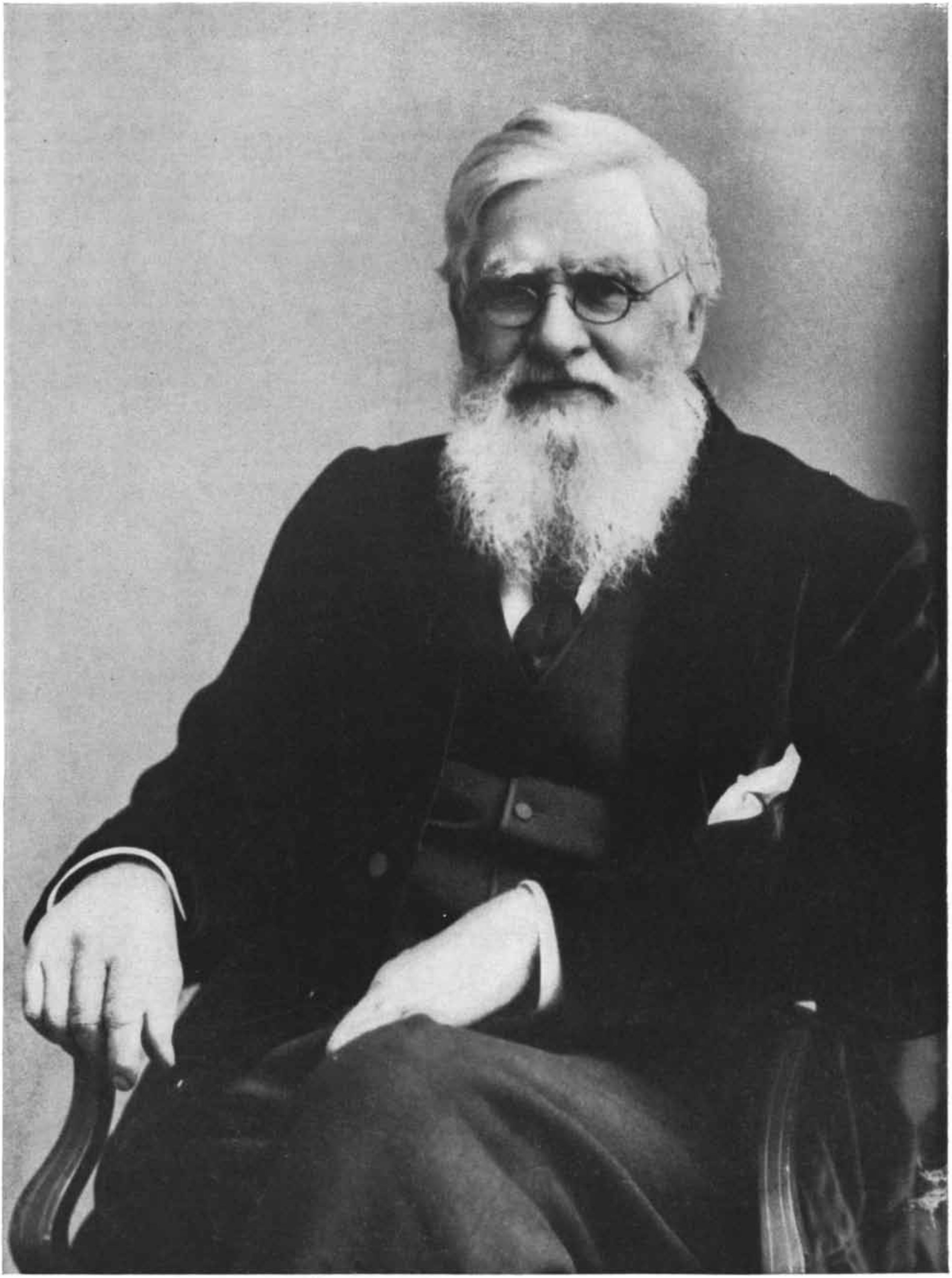
Even the fishes within the river differed. Those of the Amazon were peculiar to itself, but those of the upper tributaries were distinct. The number of separate species inhabiting the Amazon basin, he observed, "must be immense." He wondered a little about all that related diversity. He had read Charles Lyell's *Principles of Geology;* he was also acquainted with Robert Chambers's somewhat crude evolutionary sensation, *Vestiges of the Natural History of Creation*, which had achieved popular success before he left England for South America. A freethinker of sorts, he considered that there might be something in it. In this he differed from experienced and better-trained naturalists who had castigated it as an absurd piece of journalism.

One other thing could be put down to experience. Alone among the great Victorian evolutionists, he had actually lived with primitive men. He had not just gazed at them politely from exploring vessels. He had ventured into the high Amazons; he had visited country untrod by Europeans. He had sweated with naked savages up dangerous river portages. He had drunk at their feasts, slept in their houses, observed every aspect of their lives. There was a touch of the anthropologist as well as the naturalist in Wallace. Later on in the century these anthropological interests would reemerge and leave him somewhat isolated from his fellows. But now the Amazons had been left behind him. To what would he turn?

Early Life

In the history of that little band of men who, in the mid-19th century, swung biological thought into evolutionary channels, Alfred Russel Wallace occupies a unique position. Unlike Thomas Huxley, the brilliant, versatile debater, or Joseph Hooker, the perceptive botanist, or Lyell, the dreaming, elegant writer who was one of the founders of modern geology, Wallace independently achieved and set forth the same ideas as Darwin. He was an independent discoverer of natural selection. If it had not been for the mere chance that he chose to dispatch the account of his discovery to Darwin, we might today be acclaiming Wallace, rather than Darwin, as the founder of modern biology.

In this centennial year of 1959, 100 years since the publication of Darwin's *Origin of Species,* innumerable addresses will extol the scientific achievements of Darwin. Wallace, on the other hand, will be present in many of these historical accounts only as an attenuated shadow—a foil to the great Darwin. Many will not know his name, or, if they recognize it, will do so only with the vague impression that Wallace found out something which Darwin had already perceived more clearly. The fact that Wallace emerged from a social class different from Darwin's, that he was not a product of the traditional schools, has perhaps militated subtly against the full recognition of his scientific achievements. Moreover, Wallace, by nature modest and retiring, never thrust himself forward and his contributions have in some cases



WALLACE was born in 1823 and lived until 1913. From 1848 to 1862 he traveled widely in the valley of the Amazon and in the islands of Indonesia. This photograph of him was made in 1885, when he was 62. The photograph is from the Gernsheim Collection.

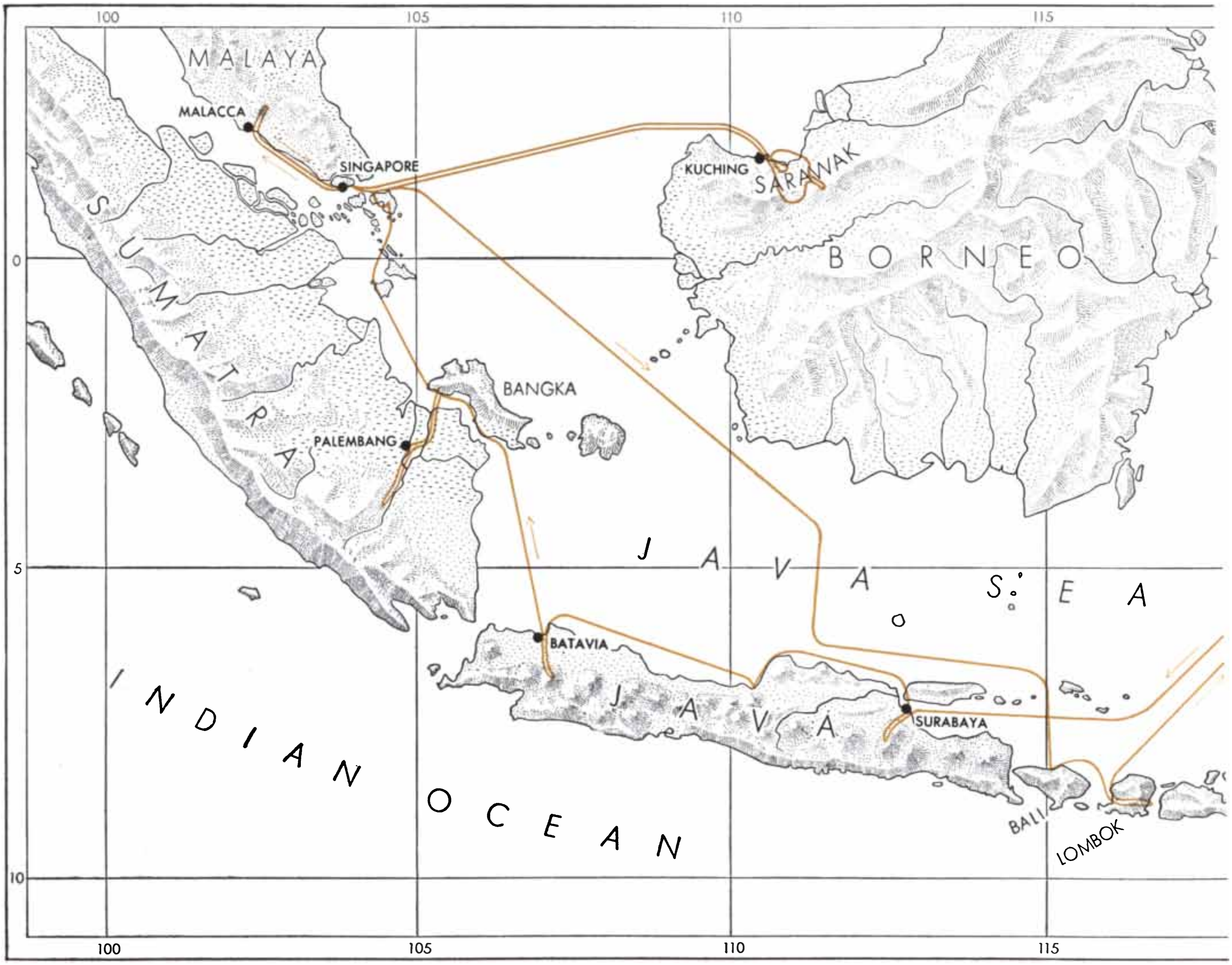
passed into the body of scientific thought without acknowledgment.

He belonged to no cliques, and avoided participation in virulent scientific and theological disputes. In terms of his later life he can be classed with Asa Gray in America as one of the more theistically inclined evolutionists who paved the way for the widespread theological acceptance of evolution in the later years of the century. The Darwinists varied individually in their attitudes toward orthodox religion. Wallace, in this regard, we might describe as far to the right of Huxley. While these philosophical matters are not really germane to our account of Wallace's scientific life, it is necessary to mention them because they play a part in certain episodes of his later years.

Wallace survived to be almost 91. In a world where human generations are short, this means that Wallace lived on into a world increasingly alien and strange to him. In some ways he found himself old-fashioned; in other ways, percipient of the future. He ranged farther in his mind and in his interests than his more contained and scientifically orthodox colleagues. Sometimes this habit led to highly successful insights, sometimes to disastrous failures, but through all his vicissitudes one is conscious of being in the presence of a fertile and inquiring mind.

Wallace was born on January 8, 1823, in the Welsh village of Usk in Monmouthshire. In this remote district of low rents and country food his parents had sought refuge from a series of financial misfortunes which had brought them to the verge of total poverty. His father appears to have been a well-intentioned but somewhat inept middle-class gentleman who by degrees had lost most of a small but comfortable inheritance. Although the family had thus fallen upon evil days before Wallace was born, it is worth noting that his father had had a good education, and was fond of books. As Wallace himself observes: "Through reading clubs or lending libraries we usually had some of the best books of travel or biography in the house." Moreover, his father was addicted to reading aloud to his wife and children in the evenings.

Before Wallace was 14, however, he had left home, and he saw little of his parents thereafter. Most of his formal



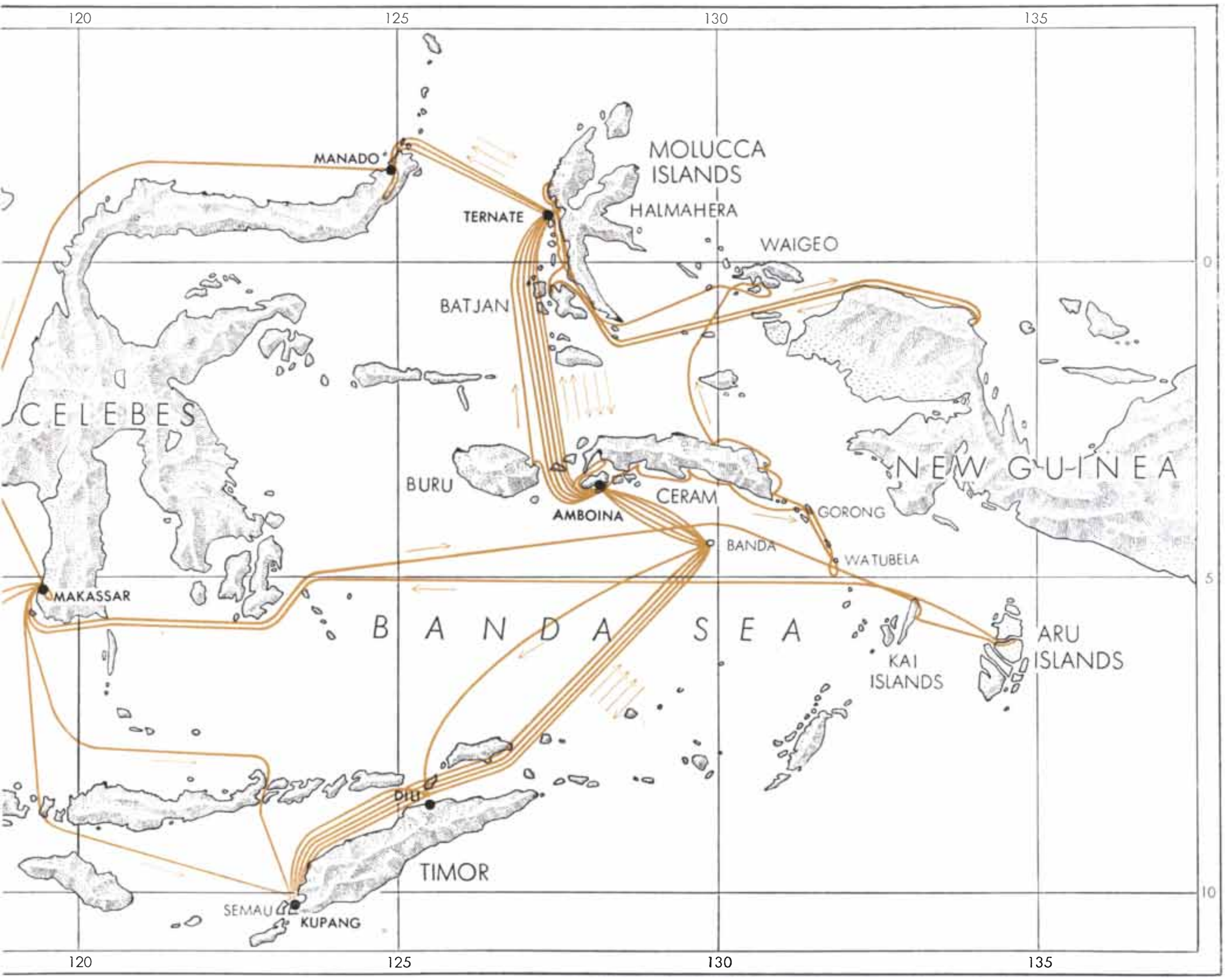
WALLACE'S TRAVELS in Indonesia, then called the Malay Archipelago, are traced in color on this map. He arrived in the Archipelago in 1854, and stayed until 1862. He referred to this period as "eight years of wandering . . . which constituted the central and

schooling, which was scant, had been obtained in the grammar school of the old town of Hertford. He remembered into old age and with great affection the meadows beyond the town, and the mill-stream with its great, dripping water-wheel. In the law courts where the assizes were held he heard the trials of poor sheep-stealers who, in those days, might be liable to transportation for life. Such painful scenes were part of the harsh criminal code so vividly pictured in W. H. Hudson's *A Shepherd's Life*. Wallace never forgot these episodes. They are a strong element in his sympathy for the socially deprived and unfortunate which sets Wallace's thinking so apart from that of many of his Victorian colleagues. He never shared the enthusiasm of some of them for unrestricted struggle within the social world of man.

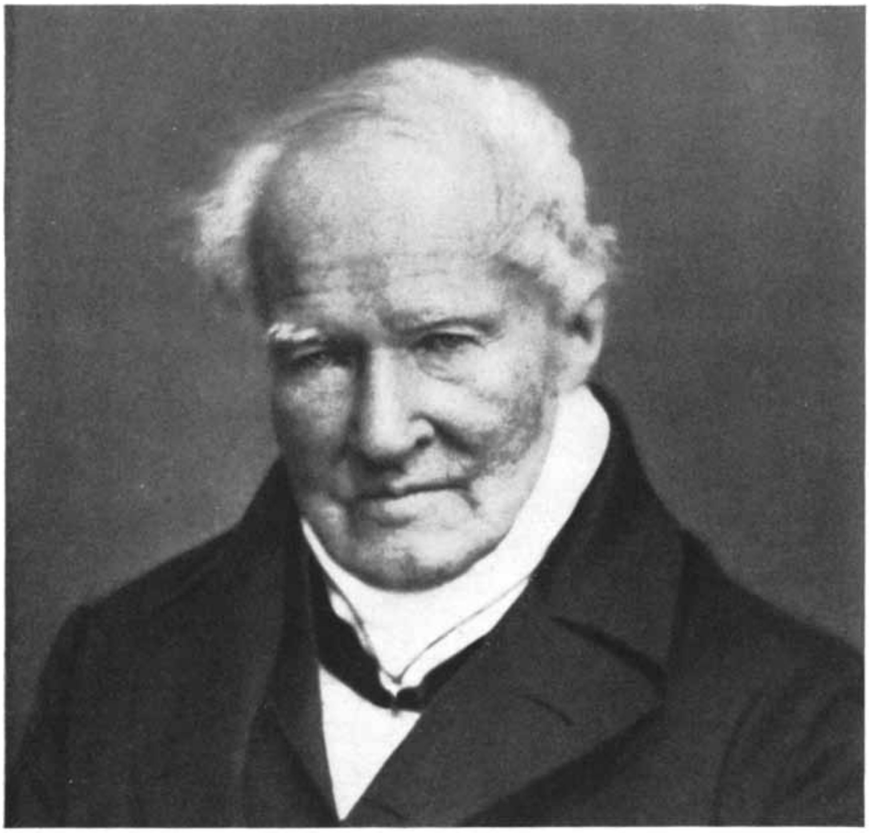
In 1837, after further family financial disasters, Wallace went to London, where he lived for a brief period with his older brother John. He was waiting for the return of another brother, William, from whom he was to learn surveying. Here he wandered about the marvelous streets of London, gazing into the newly installed plate-glass windows of the best shops, attending workingmen's lectures, and reading Thomas Paine's *Age of Reason*. Then, after a glimpse of this metropolitan fairyland, he went back into the country to become a surveyor. Here, a little like William Smith, the surveyor who had discovered the principles of stratigraphy only a few decades earlier, Wallace discovered the many fascinations of geology.

In the country around Barton, near the North Downs, between intervals of application to surveying, he wandered among streams and valleys bearing such appellations as Roaring Meg and the Devil's Dyke. He saw fossils lodged in ancient strata; he rambled in solitary fashion over a wild landscape of which he felt himself increasingly a part. In spite of Wallace's modest protestations in after years that his discovery bore about the same relation to Darwin's achievement as "one week to 20 years," one can observe that the same deep sense of kinship with nature, the same type of prolonged and thoughtful observation, had inspired both men.

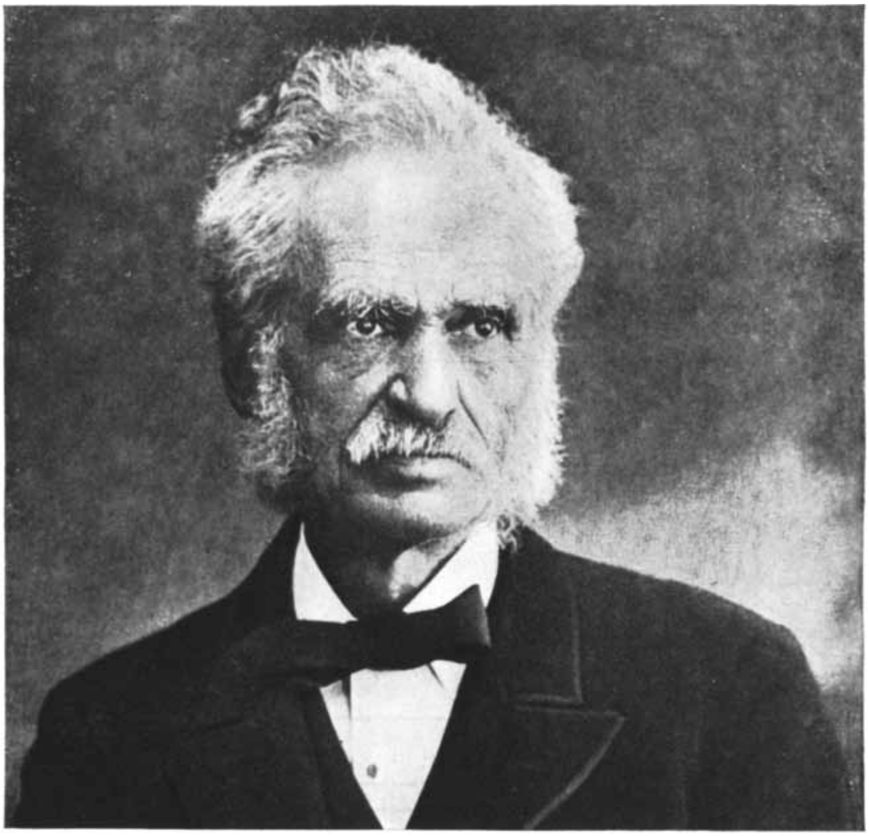
Poor though Wallace was, accident had led him to an occupation which had



controlling incident of my life." In 1858, while lying ill of a fever at Ternate in the Molucca Islands, he formed his concept of evolution by natural selection. He sent a paper on his concept to Charles Darwin a year before Darwin published his *Origin of Species*.



ALEXANDER VON HUMBOLDT wrote *Personal Travels in South America*, which, with Thomas Malthus's *An Essay on the Principle of Population*, influenced the young Wallace.



HENRY WALTER BATES traveled with Wallace. Wallace wrote him: "I should like to take some one family to study . . . with a view to the theory of the origin of species."

enticed him into the open instead of confining him to a shop. It is not without historical interest that in the same period a great literary naturalist, Henry David Thoreau, had in America chosen a similar profession. Contemplating a mountain journey of his surveying years, Wallace once remarked: "We obtain an excellent illustration of how nature works in moulding the earth's surface by a process so slow as to be almost imperceptible."

It was in this pursuit that Wallace spent the years that most young men of today give to high school and college. Nevertheless it was in many ways one of the happiest periods of the great naturalist's life. He was with a responsible older brother whom he loved and who cared for him with great tenderness. He was out in the open air, living a frugal but healthy existence. As he himself tells us, "If I had continued to be similarly employed after I became of age, I should most probably have become entirely absorbed in my profession. It seems unlikely that I should have ever undertaken a journey to the almost unknown forests of the Amazon."

In 1843 Wallace's father died; his brother, having no work in prospect, was forced to advise the youth that he must look out for himself. Once more Wallace drifted to London. He tells us that he was shy, frail and lacking in physical courage. Sensitive and a lover of solitude he undoubtedly was, but we must entertain reservations about his confession of cowardice. For this was the young man who, like the great English voyagers before him, was later to wander alone into the depths of the Amazon forest or venture by native *prau* among the dangerous islands of the Malayan seas. As his friend James Marchant stated, "Wallace, at no time during these wanderings, had any escort or protection, having to rely entirely upon his own tact and patience, combined with firmness, in his dealing with the natives."

In 1844 Wallace obtained a small teaching post in a school at Leicester, where he stayed for a little over a year. Here in a good town library he continued his own reading interests, including Alexander von Humboldt's *Personal Travels in South America* and Thomas Malthus's *An Essay on the Principle of Population*, which had also influenced Darwin. Years later, referring particularly to Humboldt, Joseph Hooker wrote to Darwin: "I think Humboldt is underrated nowadays. Well, these were our Gods, my friend, and I still worship at their shrines a little." In this wistful phrase Hooker has caught the essence of a bygone day. Humboldt, the great traveler, had had an influence on the youthful naturalists of Darwin's and Wallace's time which can only be compared to Linnaeus' great influence in the 18th century.

It can already be seen that, although they were separated by a vast social distance, Darwin and Wallace had pretty much the same reading background, except that Wallace had a greater concern for social movements and perhaps a deeper and more intense interest in the study of man. Both had been stimulated by their scientific predecessors, Lyell and Humboldt. Darwin had already made his voyage and was working secretively at Down while Wallace, 14 years younger, was still teaching children to read. No one could possibly have imagined that this unpromising, unlettered young schoolteacher would catch up to, and share honors with, the greatest biologist of the age, but so it was to be.

In the town library of Leicester, Wallace met and became fast friends with Henry Walter Bates, the entomologist with whom he was later to journey to South America. The death of William Wallace caused Alfred to resign his teaching position, and to move for a brief period to Neath. Wallace continued to correspond with Bates, however, and together they began to dream of a tropical collecting expedition.

The young men's letters reveal that both were greatly stimulated by Chambers's *Vestiges of the Natural History of Creation*, to which I have previously referred. "I begin to feel dissatisfied," Wallace wrote to Bates, "with a mere local collection. I should like to take some one family to study thoroughly, principally with a view to the theory of the origin of species."

These words were written 12 years before the *Origin of Species* was published. Wallace had read Darwin's *Journal of Researches;* he had also read the *Vestiges*. "I have rather a more favorable opinion of the *Vestiges* than you appear to have," Wallace wrote his friend Bates, and from then on his attention to the problem of evolution never wavered. Moreover, it is pleasing to record that, unlike some of the later Darwinists, he never abused Chambers. "The *Vestiges* is a book," he said in later years, "which has always been undervalued." He knew well that it had been a vital stimulus to many.

In the end, nevertheless, it was to be an American, William Henry Edwards, who was to center the plans of Bates and Wallace upon the Amazon as their first great adventure. In 1847 they chanced to read Edwards's book entitled *A Voyage up the River Amazon.* "The whole region north of the Amazon," wrote Edwards, himself a naturalist and collector of no mean descriptive powers, "is watered by numberless rivers, very many of which are still unexplored. It is a sort of bugbear country, where cannibal Indians and ferocious animals abound to the destruction of travelers. This . . . has always been Fancy's domain."

Scarcely had Wallace and Bates perused the book—with its accounts of rare animals, birds and insects, its observation of "monkeys who vary in species with every degree of latitude or longitude"—when the young naturalists hastened to the British Museum for advice. Here they were assured that the whole of northern Brazil was very little known and that collections made there would easily pay the expenses of the trip. By chance they discovered that Edwards was visiting London. Accordingly Bates and Wallace called upon him. He encouraged them in their ambitions and gave them letters to some of his friends in Pará. There was wide enthusiasm for natural-history collections among the well-to-do in these years, and the young men were fortunate in securing a reliable agent to handle their collections and keep them informed of the market. Early in April of 1848 they sailed in the bark *Mischief* for Pará.

Their initiation to life at sea was remarkably like that of Darwin's on the *Beagle*. Soon after they put to sea they were beset by a violent storm. Part of their bulwarks was carried away, and the ship almost foundered. For a week Wallace lay desperately ill from seasickness. Finally the storm passed and the ship had fine sailing weather for the rest of the voyage. Wallace was to remember into old age the exquisite blue of the tropic sea by day, and the shining phosphorescence of the ship's wake by night.

When they went ashore in Pará, he was awed and inspired, as Darwin had been, by the primeval forest. "Here," he wrote, "no one who has any feeling of the magnificent and sublime can be disappointed; the sombre shade, scarce illumined by a direct ray even of the tropical sun, the enormous size and height of the trees, most of which rise like huge columns a hundred feet or more without throwing out a single branch, the strange buttresses around the base of some, the spiny or furrowed stems of others, the curious and even extraordinary creepers and climbers which wind around them, hanging in long festoons from branch to branch, sometimes curling and twisting on the ground like great serpents, then mounting to the very tops of the trees, thence throwing down roots and fibres which hang waving in the air or twisting round each other, form ropes and cables of every variety of size and often of the most perfect regularity. These, and many other novel features—the parasitic plants growing on the trunks and branches, the wonderful variety of foliage, the strange fruits and seeds that lie rotting on the ground—taken altogether surpass description. . . . Here lurk the jaguar and the boa-constrictor, and here amidst the densest shade the bell-bird tolls his peal."

This was to be Wallace's world for the next four years; a world where gecko lizards walked upside down on one's ceiling, where one's spoons, cups and bottles were made from gourds, where tree frogs were as gaily colored as children's toys, and where through the vast, illimitable forests the only thoroughfares were the enormous rivers emerging out of the unknown and hurrying with all manner of natural wreckage toward the sea. The spoonbill and the scarlet ibis stalked in the shallows. Overhead in the forest attic flew shrieking parrots. Innumerable monkeys, astonishing little caricatures of men, contemplated life while hanging by the ends of their prehensile tails from that same refuge. It was a world where the floods of the great rivers and the dimness of the forest had driven life to the upper levels of the branches.

As for man, whether primitive or civilized, the waterways were his only grasp upon reality, his only means of orientation, even his only means of emerging into the sun. For four years Wallace was to be a wandering corpuscle along the muddy arteries of a continent. At the end of that time, and after the loss of the young brother who had bravely come out to join him in 1849, Wallace decided to return home. "My health," he observed in his autobiography, "had suffered so much by a succession of fevers and dysentery that I did not consider it prudent to stay longer." Bates, his companion of the outward voyage, stayed for seven years more, producing in 1863 *The Naturalist on the River Amazons*, now a great English classic.

Travels in Malaya

We have already seen under what circumstances Wallace reached home in 1852. Coming ashore with nothing but the clothes he stood in, he sought refuge in the family of a married sister, and for the next 18 months busied himself with a book of his own travels on the Amazon and the Río Negro. He also composed a now-rare little book on palm trees, based on sketches which he had salvaged from the wreck. A small sum of insurance, through the foresight of his agent, helped him. "Fifty times," he wrote to a friend, "I vowed never to trust myself more on the ocean. But good resolutions soon fade and I am already only doubtful whether the Andes or the Philippines are to be the scene of my next wanderings." The tropics had got into his blood.

By now Wallace was reasonably well known to naturalists through his constant attendance at the meetings of the Zoological and Entomological societies in London. After much careful collecting of information from fellow-travelers and scientists, he came to the conclusion that the Malay Archipelago offered excellent opportunities for an exploring naturalist who had to live by his collections. The islands were regarded as healthier than the Amazon, and Wallace determined to go there if he could secure free passage in some Government ship. Through the representations of Sir Roderick Murchison, then president of the Royal Geographical Society, this request was granted by the Government. The fact is worth noting because it indicates that the 30-year-old author of two books was already favorably known in scientific circles before he left for the jungles of the East.

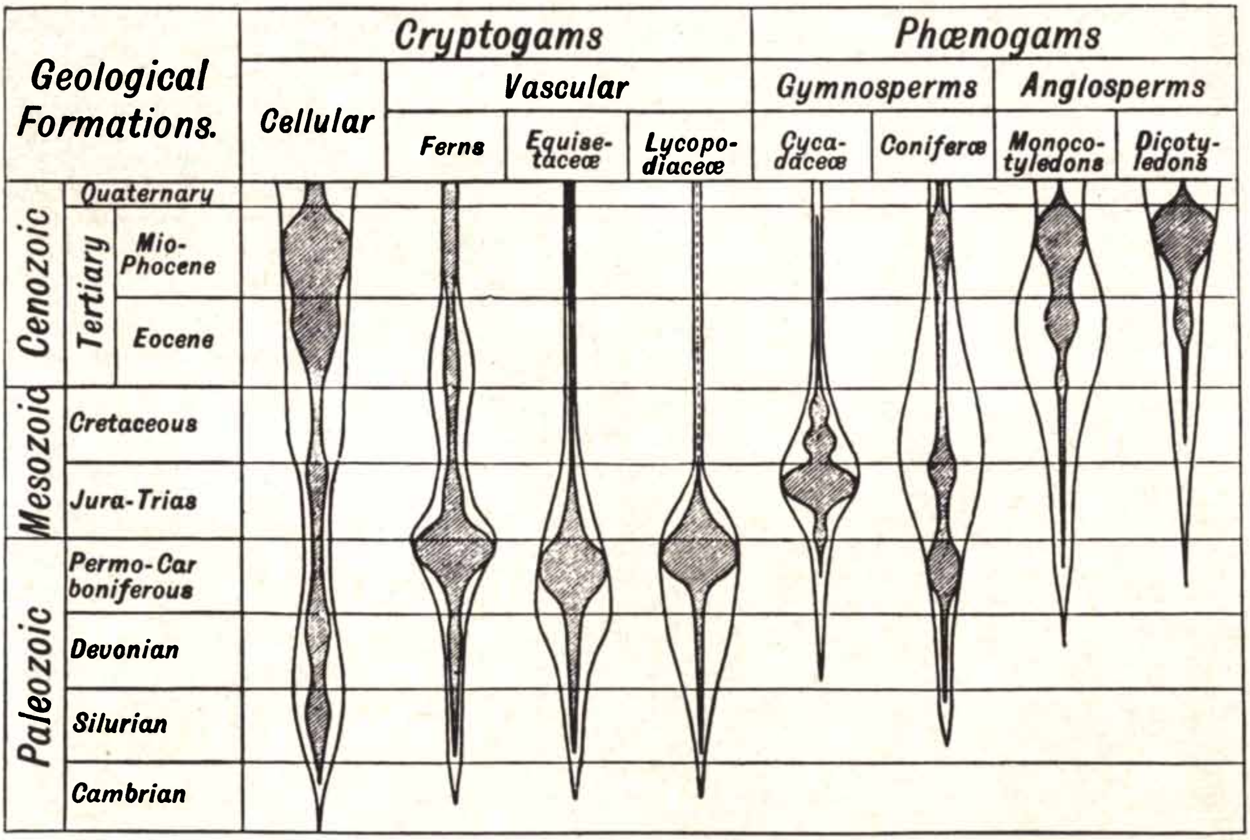
In April of 1854 he had reached Singapore with a young English assistant whom he had brought out with him. Behind them lay Suez. This was before the days of the canal, and Wallace in a letter gives a vivid picture of the journey across the neck of the isthmus in horse-drawn omnibuses along a desert road littered with the bones of camels. It was from Singapore, however, that, as Wallace himself wrote afterwards, "I was to begin the eight years of wandering throughout the Malay Archipelago, which constituted the central and controlling incident of my life."

"Singapore is rich in beetles," he exulted in a letter home, for beetles were a favorite collector's item. "I shall have a beautiful collection of them." The assistant, Charles, he confides, "is doing the flies, wasps and bugs. I do not trust him yet with beetles."

In Malacca he suffered again from fever. "I went to the celebrated Mount Ophir and ascended to the top, sleeping under a rock. The walk there was hard work, thirty miles through jungle in a succession of mud-holes, and swarming with leeches which crawled all over us and sucked when and where they pleased. . . . I got some fine new butterflies there and hundreds of other new or rare insects. Huge centipedes and scorpions, some nearly a foot long, were common."

He speaks in turn and with equal interest and affection of tigers and pitcher plants, orangutans and birds of paradise. "The more I see of uncivilized people," he wrote in a fashion of which more would be heard later, "the better I think of human nature on the whole, and the essential differences between civilized and savage man seem to disappear."

Over the map of Indonesia the spidery lines of his travels lengthened year by year. Marchant, his editor and biographer, records that during the eight years of his eastern sojourn he traveled some 14,000 miles within the Archipelago and collected well over 125,000 specimens. He was the first Englishman to see birds



EVOLUTION OF PLANTS is outlined in this chart reproduced from Wallace's book *Darwinism*. The major groups of plants are at the top of the chart; the geological formations are at left. The hatched areas show the abundance of each group in each formation.

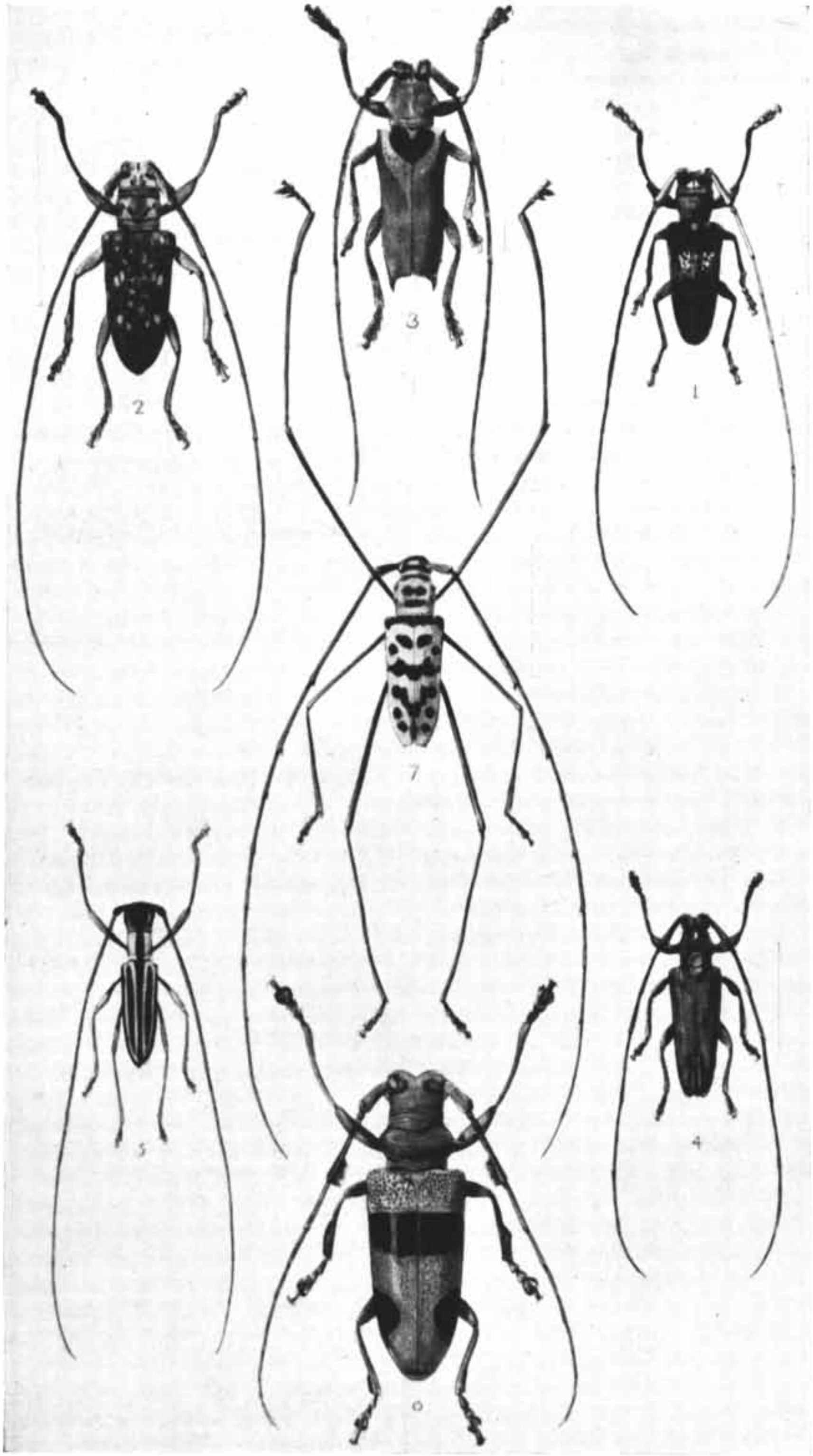
of paradise in their natural habitat. He almost fainted with excitement and esthetic delight when he captured one of the rare bird-winged butterflies of iridescent green.

Yet if this last should suggest to some minds an effeminate character, let this record of a single journey in a Malay sailing vessel suffice to reveal the iron in Wallace: "My first crew ran away; two men were lost for a month on a desert island; we were ten times aground on coral reefs; we lost four anchors; our sails were devoured by rats, the small boat was lost astern; we were thirty-eight days on the voyage home which should have taken twelve; we were many times short of food and water; we had no compass lamp owing to there not being a drop of oil in Waigiou when we left; and to crown it all, during the whole of our voyage, occupying in all seventy-eight days, we had not one single day of fair wind."

This voyage was but one of the many of which he writes about "laying in stores, hiring men, paying or refusing to pay their debts, running after them when they try to run away, going to the town with lists of articles *absolutely necessary* for the voyage, and finding that none of them could be had for love or money, conceiving impossible substitutes and not being able to get them either." Nevertheless he can turn from these tribulations to say to his brother-in-law: "Your ingenious arguments to persuade me to come home are quite unconvincing. I have much to do yet. I am engaged in a wider and more general study—that of the relations of animals to space and time." During this period of deep thought he also wrote to a boyhood friend, George Silk: "You cannot imagine how I have come to love solitude. I seldom have a visitor but I wish him away in an hour."

Although Wallace appears to have been a believer in the general principle of evolution since the time of the *Vestiges*, it was here in Malaya, amidst fever and the long indoor days of the rainy season, that Wallace began to marshal the thoughts that would place him beside Darwin. Wallace was tremendously interested in plant and animal distribution. He studied William Swainson and Humboldt. He now had had experience in both the New World and Old World tropics. The question of the origin of species, he tells us, "was rarely absent from my thoughts." Traveler though he was, he carried books with him. "The great work of Lyell," he remarks in his autobiography, "had furnished me with the main features of the succession of species in time." By combining Lyell's observations with the facts of animal distribution, Wallace thought that "valuable conclusions might be reached." In thus using data from more than one field he was revealing the same great synthesizing power which had stimulated the mind of Darwin.

While visiting Borneo in 1854 and 1855 he prepared a paper "On the Law which Has Regulated the Introduction of New Species." He sent it to the *Annals and Magazine of Natural History*, where it was published in September of 1855. "Every species," Wallace wrote as his principal conclusion, "has come into ex-



BEETLES COLLECTED BY WALLACE in the Malay Archipelago appear in *Transactions of the Entomological Society*. Wallace traveled mainly to gather specimens for collectors.

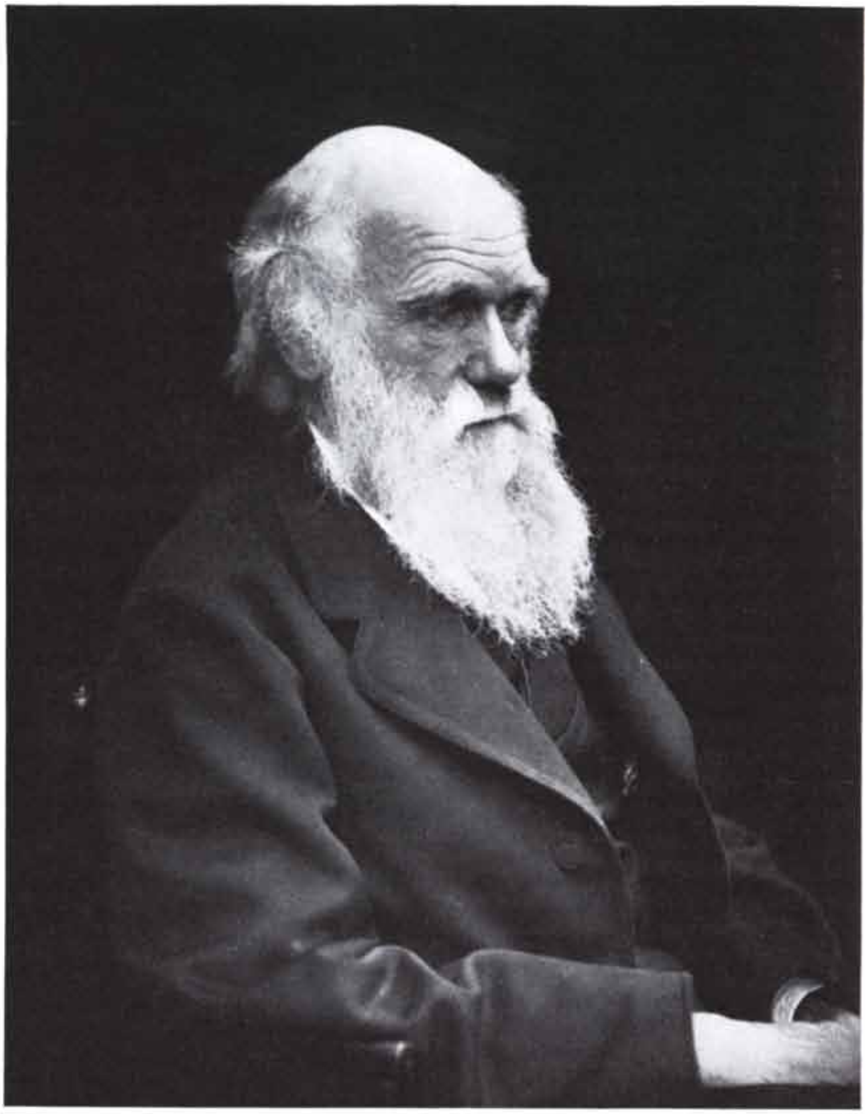
istence coincident both in space and time with a pre-existing closely allied species." This principle is not, of course, Darwinian natural selection, but it points to the fact that only organic change in time could explain such a close connection between the life of the present and that of the past. It was another way of driving home the fact that biological evolution was the only rational explanation for linking living forms with related extinct fossils.

Wallace was not, of course, quite as original as he thought when he wrote this paper. The idea has a long history running back through Darwin to John Hunter, but there was no way for the young Wallace, far from the great libraries, to realize this. Furthermore, the older statements of the principle are less precise. Wallace had a gift for clear, incisive statement, and it emerges in this, his first evolutionary paper. The young naturalist was disappointed when the article passed almost unnoticed. Darwin, with whom he had now had some correspondence, comforted him. Lyell and Edward Blyth, the great student of the South Asian faunas, Darwin wrote, had both called it to his attention.

Once more Wallace turned to the practicalities of the sea and the islands, setting forth on a search for birds of paradise. There is evidence, however, that a rarer, wilder search was by then running in the huntsman's head. In 1858 he referred once more to his paper. "It is," he wrote to his old friend Bates, "merely the announcement of the theory, not its development." He goes on: "I have been much gratified by a letter from Darwin. He is now preparing his great work on 'Species and Varieties,' for which he has been collecting materials twenty years." The letter indicates that he had no notion of Darwin's theory, though he looked forward to its publication with curiosity. Just two months later the huntsman had stumbled upon his quarry. In the mind of the solitary wanderer the present had become one with the past.

Fever and Discovery

During the early months of 1858 Wallace was living at Ternate in the Molucca Islands off the western tip of New Guinea. He was suffering severely from intermittent fever, and during one of these attacks, while lying weak but lucid on his bed, his mind began to revolve upon the "species problem" which had fascinated him since those days when he had read the *Vestiges*. "Something," he says, "brought to my recollection Mal-



DARWIN was stimulated to publish *Origin of Species* when Wallace sent him his paper on the theory of evolution by means of selection. Darwin wrote: "I would far rather burn my whole book than that he or any other man should think I had behaved in a paltry spirit."

thus's *Principle of Population* which I had read about twelve years before."

Suddenly it occurred to the feverish naturalist in a lightning flash of insight that Malthus's checks to human increase —accident, disease, war, and famine— must, in similar or analogous ways, operate in the natural world as well. "Vaguely thinking over the enormous and constant destruction which this implied, it occurred to me," he tells us, "to ask the question, 'Why do some die and some live?' " The answer, Wallace felt, was clear: the best fitted live. "From the effects of disease the most healthy escaped; from the enemies the strongest, the swiftest, or the most cunning; from famine, the best hunters."

Again his mind leaped forward. "Considering the amount of individual variation that my experience as a collector had shown me to exist, then it followed that all the changes necessary for the adaptation of the species to the changing conditions would be brought about; and as great changes in the environment are always slow, there would be ample time for the change to be effected by the survival of the best fitted in every generation."

It was Darwin's unpublished conception down to the last detail, independently duplicated by a man sitting in a hut at the world's end.

"I waited anxiously for the termination of my fit," Wallace goes on with unconscious humor, "so that I might at once make notes for a paper." In two evenings he was ready to dispatch it to Darwin. "I hoped," he said, "that the idea would be as new to him as it was to me." In this he was sadly disappointed.

The paper reached Darwin at Down

in June of 1858. Wallace's innocent elation was to be Darwin's despair. "All my originality, whatever it may amount to, will be smashed," Darwin wrote to Lyell on the same day. "I never saw a more striking coincidence. . . . Your words [here Darwin was referring to earlier warnings by Lyell that he might be anticipated] have come true with a vengeance."

In a genuine agony of spirit Darwin sought the advice of his friends. Could he now publish honorably? "I would far rather burn my whole book," he protested, "than that he or any other man should think that I had behaved in a paltry spirit."

Wiser counsels prevailed. Darwin, fortunately, had a copy of a letter sent to Asa Gray at Harvard College, which validated his priority. After much self-questioning by Darwin and judicious consideration by Lyell and Hooker, it was decided to read Wallace's paper along with Darwin's letter to Gray and an extract from his unpublished sketch of 1844, before a meeting of the Linnaean Society on July 1, 1858. This was the dramatic prelude to the great intellectual storm which would shake the latter half of the 19th century and be reflected in the Scopes trial of the 1920s here in the U. S. [see "A Witness at the Scopes Trial," by Fay-Cooper Cole; SCIENTIFIC AMERICAN, January].

Yet the beginning was deceptively quiet. Wallace was traveling among the islands, unaware of fame, lost in a dream of rare birds and rarer butterflies. Darwin, who did not attend the meeting, was nursing a sick child. There was no discussion before the Society. "The interest," Hooker commented later, "was intense, but the subject was novel."

The Fellows of the Society were overawed by the tacit approval of such prominent scientists as Hooker and Lyell. The storm, the controversies, would come later with the publication of the *Origin of Species* in the following fall of 1859. Wearily Darwin picked up his pen once more, but finally, in better humor, he wrote to Hooker, "I find it amusing and improving work. I am now most heartily obliged to you and Lyell for having set me on this. I confess I hated the thought of the job."

A man pursuing birds of paradise in a remote jungle did not yet know that he had forced the world's most reluctant author to disgorge his hoarded volume, or that the whole of Western thought was about to be swung into a new channel because a man in a fever had felt a moment of strange radiance. The path led on. It always did for Wallace. In

1862, aware now, in some degree, of the change in his fortunes, he turned homeward. Two roach-eating birds of paradise were his companions. Wallace has unwittingly left us a vivid picture of sea travel in his time. "Every evening," he explains, "I went to the storeroom in the fore part of the ship where I was allowed to brush the cockroaches into a biscuit tin." At Malta a bakery supplied the roaches. The birds and Wallace arrived home in good health.

Views on Man

"I am convinced," Wallace used to contend to his old friend Silk, "that no man can be a good ethnologist who does not travel, and not *travel* merely, but reside as I do; months and years with each race." This statement is a revelatory one. It shows, as does his youthful writing about his experiences in Wales, an intense interest in human beings. He was fascinated by their cultural habits, and the tenor of the remarks I have just quoted indicates that he was aware very early in the history of anthropology of the importance of direct field observation in foreign cultures.

This interest in human behavior is far more intense than one finds it to be among others of the Darwinian circle. In this respect Wallace was a more able anthropologist than Darwin. It is not without significance, therefore, that when the two men came to differ—and differ they eventually did—it was over man that their disagreement arose.

Darwin, in the *Origin of Species,* had avoided the subject of human evolution as tinged with emotion and prejudice. After the success of his book, however, it was inevitable that man would become a prime topic of discussion among all concerned with the new doctrines. Lyell wrote a cautious volume (1863) dealing with human antiquity, which disappointed Darwin. Huxley treated the anatomical aspects of man's relationship to the primates (1863), and Darwin himself was engaged with the preparation of his *Descent of Man,* which was not published until 1871.

Wallace, who unfortunately never wrote a book on the subject, probed deeper into the nature of man than any of the circle immediately around Darwin. Because in the end science has so thoroughly accepted them, we have not only forgotten their source but also forgotten how heretical some of his views were at the time they were uttered. First Wallace postulated an erect, small-brained bipedal stage of human development, followed by a second phase in which the human brain and cranium assumed its present size and form. Only with the present-day discovery of the Australopithecine man-apes is the early stage beginning to be documented. Second, he quickly saw that the complete fossil history of man might well be prolonged far beyond Pleistocene times, and that the big-brained men of the upper Pleistocene, who were at that time troubling the evolutionists, need not be regarded as an effective argument against the reality of the human transformation. Rather, the scientists must cease confusing living races with grades or levels on the evolutionary scale of the past—something which was at that time exceedingly common. Natives were often described as apelike in appearance, and there was a strong unconscious tendency to see the whole story of human evolution revealed in a sequence from such existing apes as the gorilla through the "lower" living races to Caucasian man.

It is just here that Wallace's deep humanity and long experience with primitive peoples reveal with particular clarity his more sophisticated approach to the subject. At a time when many naive observers were comparing the languages of primitives to the chattering of apes or monkeys, Wallace stated unequivocally: "Among the lowest savages with the least copious vocabularies the capacity of uttering a variety of distinct articulate sounds, and of applying to them an almost infinite amount of modulation and inflection, is not in any way inferior to that of the higher races."

Wallace believed that, however the fact had come about, all the existing races were mentally pretty much equal, having attained their *Homo sapiens* status a long time ago. Why human beings scattered over such remote distances should be so similar in intellectual capacity, while at the same time varying so vastly in their technological achievements, he did not profess to know. Of one thing, however, Wallace felt certain. Man, even savage man, possessed latent mental powers—ability to understand and produce music, mathematics, art—which were not accountable for, Wallace felt, in terms of the simple utilitarian struggle for existence as portrayed by the Darwinists.

In 1864, shortly before marrying Annie Mitten, the daughter of the leading English authority on mosses, Wallace composed a paper which led eventually to strong intellectual differences, but never a personal break, with his friend Darwin. In this paper he gave vent to a new view; namely, that with the rise of the human brain a creature

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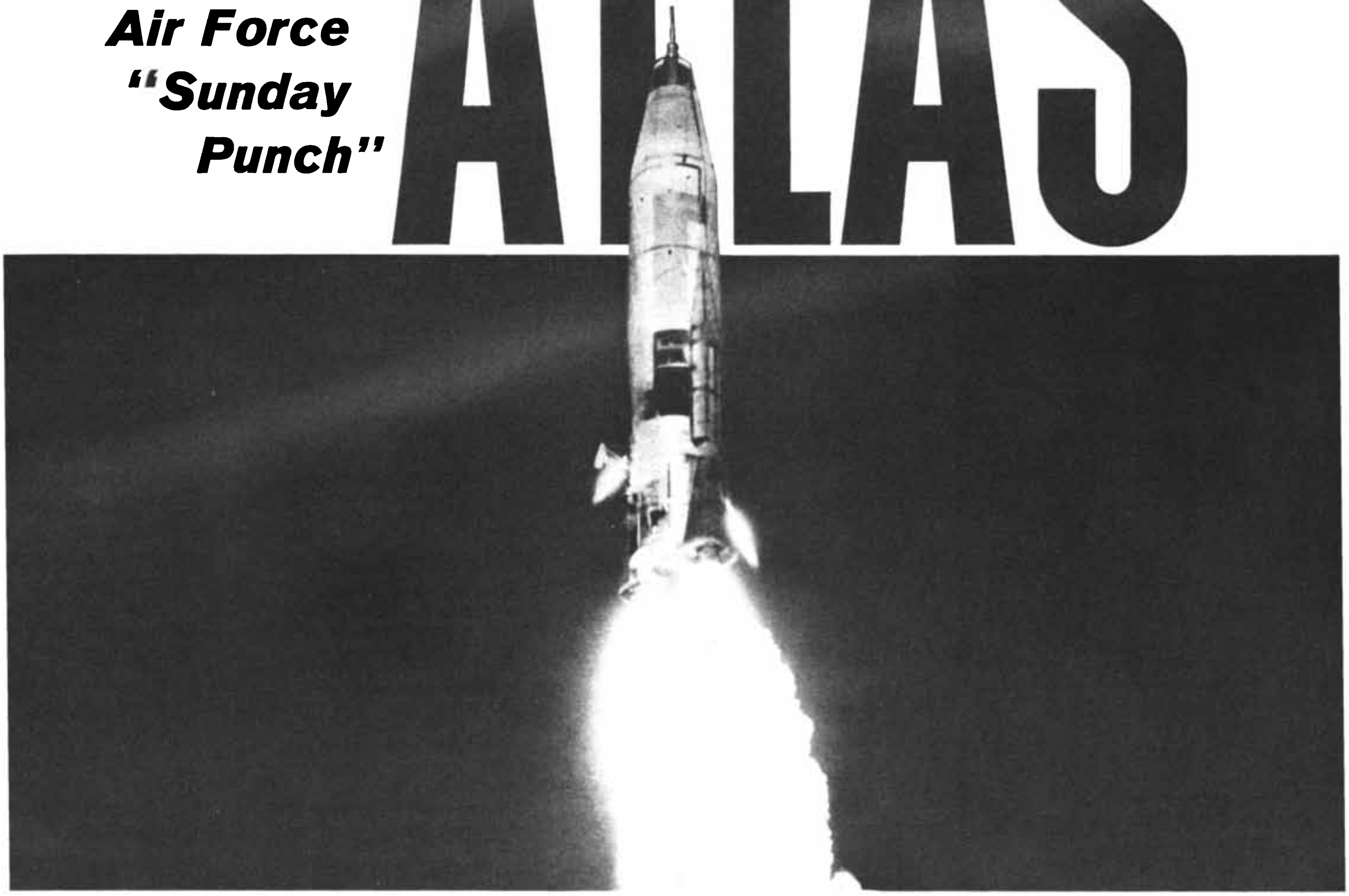

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had emerged who, for the first time in the long history of life, had escaped from the specialization of *parts* toward which evolution seemed always to progress.

With man this process was apparently at an end. Man, in his brain, had developed a specialized organ whose whole purpose was to enable him to escape specialization. He could now increasingly assign to his clothing and implements the special activities for which the animal had to develop organs in its own body. Man, by contrast, could take off and put on. Specialization could be left to his cultural shell, his technology. Armored within that shell, great-brained man was in the process of acquiring a sort of timeless, unchanging body in the midst of faunas and floras still forever evolving and vanishing.

Wallace did not deny that small alterations might still be taking place in man, but he regarded them as insignificant. "With our advent," Wallace maintained, "there had come into existence a being in whom that subtle force we term *mind* became of far more importance than mere bodily structure." We have taken away from nature the power of change which she exercises over all other animals. "Man does this by means of his intellect alone," Wallace argued, "which enables him with an unchanged body still to keep in harmony with the changing universe." Wallace, leaping beyond his colleagues, had glimpsed the full anthropological significance of the evolved brain. The idea was hailed by prominent thinkers. John Fiske spoke of it as opening up "an entirely new world of speculation."

Darwin expressed his admiration of the paper to Hooker, calling it "most striking and original." He agreed to the leading idea, and expressed the wish that Wallace had written Lyell's chapters on man. It was only later, as Wallace's bepuzzlement over man increased, that the two men came to a parting of the ways.

"Natural selection," pondered Wallace, "could only have endowed savage man with a brain a few degrees superior to that of an ape, whereas he actually possesses one very little inferior to that of a philosopher." Man's curious hairlessness, the structure of the human larynx, and other odd human features began to loom impressively in Wallace's thinking. Finally the man who had not been impressed in his youth by organized religion was led to suggest that a higher intelligence might have played a hand in the development of our kind.

"I differ grievously from you, and am very sorry for it," wrote Darwin courteously.

Huxley was severely critical.

Hooker wrote to Darwin of Huxley's remarks: "The tumbling over of Wallace is a . . . service to science."

This was curious emotionalism. It is written about the man who aided Darwin to recognize the full sweep and significance of variation and to strengthen the account of it in the later editions of the *Origin*. It is spoken about the worker whose two-volume work, *The Geographical Distribution of Animals,* is a biological classic. It is said of the man for whom Wallace's Line, dividing the faunal region of continental Asia from that of New Guinea and Australia, is named. It is said of one who did much to destroy narrow Victorian racial prejudices, and whose contributions on a variety of subjects have been appropriated and passed down to our day without acknowledgement.

It is comparatively easy to give a fair account of a man who dies within his generation. He is encapsulated in his own time, and his follies and achievements can be comprehended accordingly. It is not so simple to evaluate the career of Alfred Russel Wallace. He was born in one age and survived to die in another. As a young man he had surveyed for the first railroad lines in England. He had been shipwrecked in the days of sail. Yet it was his fate to live on into the first days of the airplane and the automobile.

His was a full life—that much can be said. A lengthy biographical study would have to incorporate much that cannot be included here: his growing interest in spiritualism, his odd antipathy to vaccination, his lifelong defense of the poor and helpless, his bitter memories of the worst of the Industrial Revolution. Many of his ideas were mistaken. Some forecast the future with uncanny perception. Some, as we have seen, outran with a flashing brilliance even his friend and colleague, Darwin.

Wallace never compromised his beliefs even when they caused contemptuous comment among his associates. He was an individualist of a sort rarely seen in the "team science" of the modern era. In the celebrations of the Darwinian Centennial he will be mentioned only perfunctorily; he belongs to another day.

"If you would learn the secrets of nature," Henry David Thoreau once remarked, "you must practise more humanity than others." It is the voice of a contemporary in the years before the green continents were despoiled. Wallace would have understood the words.

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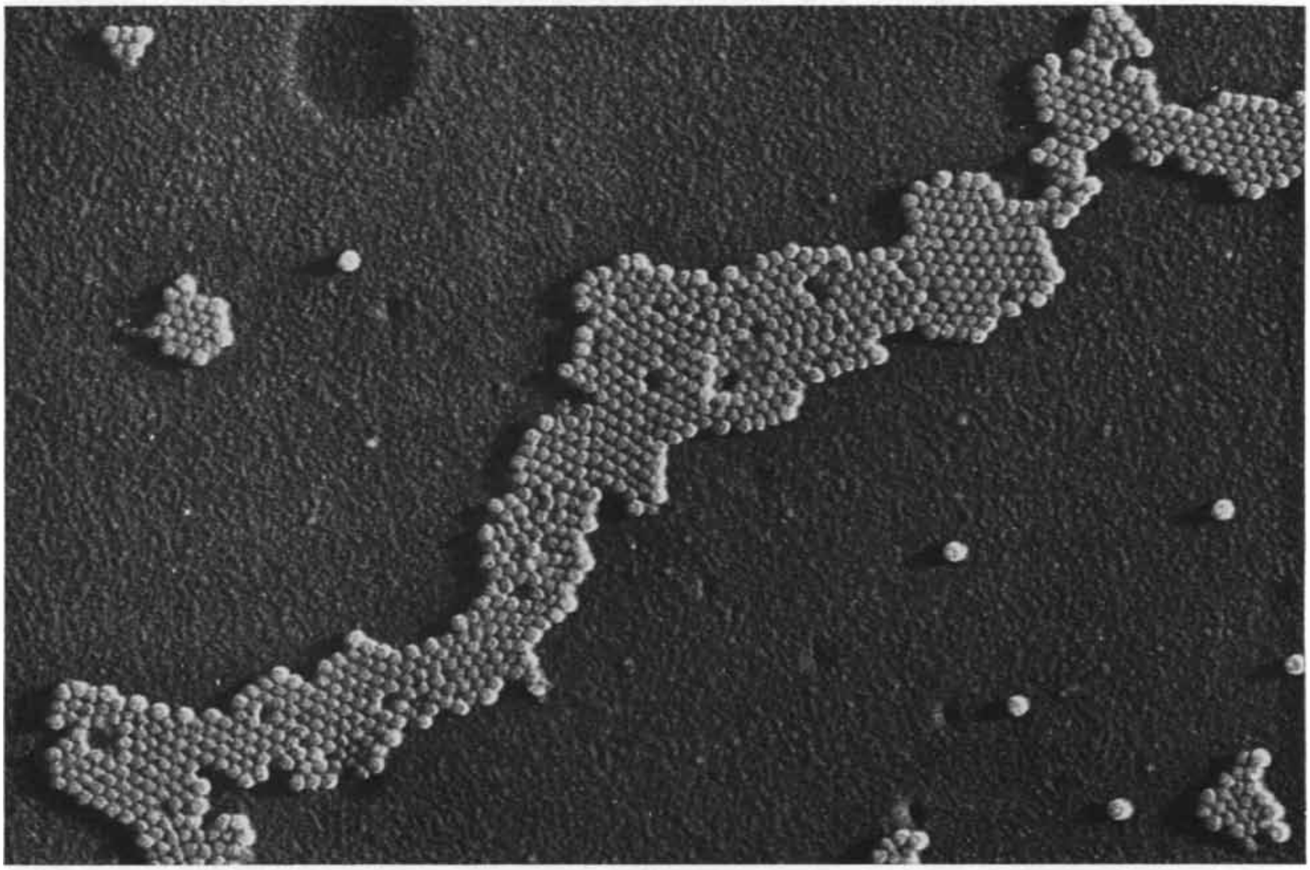
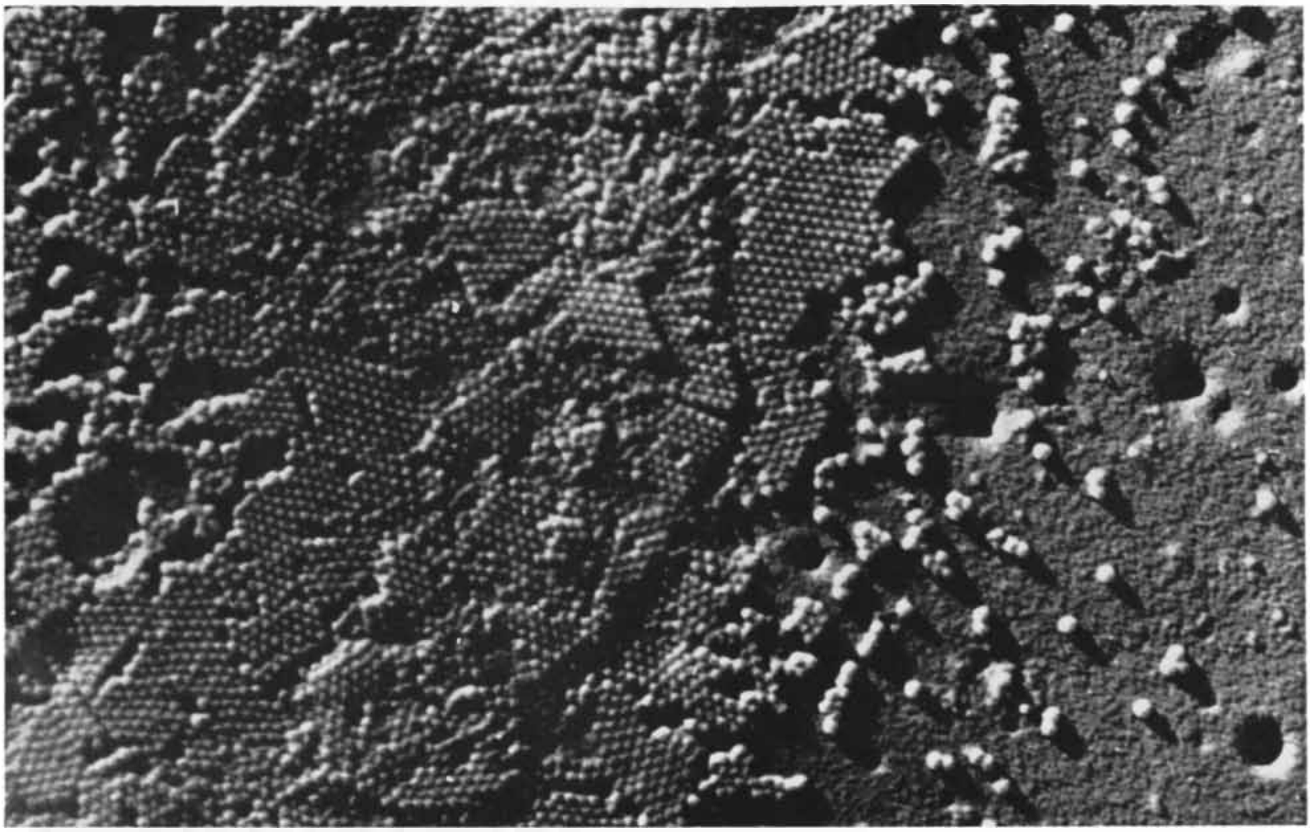


PURIFIED POLIO VIRUS is enlarged 73,000 diameters in this electron micrograph made by A. R. Taylor at the Research Laboratories of Parke, Davis & Company in Detroit. Most of the spherical virus particles lie together in regular crystalline array.



PURIFIED COXSACKIE VIRUS of Type A10 is also enlarged 73,000 diameters. Each particle is 28 millimicrons in diameter. The electron micrograph of this virus was made by S. S. Breese and A. Briefs of the Walter Reed Armed Forces Research Institute.

ENTEROVIRUSES

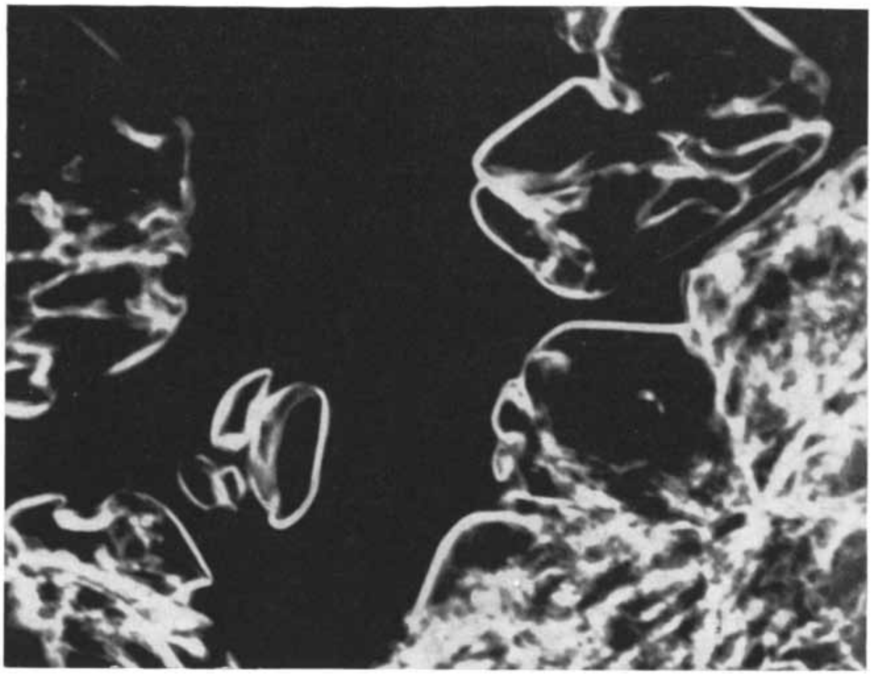
It is now apparent that the three viruses which cause polio belong to a family of more than 50 viruses which ordinarily dwell in the human alimentary tract without causing disease

by Joseph L. Melnick

Investigators began to look more than 50 years ago for the dreaded invader of the central nervous system now identified as the polio virus. Once they had isolated the virus and learned to work with it in the laboratory, they made an unexpected discovery. The virus turns up much more often in the intestinal tract than it does in the spinal cord and brain. In human beings the infection usually goes unnoticed, causing no harm and conferring a lasting immunity; only occasionally does it involve the nervous system and bring on serious illness. The tracing of the polio virus to its habitat in the gut has led more recently to the discovery that it is a member of a large family of viruses. They all produce the same sort of benign infection in the alimentary tract, and exhibit the same tendency to invade other tissues, especially the nervous system, with more serious consequences. The so-called enteroviruses now number more than 50. Some have proved to be the agents of hitherto mysterious illnesses. Although other members of the family have not yet been incriminated, they remain under close surveillance, for there are a number of diseases that have no known cause, and the enteroviruses have not been eliminated as suspects.

Until about 10 years ago polio workers were obliged to experiment with live monkeys. The virus would not consistently cause infection in smaller and more abundant laboratory animals such as mice and guinea pigs. A paralytic infection in a monkey furnished the sole proof of the presence and identity of the virus. No wonder it took 40 years to establish the existence of three distinct types of polio virus! Then in 1949 the Harvard Medical School group of John F. Enders, Frederick C. Robbins and Thomas H. Weller developed their technique for growing the virus in cultures of monkey or human tissue, a method now employed by laboratory technicians the world over. The tissue culture is started by planting a relatively small number of live tissue cells on the wall of a test tube or bottle and immersing them in nutrient fluid. The cells multiply in a few days to cover the wall of the vessel with a mat of tissue one cell thick. At this point the fluid is poured off and a few drops of virus suspension are spread over the sheet of cells. In the case of test-tube cultures, fresh nutrient is now added; the cultures are then examined daily under the microscope. When the culture is in a bottle, the virus particles are held in place by pouring a thin layer of warm agar over them. The agar solidifies on cooling, limiting the spread of virus from an infected cell to those adjacent to it. As the virus multiplication cycle is repeated in cell after cell, virus colonies make themselves visible as distinctive "plaques" marking the points at which the viruses have destroyed the cells and erupted from them. With these techniques the culturing of viruses in the laboratory is becoming almost as routine as the culturing of bacteria [see "A New Era in Polio Research," by Joseph L. Melnick; Scientific American, November, 1952].

One monkey now provides cells for hundreds of tests instead of just one; monkey cells, properly treated, can be



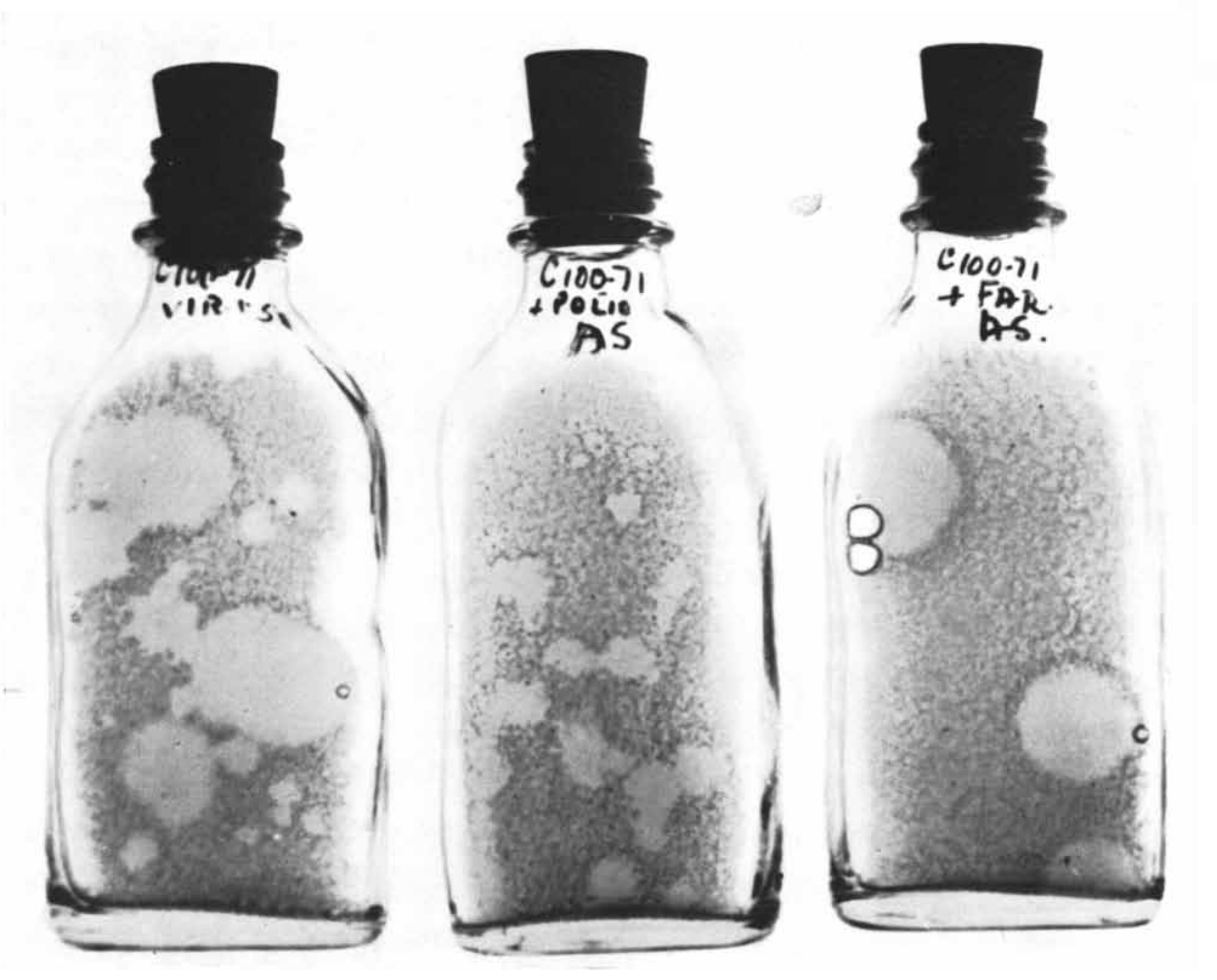
CRYSTALS of the Coxsackie virus shown on the opposite page were photographed with dark-field illumination by C. F. T. Mattern and H. G. du Buy of the National Institutes of Health.

shipped by air for use in tissue-culture tests at distant points. For a time our laboratory received a regular supply of monkey cells from India, and many laboratories presently receive shipments from a center in South Carolina maintained by the National Foundation (formerly the National Foundation for Infantile Paralysis). Monkey tissue cultures have actually proved to be more sensitive detectors of viruses than the monkeys themselves. Viruses that do not cause illness in monkeys will still grow in tissue cultures, causing visible damage to the cells. Cultivation of the virus in tissue cultures changed the pace of polio investigation and led to several important developments, the most notable being the Salk killed-virus vaccine.

The tissue-culture technique also facilitated large-scale epidemiological surveys of the distribution of the polio virus and of immunity to it in the community. With the finding that the virus may be present in the intestinal tract, it became possible to make such surveys by testing stool specimens taken from representative samples of the population. Investigators soon discovered that viruses other than polio viruses also reside in the intestinal tract. Many turned up that did not appear to cause any disease in monkeys. Some were identified as polio viruses by their serological reactions; that is, they were inactivated by serum from monkey blood containing antibodies specific for polio and so failed to multiply in the tissue culture. Others betrayed characteristics not found in the polio family.

Among these are the Coxsackie viruses, named after the village in New York where the first one was isolated in 1948. Gilbert Dalldorf, then of the New York State Department of Health, had just introduced the use of newborn mice to the virus laboratory, and had discovered a new human virus which produced a disease in these mice. Although the virus had been isolated from a patient with paralytic disease, it could not be said that it had caused the disease; the patient might also have been infected with polio virus at the same time. Soon reports came in from all parts of the world of other viruses which resembled the Coxsackie virus, and which could be made to grow in newborn mice. Coxsackie viruses seem to have an actual affinity for young tissue in mouse or man; the discovery of Coxsackie virus in the spinal fluid of two adult patients with brain tumors suggests that the rapidly multiplying young cells of the tumor created a freakishly compatible environment.

Some Coxsackie viruses (Group A) produce extensive damage to the skeletal



BOTTLE CULTURES of monkey-kidney cells on which the enteroviruses can grow were used in detecting mixtures of viruses in genetic studies performed by M. Benyesh and Melnick at Yale University. The bottle at left contains two kinds of plaques (*clear areas*): large ones characteristic of polio virus; small irregular ones, of ECHO virus. In the center bottle polio antiserum inhibited the growth of polio virus and only ECHO virus grew. At right ECHO antiserum permitted the isolation of polio virus.

muscle of the baby mice; others (Group B) affect the brain, the pancreas, the heart muscle and particularly the embryonic fat pads under the skin. At least 19 members of Group A and five members of Group B are recognized today. All five viruses of Group B have been associated with human illness, the most important being an aseptic (nonbacterial) meningitis that is clinically indistinguishable from nonparalytic poliomyelitis; pleurodynia, a painful disease of the muscles of the chest and diaphragm; fatal inflammation of the heart in newborn infants; and even a few cases of polio-like paralytic illnesses. Several of the Group-A viruses have proved to be the agents of herpangina, an illness common in children, which is marked by fever and the eruption of blisters in the throat. The appearance of these viruses in the tissue-culture surveys undertaken to clarify the epidemiology of polio clearly reaffirmed the Coxsackie strains as intestinal viruses.

The polio surveys also turned up a large number of viruses that multiplied in tissue cultures but could not be classified with any of the previously known disease agents. They were excluded from the polio family by the fact that they failed to produce the disease in monkeys and could not be neutralized by polio antiserums. They were similarly distinguished from Coxsackie viruses by their failure to produce disease in newborn mice, and by the fact that they could not be neutralized by Coxsackie antiserums. These organisms were first called "orphan" viruses because they could not be related to any disease in either humans or laboratory animals. Many members of this group, however, are now established as the cause of human illness, notably aseptic meningitis. They have been renamed ECHO viruses ("enteric cytopathogenic human orphan" viruses), indicating that their natural habitat is the human intestinal tract, and that they are capable of destroying cells in tissue culture. Serological tests distinguish several types. A committee under the auspices of the National Foundation has been set up to supervise the characterization and classification of these and other prototypes of new human enterovirus strains. To date, through the work of this committee and investigators collaborating with it, 25 serologically distinct ECHO types have been established.

Despite their preference for the alimentary tract, the enteroviruses are apparently innocent of blame in "intestinal flu," "turista" and related up-sets which current folklore lays to viruses. They seem to cause objectively identifiable illness only when they infect tissues outside the alimentary tract. For example, when Coxsackie-B virus shows up in the cerebrospinal fluid, the clinical picture is that of meningitis. If it invades the muscles of the chest and diaphragm, the patient experiences the pains of pleurodynia. In a single epidemic the same virus may cause pleurodynia, or meningitis or both, depending on the tissues involved. Similarly, epidemics of ECHO Type-9 infections may be attended by an illness characterized by fever and a skin rash, by aseptic meningitis or by a combination of both. Paralysis from polio virus is directly proportional to the degree of virus multiplication in the spinal cord. Evidence is mounting that Coxsackie and ECHO viruses can also produce muscle weakness and moderate paralysis indistinguishable from polio; fortunately the illness is ordinarily less severe than polio, and with the passage of time recovery is usually complete. More often, however, the enteroviruses, including even the virulent polio strains, produce inapparent infections. Tissue-culture tests demonstrate that, once the virus gains a foothold, it multiplies continuously in the human intestinal tract for a period of weeks,

	ENTEROVIRUSES		ASSOCIATED DISEASES	DESCRIPTION
POLIO VIRUSES			PARALYSIS	COMPLETE TO SLIGHT MUSCLE WEAKNESS
			ASEPTIC MENINGITIS	NONPARALYTIC POLIOMYELITIS
			UNDIFFERENTIATED FEBRILE ILLNESS	FEVER OCCURRING PARTICULARLY DURING THE SUMMER
COXSACKIE VIRUSES GROUP A			HERPANGINA	ILLNESS COMMON IN CHILDREN, WITH FEVER AND BLISTERS IN THROAT
			UNDIFFERENTIATED FEBRILE ILLNESS	FEVER OCCURRING PARTICULARLY DURING THE SUMMER
			ASEPTIC MENINGITIS	INDISTINGUISHABLE FROM NONPARALYTIC POLIOMYELITIS
			FEBRILE ILLNESS WITH RASH	
COXSACKIE VIRUSES GROUP B			ASEPTIC MENINGITIS	INDISTINGUISHABLE FROM NONPARALYTIC POLIOMYELITIS
			PLEURODYNIA (BORNHOLM DISEASE)	PAINFUL DISEASE OF MUSCLES OF CHEST AND DIAPHRAGM
			UNDIFFERENTIATED FEBRILE ILLNESS WITH PHARYNGITIS	FEVER WITH INFLAMMATION OF NOSE AND THROAT
			MYOCARDITIS OR ENCEPHALOMYOCARDITIS OF INFANTS	INFLAMMATION OF HEART, WITH OR WITHOUT MILD PARALYSIS
			MILD PARALYSIS OR ENCEPHALITIS	SIMILAR TO PARALYTIC POLIOMYELITIS
ECHO VIRUSES			ASEPTIC MENINGITIS	INDISTINGUISHABLE FROM NONPARALYTIC POLIOMYELITIS
			FEBRILE ILLNESS WITH RASH	COMMON IN CHILDREN
			BOSTON EXANTHEMA	RASH CAUSED BY ECHO 16
			UNDIFFERENTIATED FEBRILE ILLNESS	FEVER OCCURRING PARTICULARLY DURING THE SUMMER
			MILD PARALYSIS OR ENCEPHALITIS	SIMILAR TO PARALYTIC POLIOMYELITIS
			SUMMER DIARRHEA OF INFANTS AND CHILDREN	

DISEASES ASSOCIATED WITH ENTEROVIRUSES vary in kind and severity. Several of the viruses can produce the same disease. The causative agent is then identified by its ability to produce disease in monkeys (*polio viruses*), to produce disease in newborn mice (*Coxsackie viruses*) or to form characteristic plaques on tissue culture (*polio, Coxsackie B and ECHO viruses*).

but produces no symptoms of any kind.

All the enteroviruses have approximately the same size and shape. They are spherical, with diameters of about 25 millimicrons (.000025 millimeter), as measured by filtration through collodion membranes of graduated-pore size, by ultracentrifugation and by studies with the electron microscope. These measurements were recently confirmed by a new technique that employs ionizing radiation to measure not only the size of the virus but also the size of its component functional parts. This technique relates the measurement of size directly to the biological activity of the particle: the rate at which a given biological property is lost in irradiation is directly proportional to the size of the unit involved in that property. Such studies show that the infective or reproductive unit is 25 millimicrons in diameter and that one antigenic part of the virus, the so-called complement-fixing component, is 10 millimicrons in diameter. The polio viruses and one of the Coxsackie viruses contain nucleic acid of the ribose type (RNA), and, as with other viruses studied, the infective unit seems to be contained in the nucleic-acid part of the virus particle.

The major types of enteroviruses may be distinguished by the way in which they grow in tissue culture. Polio viruses flourish on cultures of monkey cells from many different organs: kidney, testicle, muscle. Coxsackie-B viruses are just as versatile, but only a few of the 19 Coxsackie-A viruses have been successfully cultivated in tissue cultures. ECHO viruses grow well only on cultures of primate kidney tissue, preferably from the Asian rhesus monkey. They grow with difficulty or not at all on kidney tissue from the African red monkey, although polio and Coxsackie viruses grow better on the cells from this monkey than on rhesus cells. The various types of viruses may also be distinguished by the characteristic shapes and sizes of the plaques their colonies form in tissue culture under agar. Polio viruses readily form large round plaques with sharp boundaries. Coxsackie-B viruses produce similar but slower-growing plaques. The ECHO viruses, after several days' delay, grow into small plaques often with rather irregular shapes and diffuse boundaries. The presence of more than one type of enterovirus in specimens taken from human beings can often be detected by the kind of plaques formed. The different viruses may then be separated by transplanting single plaques or by growing the viruses in the presence of antiserum

SIGN OF VIRULENCE in polio viruses is the ability to grow on a layer of monkey cells maintained for many passages in tissue culture. A virulent strain (*left*) grows readily on these cells, but an attenuated strain of the same type (*right*) grows very poorly on them.

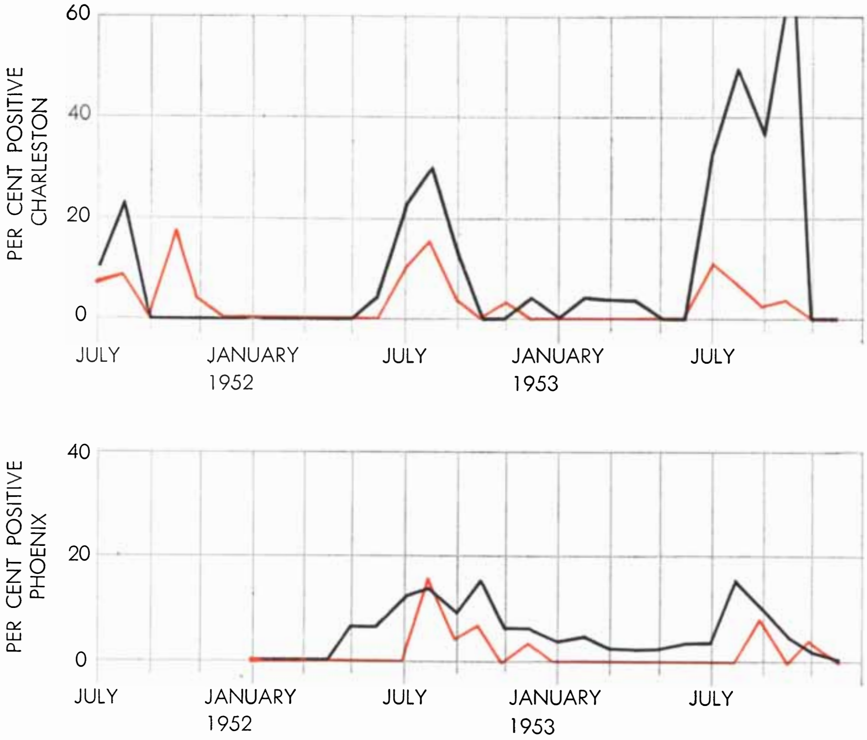
which inhibits the growth of one type.

Since different varieties of enteroviruses are often found together in the same patient, we wondered whether they might interact genetically. We subjected single cells obtained from monkey kidney to double infections with ECHO-7 and Coxsackie-A9 viruses, and studied the properties of the viruses released in the disruption of individual cells. Some cells produced virus particles, each of which possessed antigens of both parent viruses, while others yielded the parent strains as separate entities. But the doubly antigenic particles were not genetically stable. Their progeny all reverted to the original types, indicating that no true genetic recombination occurred in these experiments. We obtained similar results using mixtures of ECHO and polio viruses.

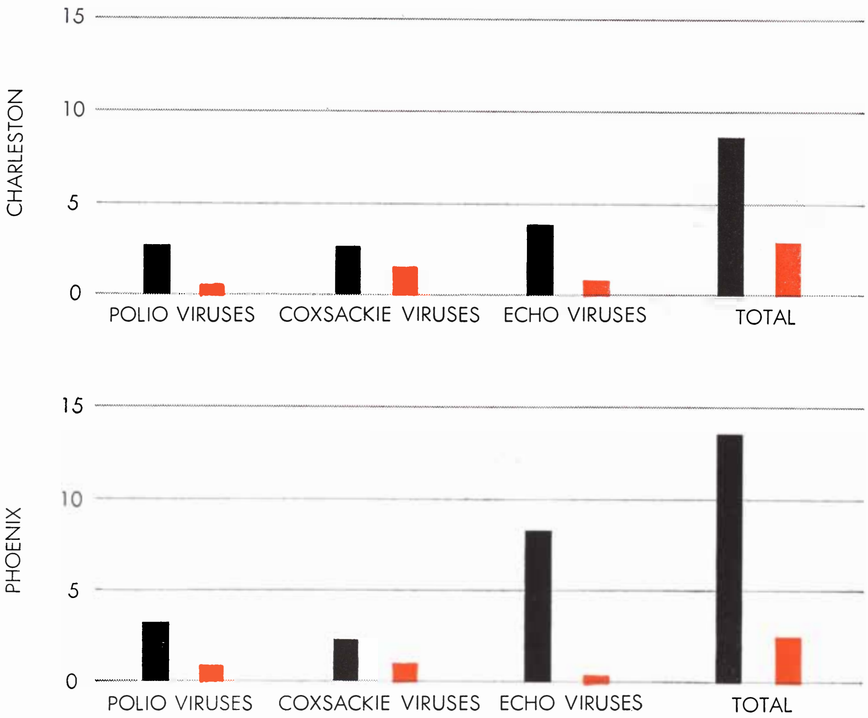
Investigation of the genetics of the enteroviruses is seriously handicapped by the lack of adequate genetic "markers" to distinguish the strains from one another in the test tube. It is becoming increasingly difficult, moreover, to distinguish the viruses from one another by their preferences for various hosts. Such preferences provided one basis for their original classification into major types. Polio strains are now known, however, that barely cause disease in monkeys, while certain other strains produce illness in mice as well as in monkeys. Many naturally occurring strains of Coxsackie viruses, of Group B or of Type A9, lack the cardinal characteristic of virulence for suckling mice. Furthermore, one strain of Coxsackie A14 and some A7 strains can produce polio-like lesions in monkeys. The Soviet virologists Michael P. Chumakov and Marina K. Voroshilova have isolated from a paralytic patient an A7 strain that produced in monkeys a paralytic disease identical with polio. The ECHO viruses, originally designated as being harmless to newborn mice, seem also to be losing this distinction. Strains of ECHO 9 from the widespread European epidemic of 1956 and from the American epidemic of 1957 produce disease in suckling mice with widespread muscle damage resembling that caused by Coxsackie-A viruses. In these cases, however, the original material collected from human patients had to be passed through successive tissue cultures to select out the virus particles virulent for mice. All the enteroviruses studied—including members of the polio, Coxsackie and ECHO groups—have been found to infect chimpanzees at least to the extent of multiplication in the alimentary tract.

The symptomless alimentary infection, which is by far the most common infection caused by the enteroviruses, confers a solid immunity on the host, one which makes it difficult for a virus of the same type to become re-established in the gut at a subsequent exposure. When the Salk killed-virus vaccine was first introduced, we wondered whether it might not prevent later inapparent infection, and thus interfere with the natural lifelong immunity that ordinarily follows. If such were the case, then paralytic poliomyelitis might only be postponed by vaccination, perhaps to a time in life when the disease would be more dangerous than in childhood. To test this possibility we, as well as other investigators, fed attenuated polio viruses to human subjects who had been immunized by Salk vaccination, and then observed them for evidence of intestinal infection. Parallel observations were also conducted on the families of polio patients and of vaccinated children exposed to healthy carriers of polio. These studies indicate that persons immunized with Salk vaccine can pick up an intestinal infection just as readily as a nonimmunized person. There was no notable difference in the duration or intensity of infection, as indicated by the time over which intestinal specimens show signs of virus and by the amount of virus excreted.

It seems that inapparent infection during the first year after vaccination may boost the immunity of the individual, but the consequences of infection at a later period, when the vaccine-induced antibody has disappeared, remains to be determined. We conclude that while paralytic disease is significantly reduced by Salk vaccination, the actual prevalence of polio infection in the community is not affected. This is a desirable situation, for if the community were entirely dependent upon artificial immunization, the Salk vaccination would have



SURVEY OF HEALTHY CHILDREN in Charleston, W. Va., and Phoenix, Ariz., revealed that enteroviruses were prevalent mainly in summer and were carried more frequently by children from poorer homes (*black*) than by those of a higher socio-economic level (*color*).



ENTEROVIRUSES were found in less than 3 per cent of the specimens from children of the higher socio-economic districts (*color*) of Phoenix and Charleston, but in 8 per cent and 13 per cent, respectively, of those in poorer environments (*black*). The incidence of polio, Coxsackie and ECHO viruses was markedly higher among children of poorer districts.

to be repeated periodically in the entire population to protect older persons from the inevitable reintroduction of the polio virus.

The permanent immunity produced by "silent" infection still makes the possibility of vaccination with live virus attractive. Some polio strains isolated from normal individuals have very little affinity for nerve cells and yet confer full immunity against related virulent strains, and are considered to be attenuated. Attenuated strains of all three polio viruses have been obtained also by manipulation of the virulent strains in the laboratory. Any of these strains might serve as a live-virus vaccine, to be given orally either alone or after vaccination with killed virus. The most serious objection to the use of live viruses, however, arises from the possibility that an attenuated strain used for vaccination purposes may mutate to a virulent form as it spreads in the community.

At present the virulence which a polio virus may possess for the nervous system can be tested only by inoculation in monkeys. The labor and expense of this procedure make it highly desirable to seek reliable markers for this characteristic that can be detected in tissue cultures. Some markers of this type have recently been discovered. Attenuated viruses, for example, usually grow more slowly than virulent ones in cultures of fresh monkey-kidney cells under slightly acid conditions. Those delayed in growth are designated as possessing the delayed or *d* marker, and those that grow rapidly under these conditions are designated as *d*+. Another genetic marker associated with virulence in the nervous system is the ability of the virus to grow on monkey-kidney cells that have been maintained by many serial passages in tissue culture. When attenuated viruses are fed to volunteers, we find that the *d* strain usually shows up unchanged in stool specimens. Occasionally we have found mutations to the *d*+ type, but these mutant viruses still show little affinity for nerve cells. The reverse mutation from attenuation to virulence evidently requires a series of stepwise changes rather than a single alteration in the genetic constitution of the virus.

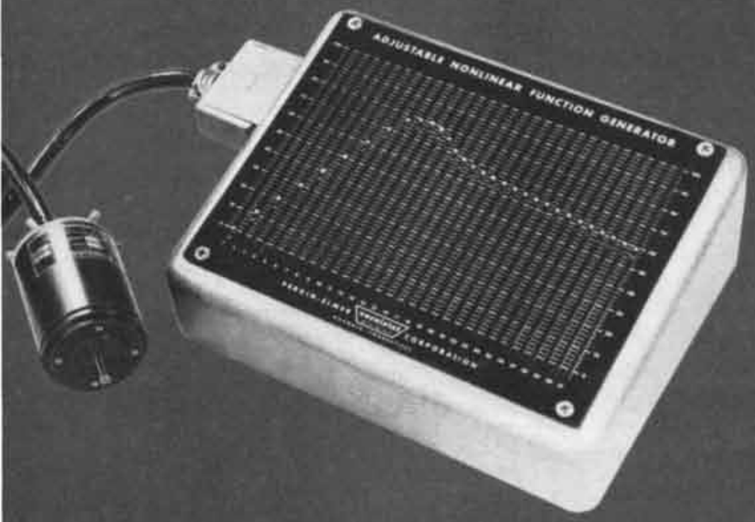
There is ample evidence to show that infection spreads readily from persons excreting virus to those in contact with them. In families of infected persons all the enteroviruses spread with ease to persons who lack immunity from previous exposure. Since the infections are rarely severe, the true picture of illness caused by an epidemic of enterovirus infection is not reflected by the number of hospitalized patients. A survey in a town of 20,000 during an ECHO-4 outbreak, with 27 reported cases of aseptic meningitis, revealed that 16 per cent of the population had illnesses that were probably attributable to the virus. Similarly, during a period when 149 inhabitants of Milwaukee, a city of 740,000, were hospitalized with ECHO-9 disease, a community survey led to the estimate that some 45,000 people were ill at home with an illness of a related kind.

Studies of several hundred normal children under five in Charleston, W. Va., and in Phoenix, Ariz., show that the frequency of virus infection in the poorer districts of each city is three to six times as great as in the middle- to upper-middle-class districts with better environmental sanitation. Among the viruses isolated in these surveys, 52 per cent were ECHO viruses, 24 per cent were polio viruses and 24 per cent were Coxsackie viruses.

The enteroviruses have a global distribution. They have been found in Eskimos living in remote regions in northern Alaska, as well as in inhabitants of tropical countries in both the Eastern and Western Hemispheres. Epidemics produced by the enteroviruses occur in the temperate zones during the summer and early autumn, although cases may continue into the winter. In the Charleston and Phoenix surveys we made almost all of our virus isolations in the summer and fall, except in the poorer districts of subtropical Phoenix, where viruses were recovered more evenly throughout the year. The seasonal prevalence of enteroviruses has been well illustrated by the monitoring of sewage and flies in a number of localities. Virus appears almost invariably in specimens collected during the summer and fall, and turns up only rarely during the cold months. The frequency with which virus is recovered in specimens will vary in the same community from one year to the next by 10 to 100 per cent. The virus type will also vary from year to year. In Topeka, Kan., for example, Coxsackie-A5 predominated in the first part of a summer and was succeeded by A6 in the fall. During one year Types A5 and A6 were predominant in Albany, N.Y.; a year later they had been replaced by Types A4, A8 and B2. Thus the apparent persistence of enterovirus infection in the population may actually reflect the spreading of a succession of waves of different types of virus through the city.

THE P-E SPECTRUM

news of advanced systems and instruments from Perkin-Elmer



ARMY DEVELOPS SPECIAL COMPUTER FOR WIND-CORRECTED MISSILE LAUNCHINGS

A new U.S. Army Signal Corps Research and Development Laboratory computer utilizing the Vernistat® Adjustable Function Generator has been developed to overcome effects of low-altitude winds on missile accuracy.

The relatively low velocity of a missile immediately after launching makes its trajectory subject to distortion by near-surface winds. To insure that the missile hits a predicted impact point, the effect of these winds must be determined accurately.

To do this, pilot balloon runs are made shortly before a missile launching and wind data are computed for its effect on the missile's programmed trajectory. Previously, these computations were done manually, required considerable time, and frequently new weather conditions made the calculations obsolete before the missile launching occurred.

The new computer determines wind conditions at various altitudes, calculates their effect on the missile, and automatically reads out the deviations from the point of impact in miles north-south and east-west. Corrections are then made in the launching mechanisms.

The computer employs two Adjustable Function Generators developed by Perkin-Elmer. These function generators were chosen because of their accuracy and ease of adjustment. They permit the input function to be changed in a matter of seconds, making the computers quickly adaptable for use with a variety of missiles.

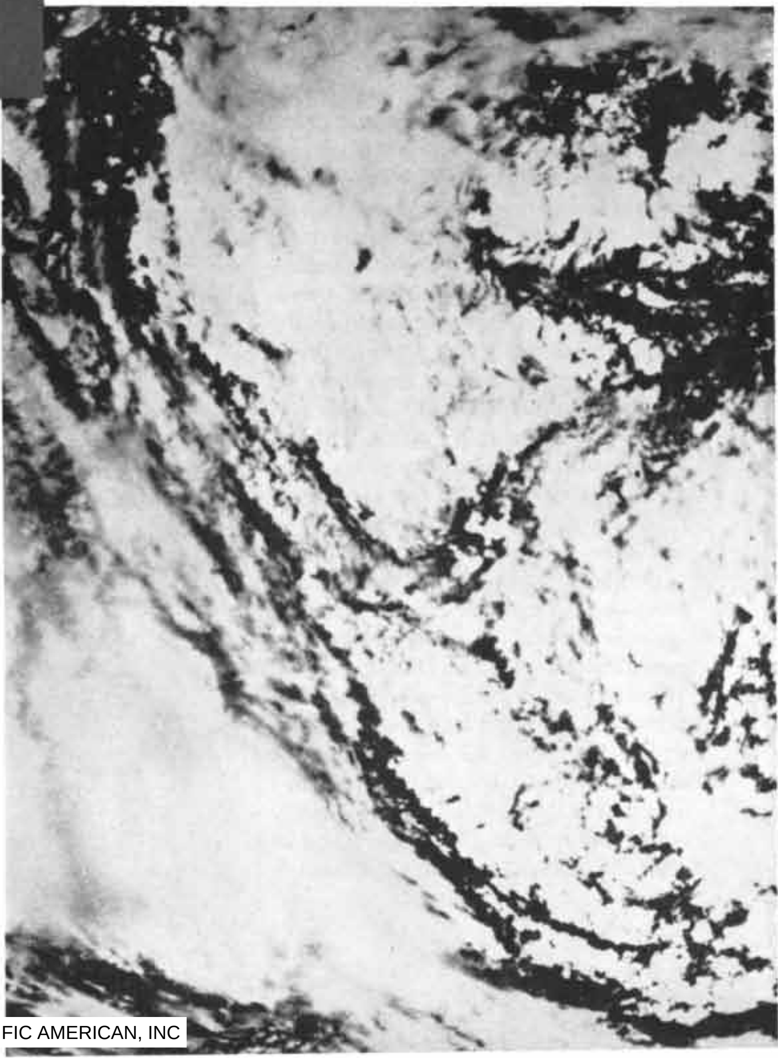
EYE FOR AN EYE — NEW PANORAMIC CAMERA PHOTOGRAPHS 30-MILE CENTER OF TYPHOON

For the first time meteorologists have gotten a bird's-eye view of a typhoon's eye in its entirety. A unique, horizon-to-horizon aerial camera developed by Perkin-Elmer recently enabled Air Force weathermen to photograph the 30-mile-wide eye of Typhoon "Kit" in the Pacific.

Clearly visible also to weather scientists who studied the photographs were the storm's nine false eyes. (See photo, right, and accompanying analysis showing small cyclonic whorls, marked "C.") The mosaic photos were taken from an altitude of approximately 55,000 feet. On some photos, transverse sea waves were visible through holes in the 48,000-foot high clouds.

The Perkin-Elmer camera employs a rotating prism which "wipes" the image on film as it scans from horizon to horizon at right angles to the flight path. The 50-lb. camera is a scaled-down version of a 1500-lb. model developed by Perkin-Elmer for the Air Force several years ago. The camera can take either adjacent or stereo-overlapping photographs automatically.

Other applications seen for the panoramic camera include military mapping operations, geological surveying, highway engineering, soil conservation studies, tree census projects and other fields requiring extremely wide-angle, continuous photographic coverage of terrain.



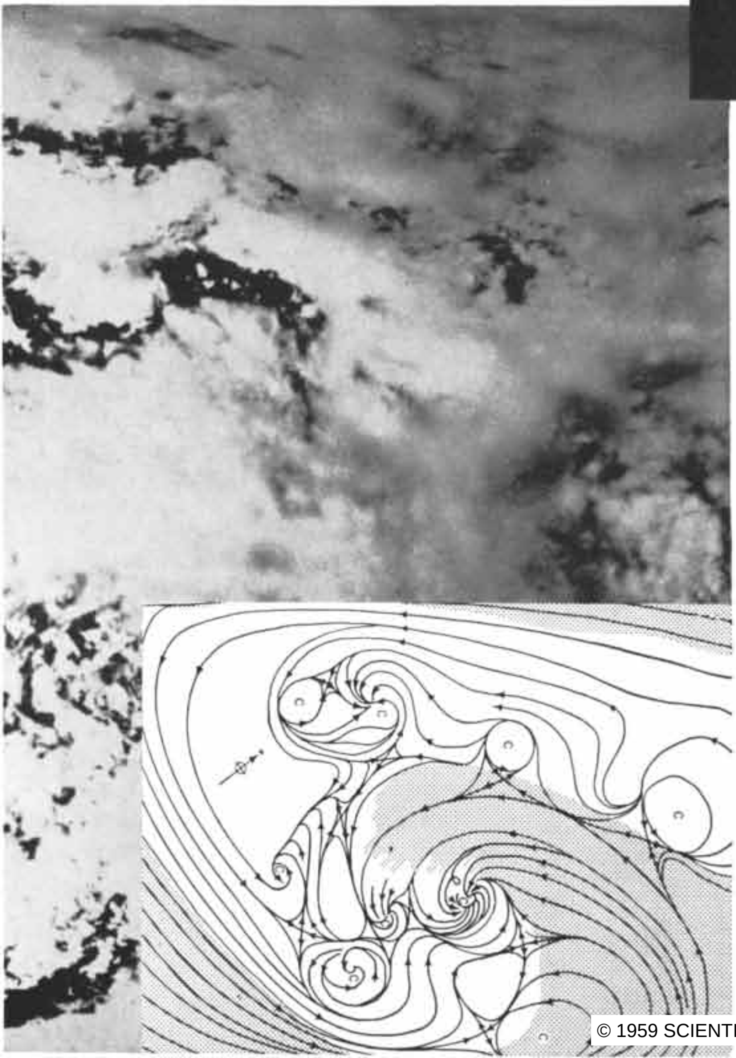
TOBACCO SMOKE TO GUN SMOKE—INDUSTRY FINDS A USEFUL NEW TOOL IN GAS CHROMATOGRAPHY

The science of gas chromatography got new impetus some three years ago when Perkin-Elmer introduced one of the first commercially successful chromatographic instruments—the Model 154 Vapor Fractometer. Since then scores of industries have reported valuable, new uses for this low-cost, easy-to-operate analytical tool. Among the latest uses for the P-E Vapor Fractometer:

Tobacco researchers at Duke University recently devised a technique for identifying nonvolatile organic acid components of tobacco smoke. Using a modified Vapor Fractometer, they were able to identify 10 acids which had not been reported previously as smoke constituents.

At the Process Research Division of Esso, a battery of eight Model 154 instruments performs more than 700 types of analyses a month. Researchers here have gotten an especially high investment return in the analysis of light ends of olefin-free gasolines. Previously this work took an average of three hours per sample. Esso now does it with a Vapor Fractometer in 15 minutes with equal or greater accuracy.

Vapor Fractometers are taking to the air at Douglas Aircraft. Their ability to make fast, repetitive analyses is being used to check the safety and in-flight effectiveness of airplane fire extinguishing systems and to test cockpit air for contamination from gun gases when the plane's armament is fired. Douglas also uses its Vapor Fractometers to separate jet and rocket fuels into components for further analysis by infrared.



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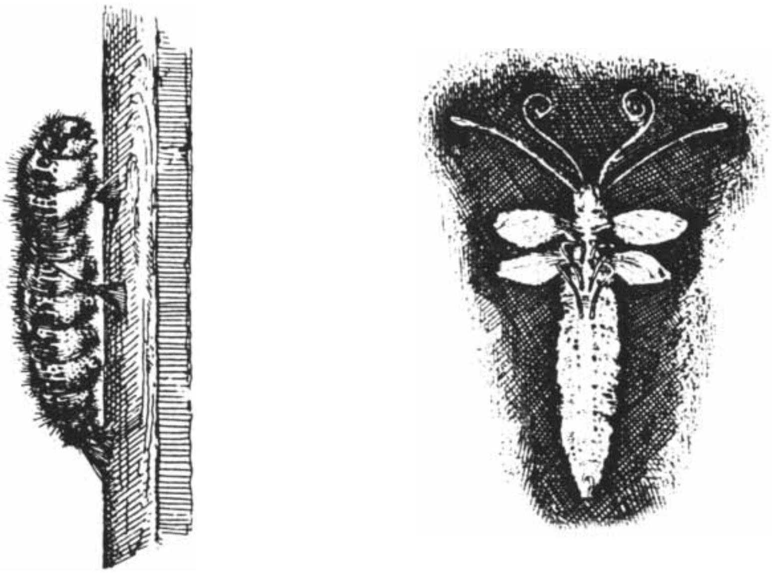
Metamorphosis, Polymorphism, Differentiation

The wondrous transformation of insects is explained by two familiar growth processes. One accounts for differences among individuals in a species; the other, for differences among tissues in an organism

by V. B. Wigglesworth

I was five years of age when I made the most important scientific discovery of my life. A caterpillar I had imprisoned in a jam jar wrapped itself in silk and then, some days afterward, emerged under my close and astonished observation a butterfly!

Later on I learned that others, including Aristotle, had anticipated me in my discovery of insect metamorphosis. Natural philosophers and small boys apparently find the same amazement in the transformations of insects from caterpillar to chrysalis to butterfly, or from grub to pupa to bee. They have also usually arrived at the same explanation for this peculiar departure from the common pattern of growth observed in other animals. According to Aristotle, the embryonic life of insects continues until the formation of the perfect insect, or imago. "The larva while it is yet in growth," he wrote, "is a soft egg." William Harvey, famous chiefly for his discovery of the circulation of the blood, surmised that the insect egg contains so little yolk that the embryo is obliged to emerge before completing its development. It then goes through a more or less prolonged larval stage during which it stores up quantities of food material—more yolk, as it were—before resuming the egg or pupa form and completing its embryonic growth. Up to the end of the last century we still find authors writing of "those sorts of eggs that are called nymphs or pupae." And in current textbooks it is common to find the view expressed that metamorphosis is to be explained by the immaturity of the insect at the time of hatching from the egg.



ADULT FORM CONCEALED in larva was discovered in 1669 by Jan Swammerdam, who dissected a caterpillar on the verge of spinning its cocoon. This demonstration of continuous growth of organs from existing structures helped dispel mystical views of metamorphosis.

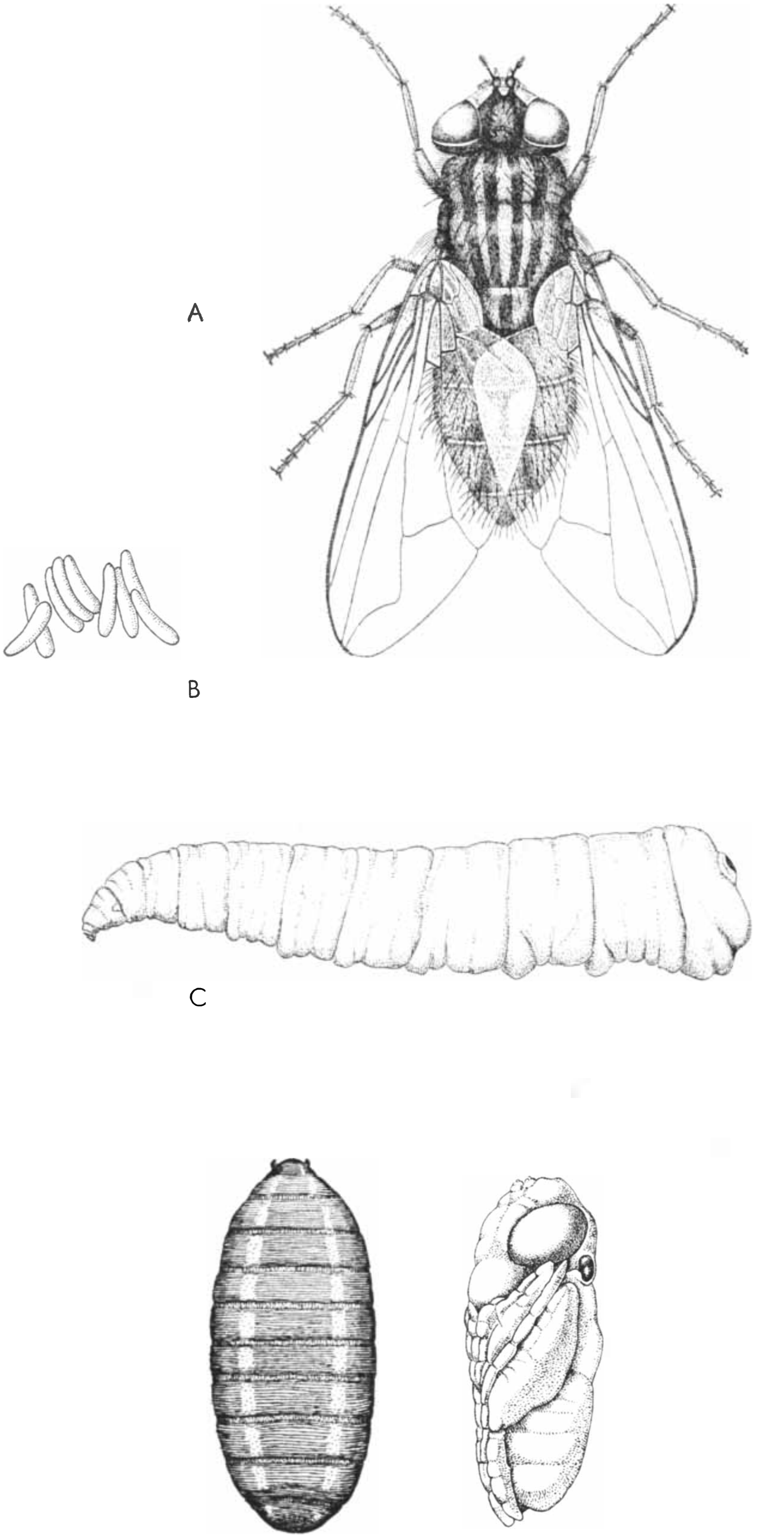
But when metamorphosis is looked at more closely, this theory is not so satisfactory. Of course the development of the pupa has much in common with development of the embryo. Certain parts of the body, such as the wings, grow enormously, drawing upon reserves elsewhere in the body, just as the growing organs of the embryo draw upon the yolk. But that is no more than an analogy; it does not prove that the pupa, nor yet the larva, is an embryo. Instead of regarding the larva, the pupa and the adult as three stages in the progressive unfolding of a complex organism, it is possible to think of them as alternative forms which an already complex organism assumes at different periods in its development. In what follows we shall see that this view has the advantage of bringing metamorphosis into line with developmental patterns that are more universal in nature. Different individuals of a species, for example, frequently display variations in form that are no less extreme than those exhibited by an insect in different phases of its metamorphosis; such variation in form is called polymorphism. Similarly, different parts of many-celled organisms vary widely in form, though all of the tissues arise from the same single cell. Insect metamorphosis provides favorable opportunities for observing this process of differentiation under experimental control.

In Harvey's conception of insect metamorphosis there was an element of the miraculous. Under the action of some mysterious influence the substance of the larva was rebuilt into an entirely new form. The Dutch naturalist Jan Swammerdam, in his *Historia Insectorum Generalis* published in 1669, strongly opposed this mysterious conception of metamorphosis. He had stripped away the skin of a caterpillar before it was due to be cast off and found the wings and other parts of the adult butterfly already in process of growth. From such observation he inferred that every structure arises by a process of continuous growth from an existing structure; that everything is already "preformed" in some state—some invisible state that we are unable to appreciate—from the earliest stages of growth.

At that time living cells were unknown, and genetics and evolution belonged to the future. Swammerdam's followers adopted the crude and exaggerated idea that all the future structures of the body were preformed in the egg, and that all growth and development consisted in the unfolding of these structures as successive covering shells were discarded. The height of absurdity was reached when observers claimed to have seen "homunculi," diminutive outlines of the human form, within the spermatozoon! Excesses such as this brought the reasonable views of Swammerdam into unfortunate disrepute.

With the advantage of current ideas on evolution and genetics and with the results of recent experiments in mind, we should be able to compose a truer picture of insect metamorphosis. The most obvious weakness of the "soft egg" theory lies in the fact that the larva of the more primitive insects, such as roaches, termites and grasshoppers, emerges from the egg in a form that more or less closely resembles the adult insect. The highest insects—the Coleoptera (beetles), the Lepidoptera (butterflies and moths), the Hymenoptera (bees and wasps) and the Diptera (flies)—offer the most striking examples of metamorphosis to be found. And yet the eggs of these insects are not notably deficient in yolk.

It can, of course, be argued that for some unknown reason these higher insects emerge from the egg at an early stage of embryonic development. But the resemblance of caterpillars or maggots to embryos is only superficial. When

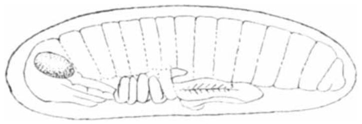


METAMORPHOSIS IN THE HOUSEFLY follows the classical pattern. From tiny embryo in egg (B) the creature grows to full-sized larva (C). The larval skin hardens and darkens to form the "puparium" that shelters the pupa (D). From pupa emerges the adult (A).

they are looked at closely they are seen to be most complex organisms, each highly adapted for its own mode of life.

At this point genetics and evolution enter decisively into the argument. Silkworm breeders long ago observed that there are many different genetic races of silkworms that can be distinguished as larvae but not as adults. Entomologists know of some species of insects that can be readily separated as larvae but only with difficulty or not at all as adults. The converse is also true. Clearly some genes affect only the structure of the larva, while others affect only the adult.

When the larva lives in conditions which differ from those in which the adult lives, it will be exposed to quite different selective pressures. In other words, it will become closely adapted to its special environment, while the pupal form and the adult form will evolve in quite different directions according to the special requirements of their environments. Indeed, as soon as there are differences in the mode of life of the adult insect and its larva, the characteristics of the two forms will tend to diverge. Such divergence may continue until we reach the extremes that separate the maggot from the fly.

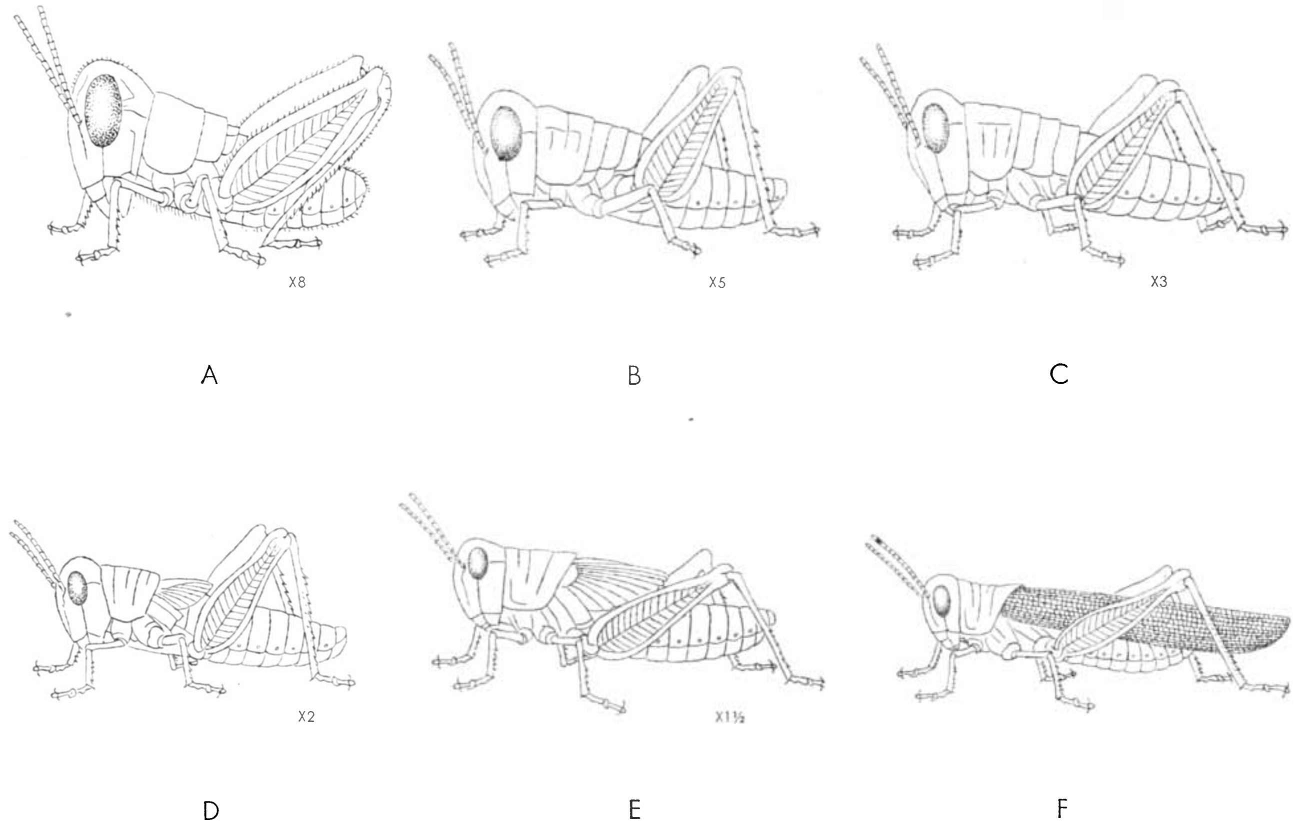


Variation in form is not, however, an exclusive distinction of insects. All animals are more or less polymorphic. Perhaps the most familiar are the male and female forms, which are often strikingly dissimilar within a single species. There is a large number of other variants. Now according to the view which holds metamorphosis to be a special example of polymorphism, the variations in form occur as successive stages in the development of an individual, instead of appearing in different individuals. But individuals of other species may undergo analogous transformation. A hen may be caused to change its plumage and become a functional cock by removal of its ovaries and implantation of a testis.

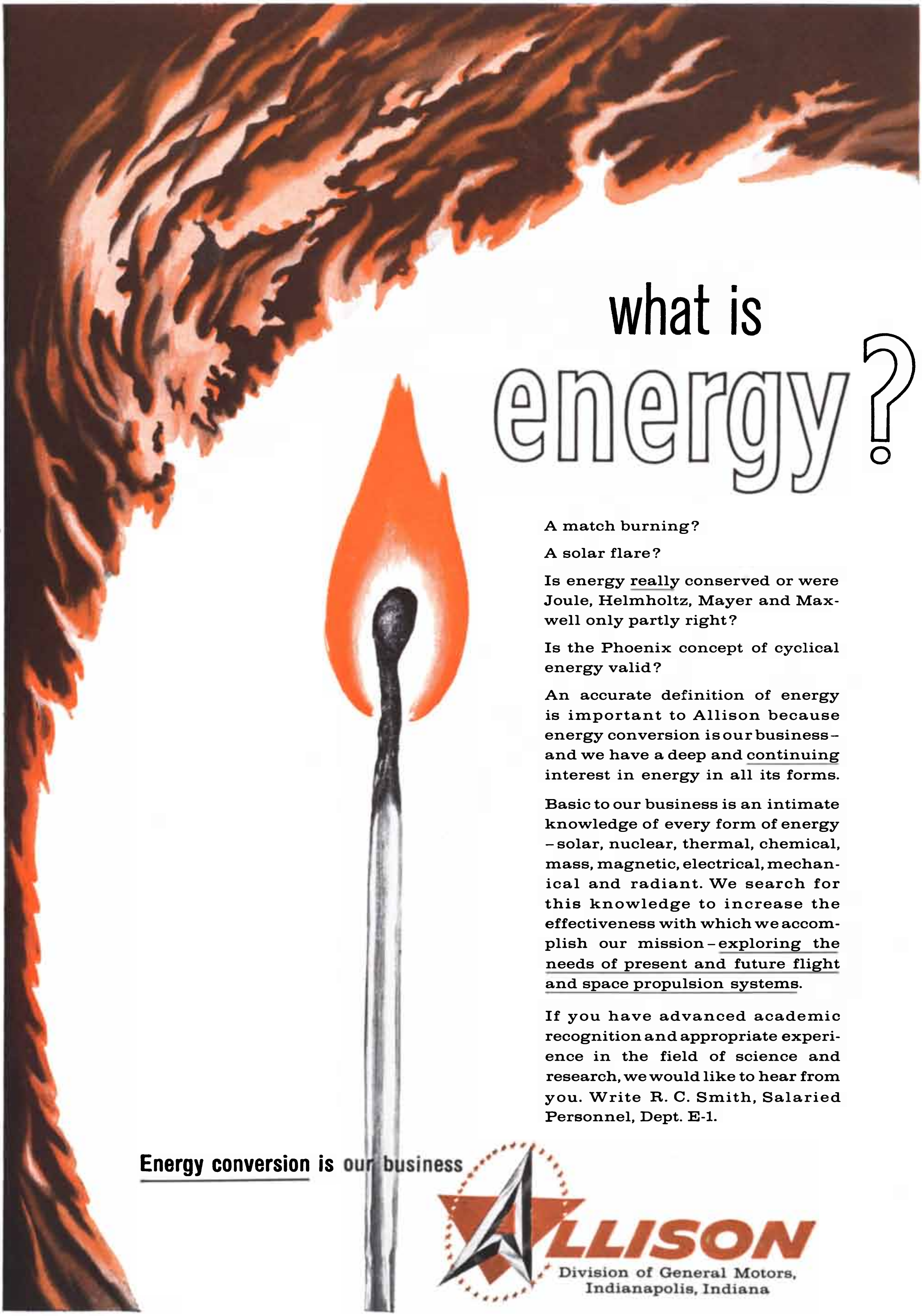
The sexual transformation of a fowl not only provides a close parallel to metamorphosis; it also raises an important aspect of the manner in which genetic inheritance is expressed in the individual. According to the simple tenets of classical Mendelism, the form of the animal is determined by the genes it carries in its cells. But in practice it does not always work out so simply, because other factors may control the manifestation or "penetrance" of some gene effects. Thus the change of sex hormones in the fowl causes its genetic constitution to find expression in an entirely new appearance and behavior.

Two genes in the fruit fly offer simpler demonstrations of the same principle. The main effect of one gene is to cause the antennae to fail to develop in the adult fly. But if the food of the larvae is rich in vitamin B-2, the genetically antennaless fly will develop normal antennae. The second mutant gene causes the modified hindwings—the little knobbed "halteres"—to develop into wings, so that these normally two-winged flies develop two pairs of wings. But this effect is greatly influenced by temperature. At 25 degrees centigrade the penetrance of this gene is 35 per cent; at 17 degrees it is only 1 per cent. Polymorphism in these cases is controlled indirectly by simple changes in nutrition and temperature.

Reversal of sex can also occur in insects. When certain solitary bees and



METAMORPHOSIS IN THE GRASSHOPPER presents far less dramatic changes than in the higher insects, and does not involve the resting pupal stage. The young grasshopper that emerges from the egg at upper left is wingless, but resembles adult except in proportion. The five nymphal (pre-adult) stages are shown same size to emphasize change in proportion. The magnification is given for each.


what is
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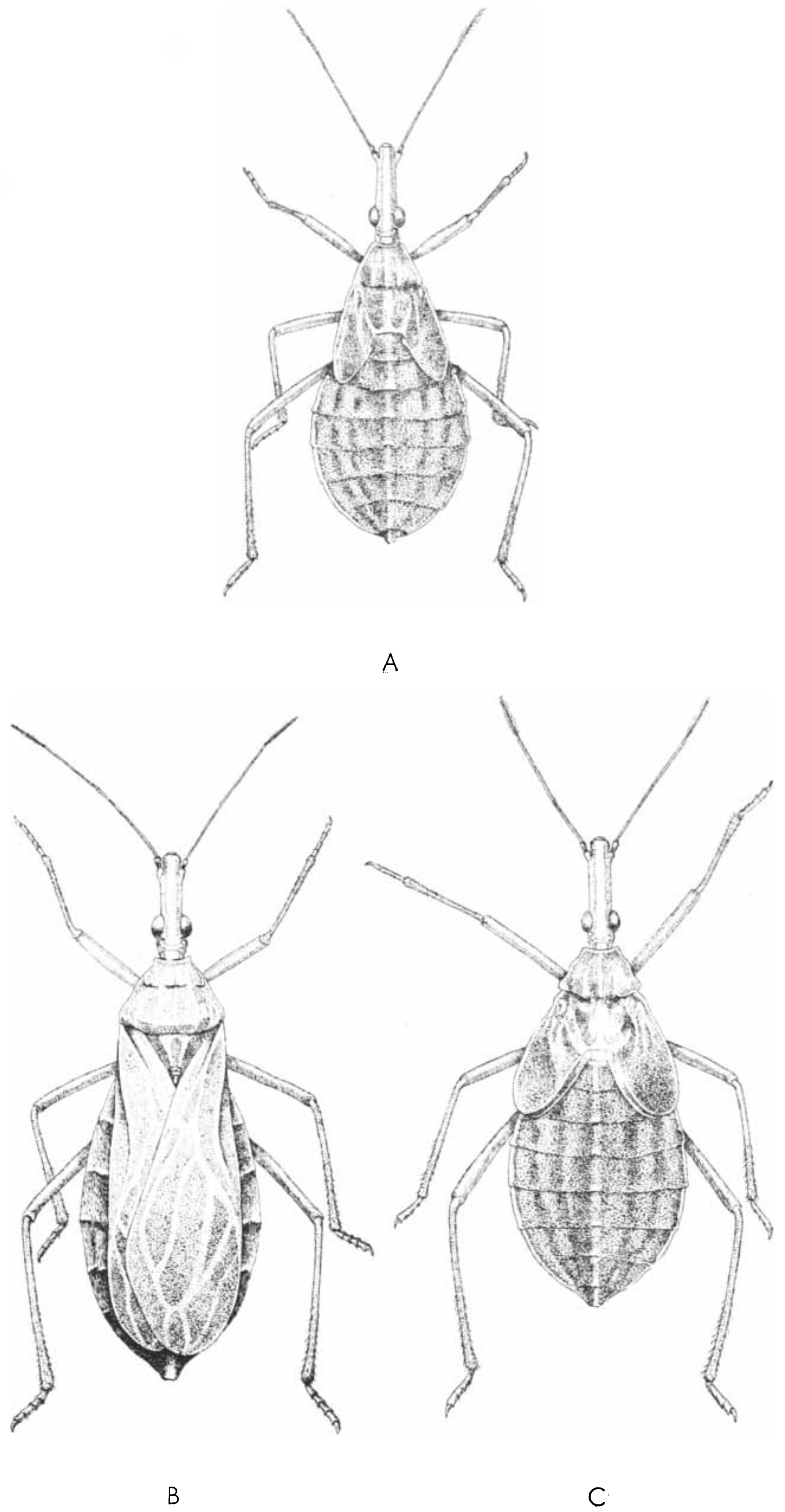


ARRESTED METAMORPHOSIS in the bloodsucking insect *Rhodnius* demonstrates the role of the juvenile hormone. At the end of the fifth stage of larval development (A) this insect normally molts to give rise to the winged adult (B). If the supply of juvenile hormone is artificially maintained by implantation of a corpus allatum gland from a young larva, however, the insect will emerge from the molting as a giant larva and without wings (C).

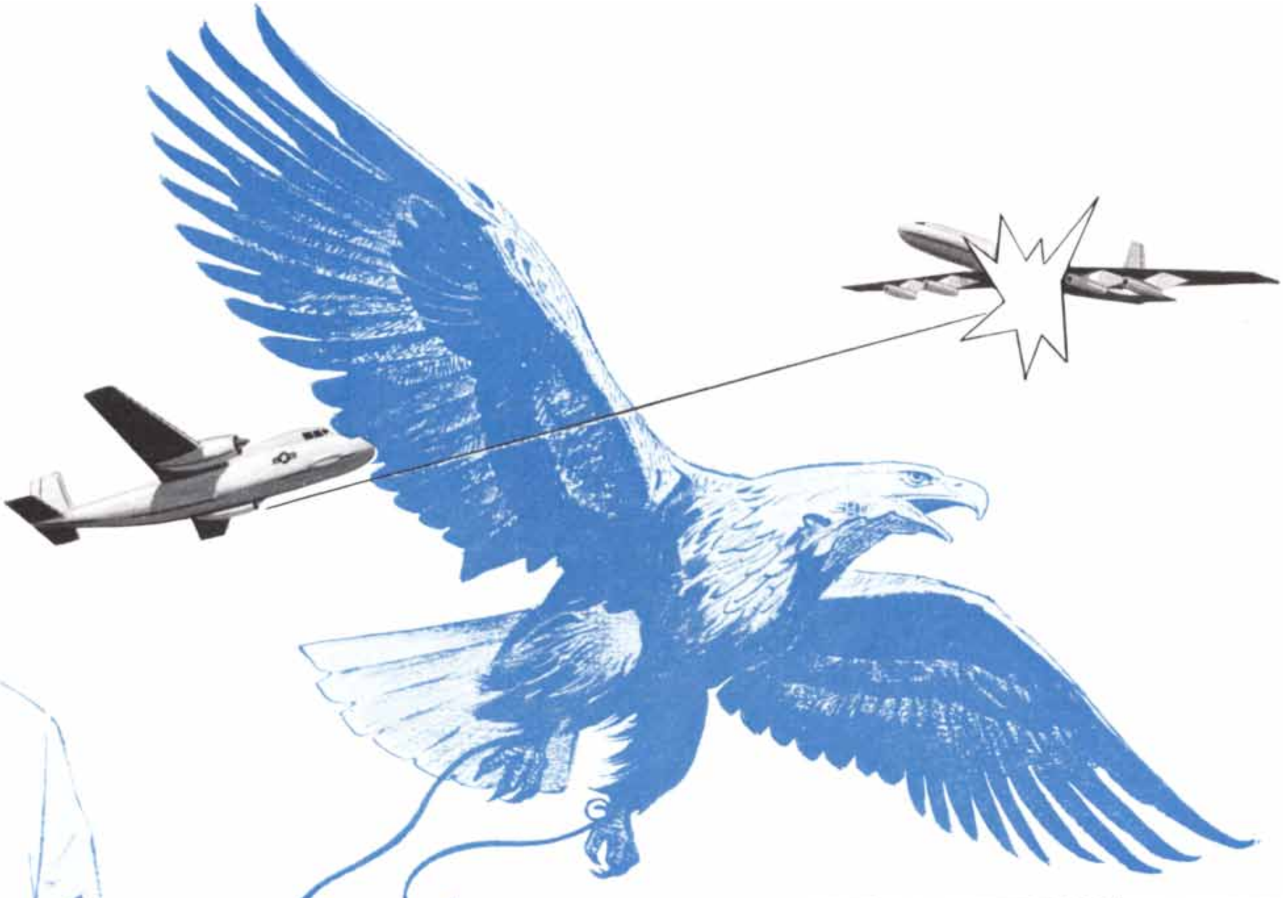
wasps are invaded during their larval life by the strange parasitic insect *Stylops*, male bees will develop the form and markings of females and female bees will acquire the characters of males. The cause of these changes seems to be nutritional; *Stylops* induces sex reversal only in those Hymenoptera which allocate a fixed ration to their larvae. If the larva is fed by its mother according to its needs, sex reversal does not occur. One must suppose that when the demands of the parasite deprive the growing organs of some essential factor in nutrition, the gene balance is upset and the latent genes of the opposite sex, which would normally be suppressed, are able to exert their action.

In some insects the whole outward form of the body may be transformed by a change in nutrition. The resulting insects may readily be mistaken for different species. The tiny parasitic wasp *Trichogramma semblidis* is an example. If its larva develops in the egg of various butterflies or moths, it arrives in the adult state as a normally winged insect. If it develops in the egg of the alder fly, however, the adult is devoid of wings, and the form of its legs and antennae is strikingly changed. Again one must suppose that some essential element in nutrition has influenced the penetrance of certain genes.

These examples of polymorphism provide all the elements of a satisfactory theory of metamorphosis. We simply picture the insect as having a larval, a pupal and an adult form. Each of these forms has evolved as an adaptation to life in a special environment, and each is controlled by its appropriate set of genes. What controls the activation, or penetrance, of these gene sets?

Twenty-five years ago it was shown by experiment that metamorphosis is controlled by a small gland known as the corpus allatum, which lies just behind the brain of an insect. During the larval stage this gland secretes a hormone, commonly called the juvenile hormone, or neotenin (the "youth substance"). Under the influence of the hormone the larval characters are retained. When the larva is fully grown, the corpus allatum no longer secretes the hormone; the adult characters are developed and metamorphosis occurs.

These facts were first established with the large South American blood-sucking bug *Rhodnius prolixus*, but they have been confirmed with almost all the other groups of insects. Furthermore, there is much evidence to suggest that in insects such as the Lepidoptera, which have a



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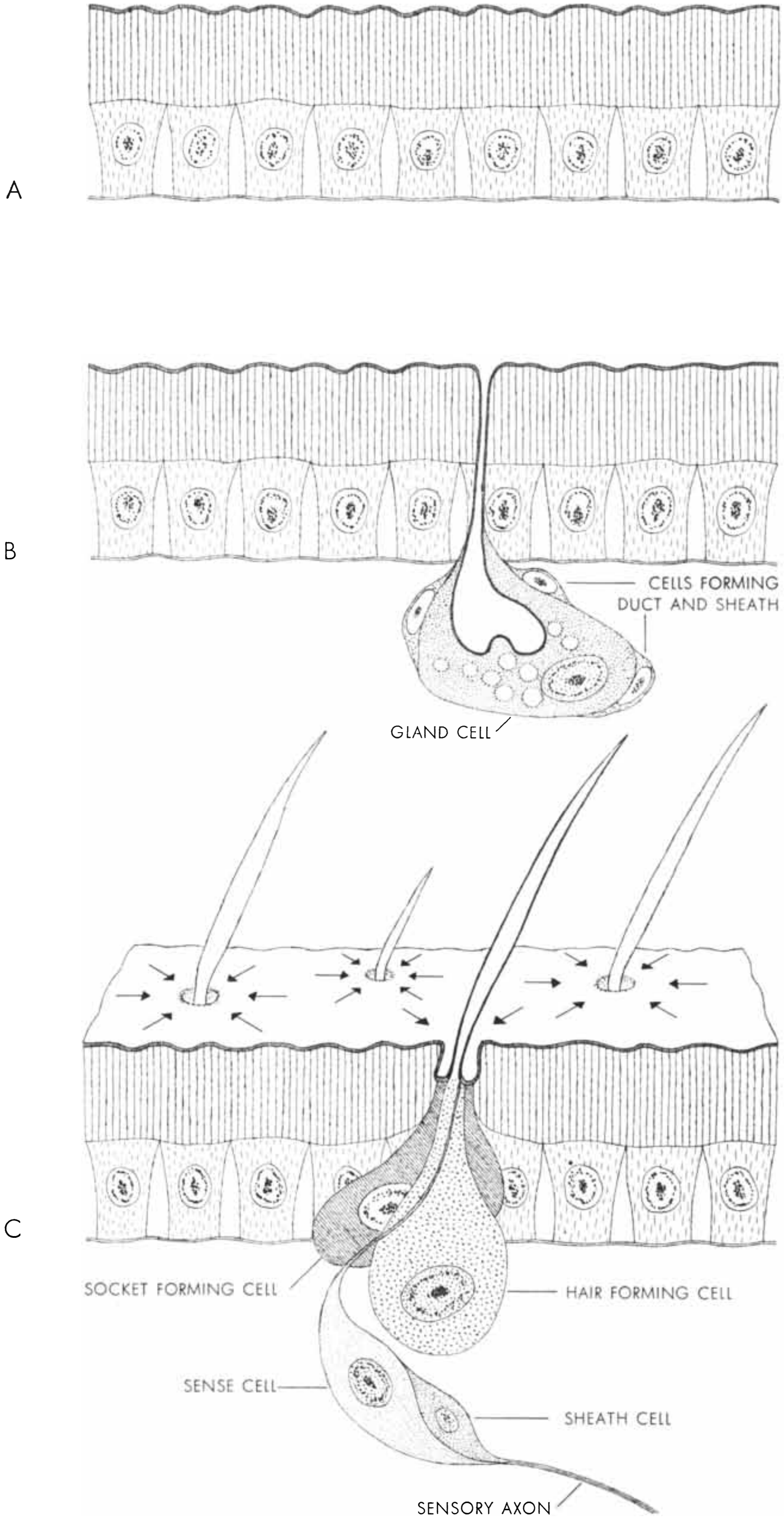


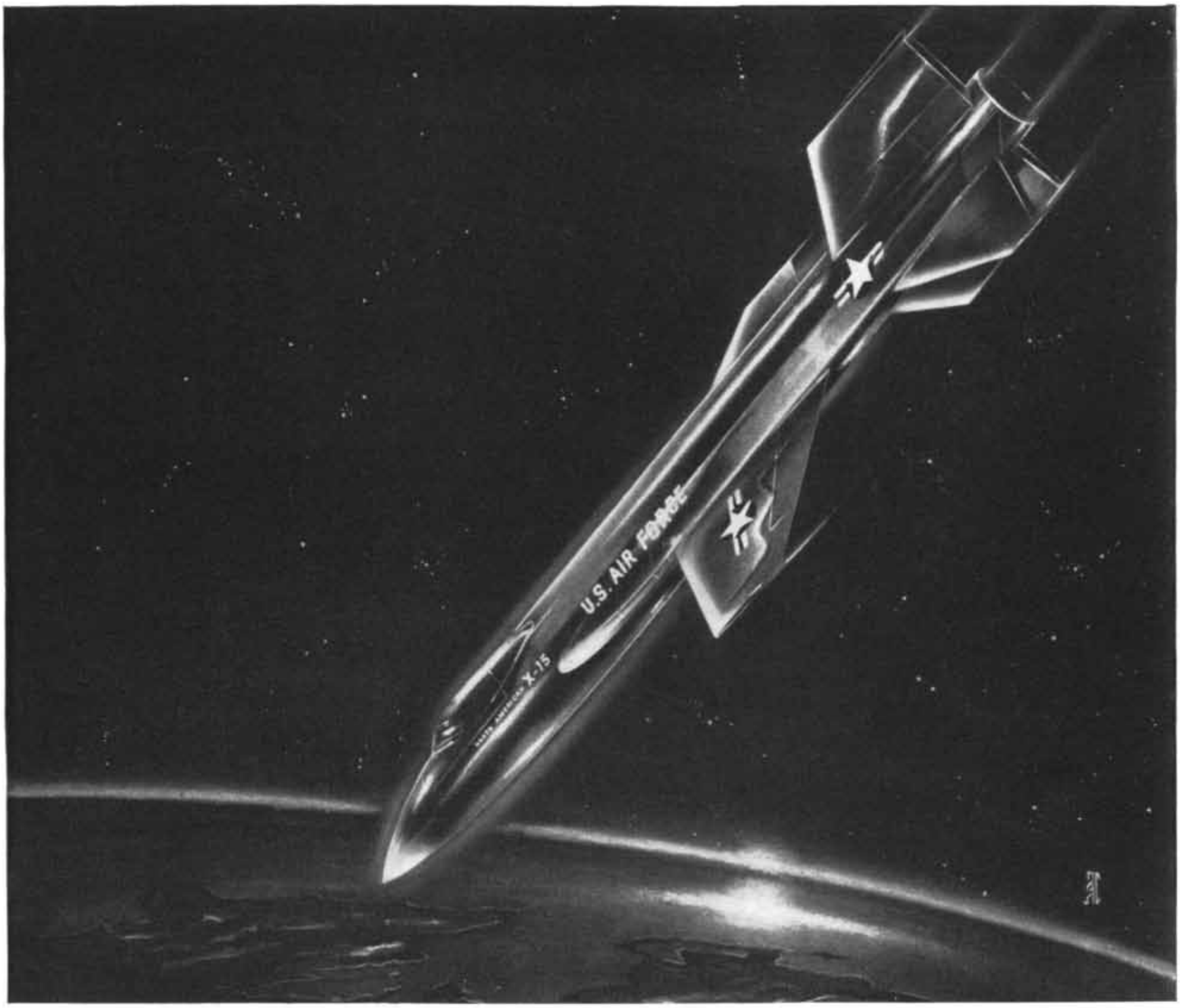
DIFFERENTIATION IN INSECT EPIDERMIS gives rise to two types of organs. In the single layer of cells which produce the hard shell of the cuticle (A) one cell may differentiate to a four-celled dermal gland (B), or it may give rise to a four-celled sensory organ (C). Supposedly a single hormone gives rise to the sensory organ when present in a greater quantity, and to a dermal gland when present in lesser quantity. In either case the response of one cell would deprive others nearby of the substance, and so control the spacing of the organs.

pupal stage, a large amount of hormone secretion is needed to produce the larval form, a very little is required to produce the pupa, while in the complete absence of hormone the adult form appears. Implantation of an active corpus allatum into a larva that is becoming full-grown causes the creature to retain its larval form and to grow into a giant larva [*see illustration on page 104*]. Conversely, removal of the gland causes the larva to undergo prococious metamorphosis and develop into a diminutive adult.

In the mature adult of many insects the corpus allatum begins once more to secrete the juvenile hormone, which may now be necessary for the proper development of the reproductive organs, notably for the deposition of yolk in the eggs. In the Cecropia silk moth, the hormone accumulates for some unknown reason in the abdomen of the male. This has made possible the preparation of active extracts of the hormone which reproduce all the effects previously obtained by the implantation of the corpus allatum.

The juvenile hormone must be a comparatively simple chemical substance, perhaps a sterol of the same general type as the sterol hormones of mammals. Indeed, Howard A. Schneiderman and Lawrence Gilbert of Cornell University have recently obtained a sterol from the adrenal gland of cattle which reproduces the effects of the juvenile hormone when injected into an insect. We have here a clear-cut example of a single chemical substance which determines whether the enzymes responsible for the development of larval characters shall be active or not. It is a reasonable assumption that the production of these enzymes is under the control of the appropriate genes. Thus when the juvenile hormone is present in quantity, the gene system of the larva is active; when little hormone is present, the gene system of the pupa asserts itself; when the hormone is absent, the gene system of the adult becomes ascendant. Just how a simple chemical substance leads to the activation of one set of genes or enzymes to the exclusion of another it is not yet possible to say. But the similarity of this phenomenon to other instances of polymorphism is obvious.

In the case of sex, as we have seen, differentiation can sometimes be reversed: one set of secondary sexual characteristics may give way to the other. This same reversal is possible also in metamorphosis. No one has succeeded in making whole insects revert from adult to larva. But when the juvenile hormone is applied to a restricted area of the abdomen of an adult *Rhodnius*, that area



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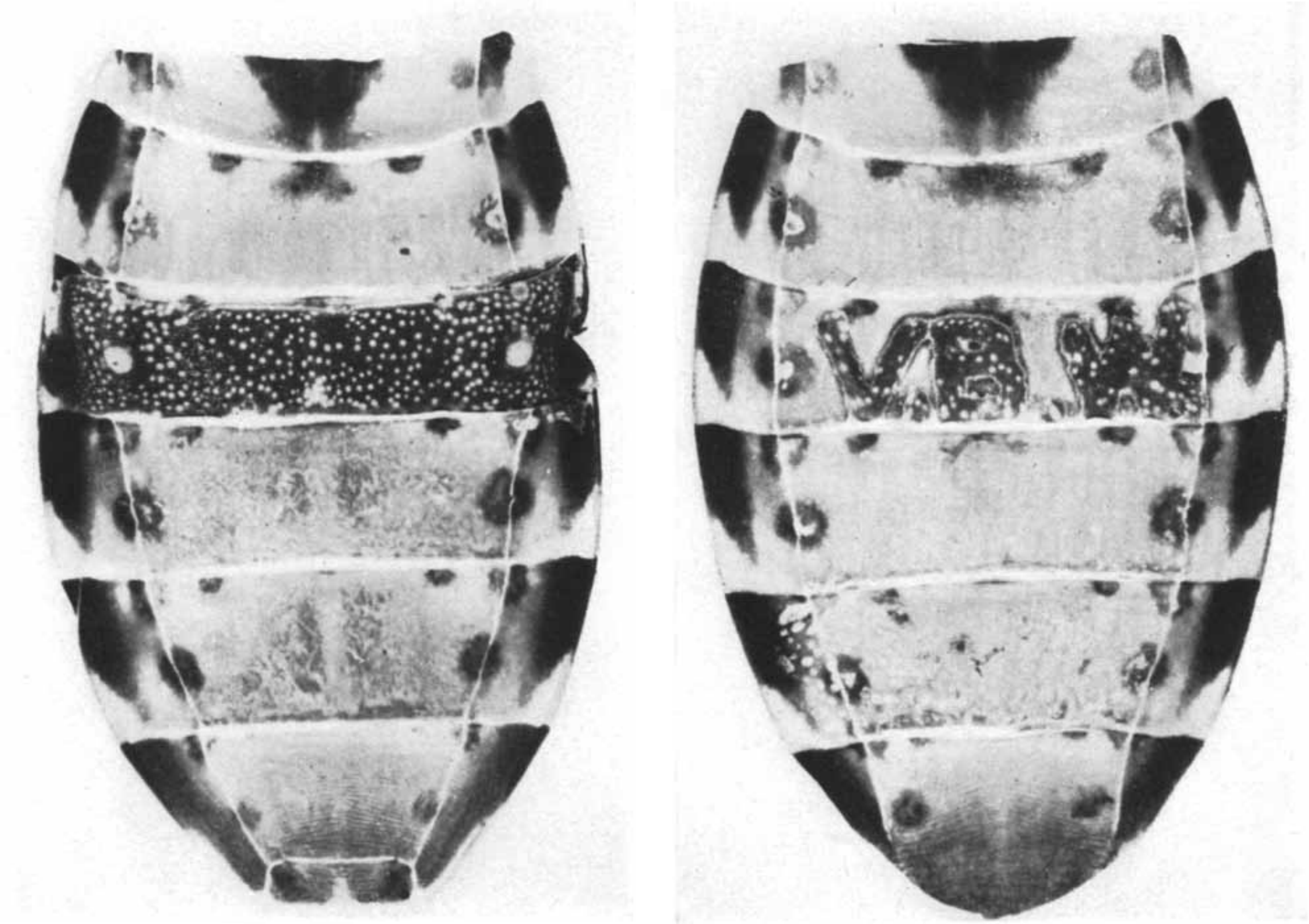

REVERSAL OF METAMORPHOSIS is demonstrated in *Rhodnius*. At left local application of the juvenile hormone has caused the cuticle of one segment in the abdomen to retain its juvenile characteristics. At right the author has traced his initials in larval cuticle.

at the next molt will lay down a cuticle with larval or partially larval characteristics [*see illustration above*]. Related effects have been reported in experiments with other insects. Clearly in some of the cells the enzyme system responsible for larval qualities is still present and capable of reactivation in the adult after metamorphosis.

We find, therefore, a close parallel between the "successive polymorphism," which we call metamorphosis, and the "alternative polymorphism," in which the different characters are developed by different individuals of a species. But there is yet another type of polymorphism which is even more familiar. I refer to the differentiation of the parts of a many-celled organism.

Such an organism begins its life as a single cell. As is well known, the process of cell division is so devised as to ensure an exact sharing of all the genetic material in the chromosomes in the daughter nuclei. It is therefore generally assumed that all the cells in the body have the same genetic constitution. But very soon after the egg cell has begun to divide, the daughter cells become differentiated. Some go on to form the head, others the limbs, others the eyes.

We have here the most striking polymorphism of all. Since the nuclei appear to be genetically uniform throughout the organism, it is generally assumed that differentiation resides in the cytoplasm, that is, that part of the cell which is outside the nucleus. Presumably the different cytoplasms activate or inhibit the nuclei in such a way that different elements in the common gene system can exert their effects. Since the differences in the different cytoplasms are presumably chemical in nature, they must exert their effect on the gene system in the nucleus by chemical means.

Cell differentiation in the developing organism thus presents another close parallel with the other types of polymorphism. However, the factors responsible for bringing out differentiation do not spread freely throughout the body; the developing embryo is divided into "morphogenetic fields," in which the cytoplasm is committed or determined to form particular structures in the body.

We do not know how these fields become different from one another in the embryo. One possible explanation is suggested, however, by the differentiation of cells in the epidermis of certain insects during metamorphosis. The insect epidermis consists of a single layer of cells which secrete the horny "cuticle," the only part of the insect which is normally visible. In the growing larva of *Rhodnius* the epidermal cells retain a certain capacity to differentiate and give rise to other organs. These organs are of two types. One is a dermal gland which secretes a thin protective covering on the outside of the cuticle. The other is a tactile sense organ which consists of an innervated hair arising from a socket at the center of a little dome of smooth cuticle. The essential parts of both organs are formed by four cells which are the daughters of a single epidermal cell [*see illustration on page 106*].

Now the organs of each type are distributed in a regular way over the surface of the cuticle. Two of the sense organs, for example, are rarely found close together. On the other hand, if there is a wide space without a sense organ, a new one is sure to appear there

at the next molt when a new cuticle is formed. If the epidermis is killed by applying a hot needle to a certain area of the abdomen, the surrounding cells multiply and grow inwards to repair the injury. The next time the larva molts this new epidermis lays down a cuticle without sense organs but with the normal distribution of dermal glands. At the following molt the sense organs reappear, spaced at the proper distance one from another.

What controls this regular distribution of organs? It is possible to suppose that the presence of a single chemical substance will induce an epidermal cell to give rise to a four-celled gland or sense organ. The hypothetical substance would be in limited supply, so that a developing organ would drain it away from the surrounding cells and thus prevent the appearance of another organ in the immediate vicinity. Beyond a certain distance, however, there would be sufficient substance to induce another cell to start differentiation. We may suppose that a larger amount is required for a sense organ than for a dermal gland. In normal development the two types of epidermal organ are quite distinct, but under certain conditions it is possible to obtain structures intermediate between the two. Admittedly no one has yet identified the controlling substance. But its postulated behavior is no more complicated than that of the juvenile hormone.

At the moment this is just a hypothesis. But it is worth pointing out that the distribution of human institutions is controlled in a similar fashion. An essential ingredient for the formation of a university, for example, is a supply of students. When a university is established, it will drain off those students and will thereby inhibit the appearance of another university in the immediate neighborhood.

The integument of *Rhodnius* provides us with a model system for the differentiation of the body in general. We have a single layer of uniform and equipotent cells. During growth a single one of these cells divides and differentiates to form a complex organ of one type or another. If the hypothesis outlined above to account for the induction of these new structures bears any relation to the truth, it is clear that differentiation, polymorphism and metamorphosis may all be regarded as different aspects of a single phenomenon: the activation of specific gene systems latent in the nuclei by appropriate chemical stimuli furnished by hormones, inductors or specific nutritional factors.

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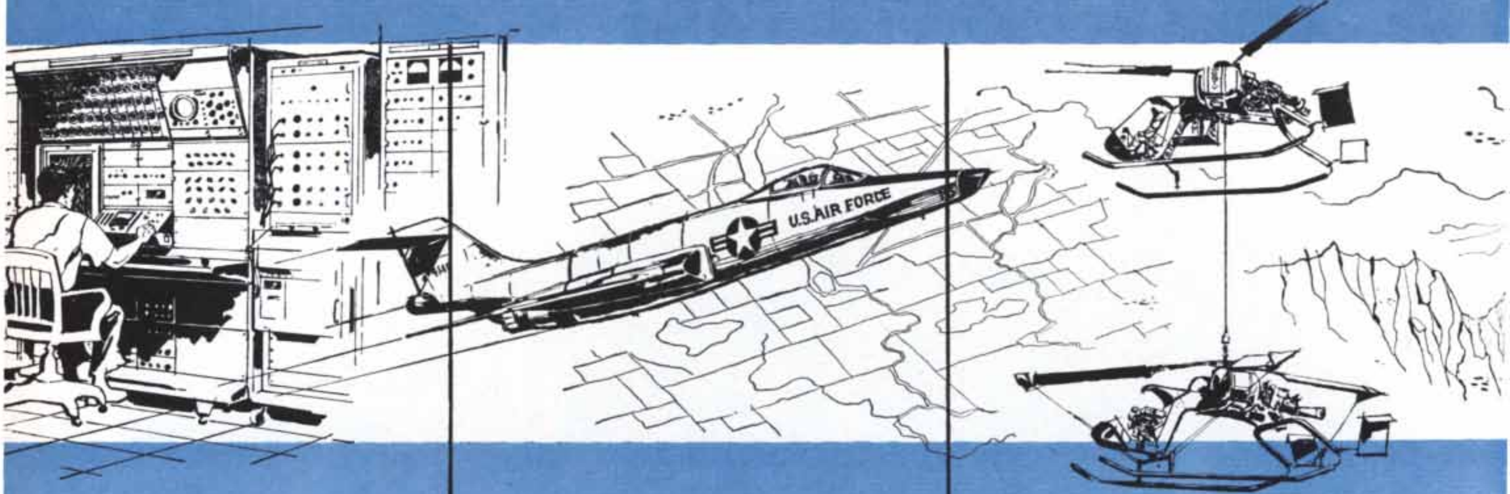

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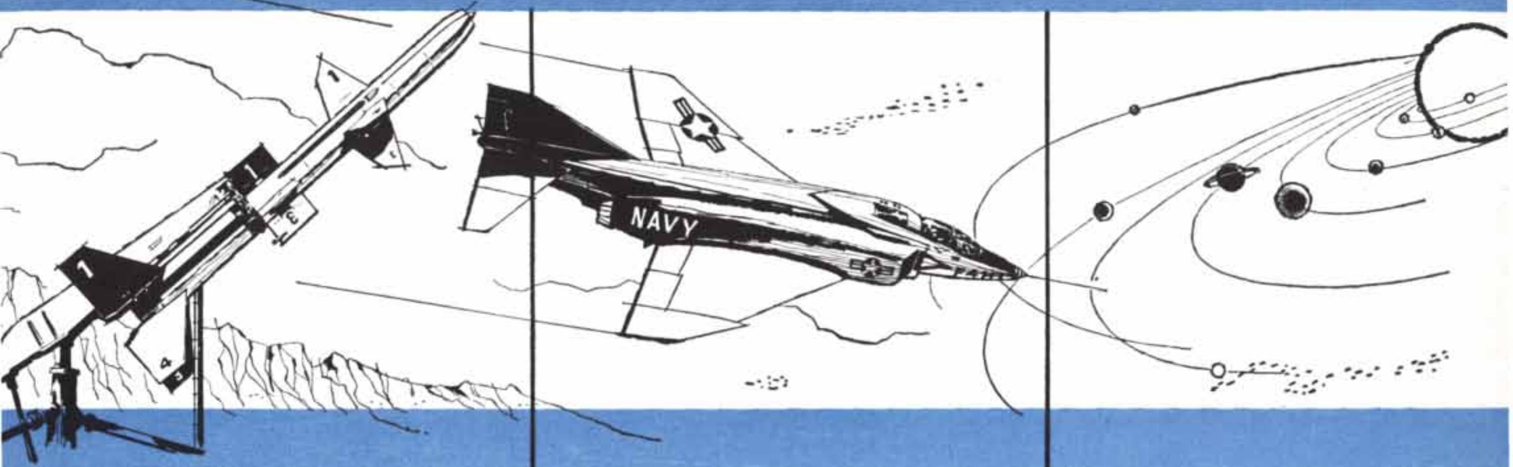

NAVY

HOW WATER FREEZES

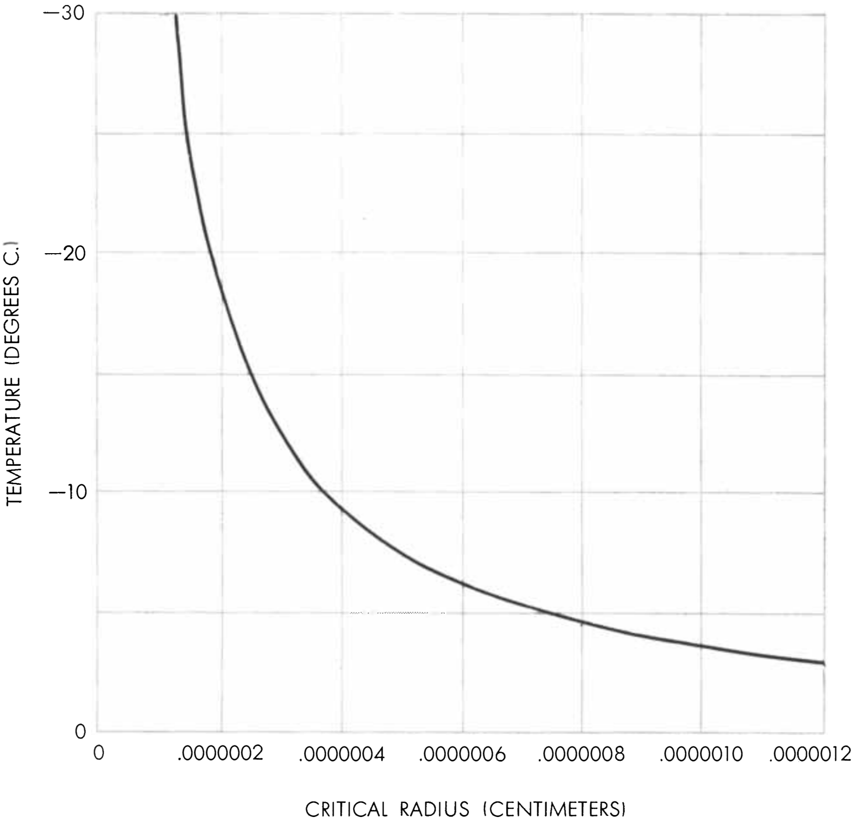
The formation of ice crystals requires not only low temperature but nuclei of appropriate size and shape. Such nuclei explain the strange diversity of snowflakes, "ice worms" and frost heaves

by Bruce Chalmers

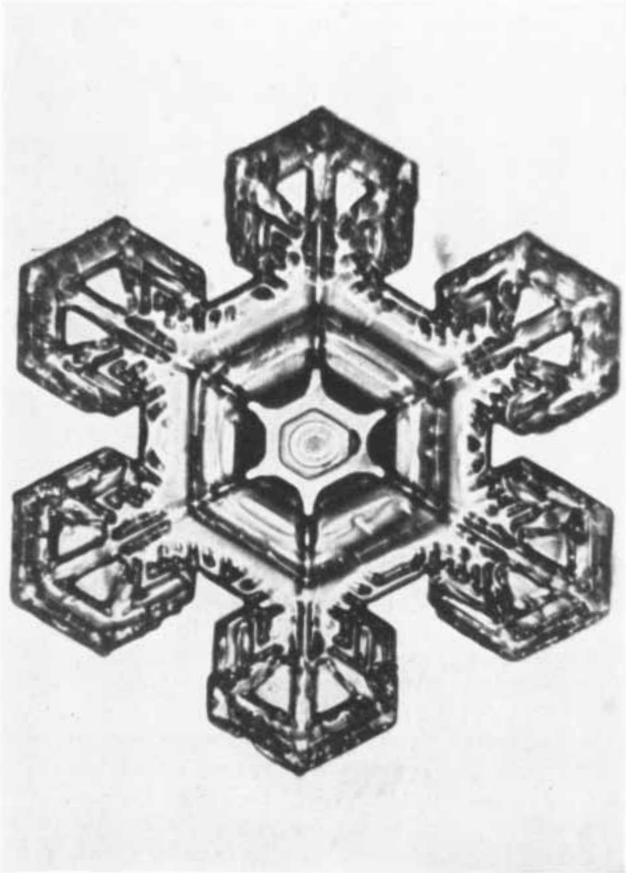
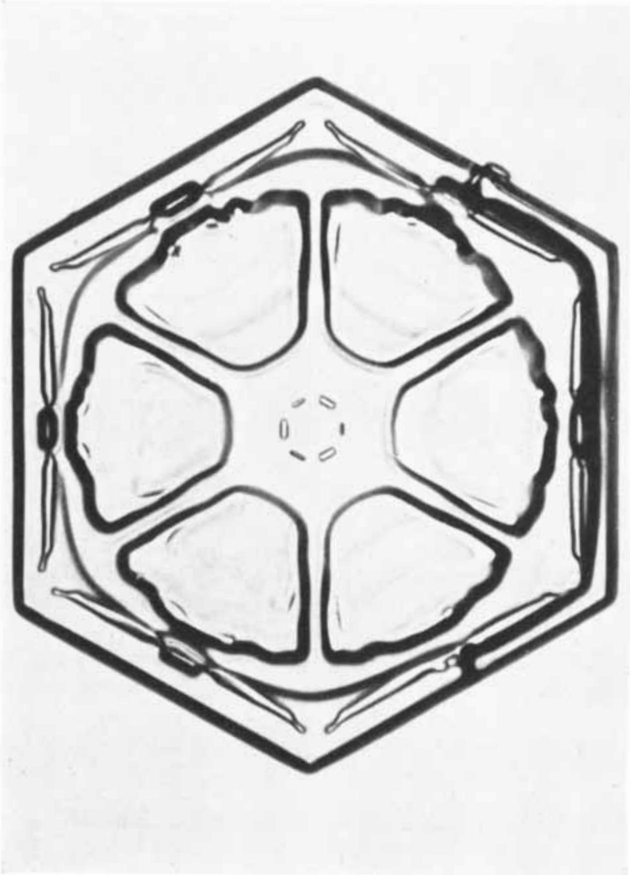
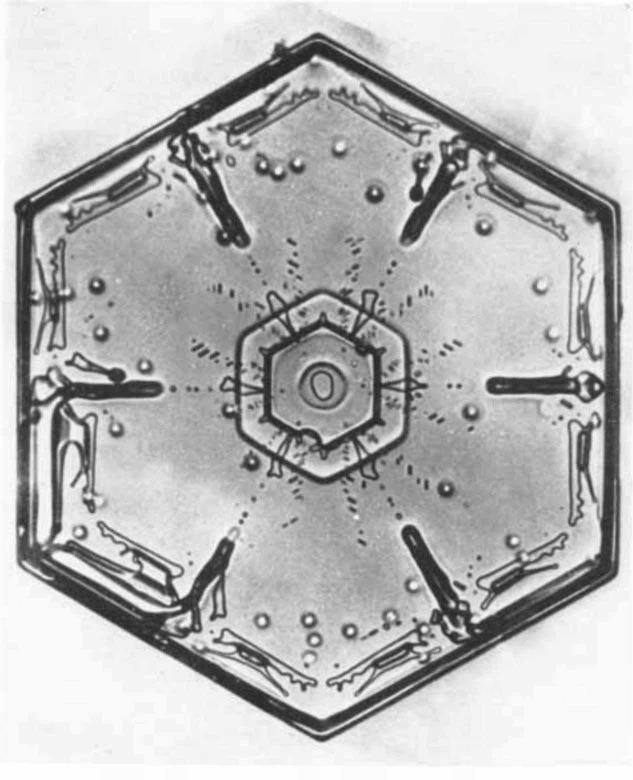
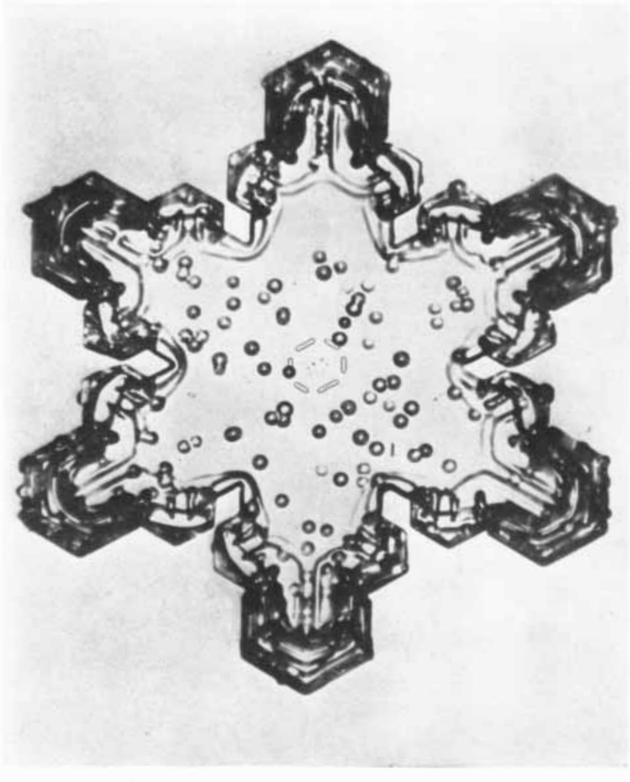
We call zero degrees centigrade (or 32 degrees Fahrenheit) the freezing point of water. Perhaps because water is so intimately associated with life, we do not take equal notice of the fact that zero degrees is also the melting point of ice. The temperature must actually be very slightly lower for water to freeze, and correspondingly higher for ice to melt. Strictly speaking, zero degrees is the equilibrium temperature: the point at which ice and water can remain in contact with one another indefinitely, neither increasing at the expense of the other. But there is more to the story than that. The equilibrium temperature varies with the barometer; it is zero degrees only at the atmospheric pressure encountered at sea level (one atmosphere, or 14.7 pounds per square inch) and decreases by .0072 degree C. with each additional atmosphere of pressure. Furthermore, the growth or the evanescence of an ice crystal depends to some extent upon its form. At each temperature and pressure the crystal has a critical radius of surface curvature which determines which way the process will go: to freezing or to melting. Thus to learn how water freezes we must consider a delicately poised interdependence of temperature, pressure and geometry. Upon closer study these variables bring unity to our understanding of the design of a snowflake and the frost heaves that buckle our highways, of "ice worms" in a refrigerator cube and the generation of lightning.

If roughly equal amounts of ice and water are mixed together, the temperature of the mixture will quickly reach the equilibrium temperature, because heat is given off by water as it freezes and is absorbed by ice as it melts. The heat is the latent heat of fusion, evolved by all substances as they pass from the liquid to the solid state. This is the energy necessary to convert the highly organized structure of the crystal into the much more random, and continuously changing, association of molecules that is the essence of liquidity. In the case of water the latent heat of fusion is equal to the 80 calories per cubic centimeter that must be removed to freeze it after it has reached the freezing point. If ice were above the melting point, some would melt, and in doing so would absorb latent heat from the remaining ice, cooling it again to the freezing point.

Another way to visualize the melting point is to consider the behavior of individual water molecules. At all times, when ice and water are in contact, some



FREEZING TEMPERATURE OF WATER is related to the shape of particles in the water which might form nuclei of ice crystals. Water may be "supercooled" to a temperature below zero degrees centigrade (*vertical coordinate*) provided it contains no particle with a radius of curvature larger than the "critical radius" for that temperature (*horizontal coordinate*). At zero the critical radius is infinite, that is, the nuclei may form on flat surfaces.

SNOWFLAKES assume an infinite variety of shapes, all of them elaborations on the basic hexagonal form of the ice crystal. Of those shown in these photomicrographs by Vincent J. Schaefer, the one at upper right is a simple hexagonal crystal plate with air enclosures. The other hexagonal crystal plate (*lower left*) and the two branching crystal plates are adorned with frozen cloud droplets.

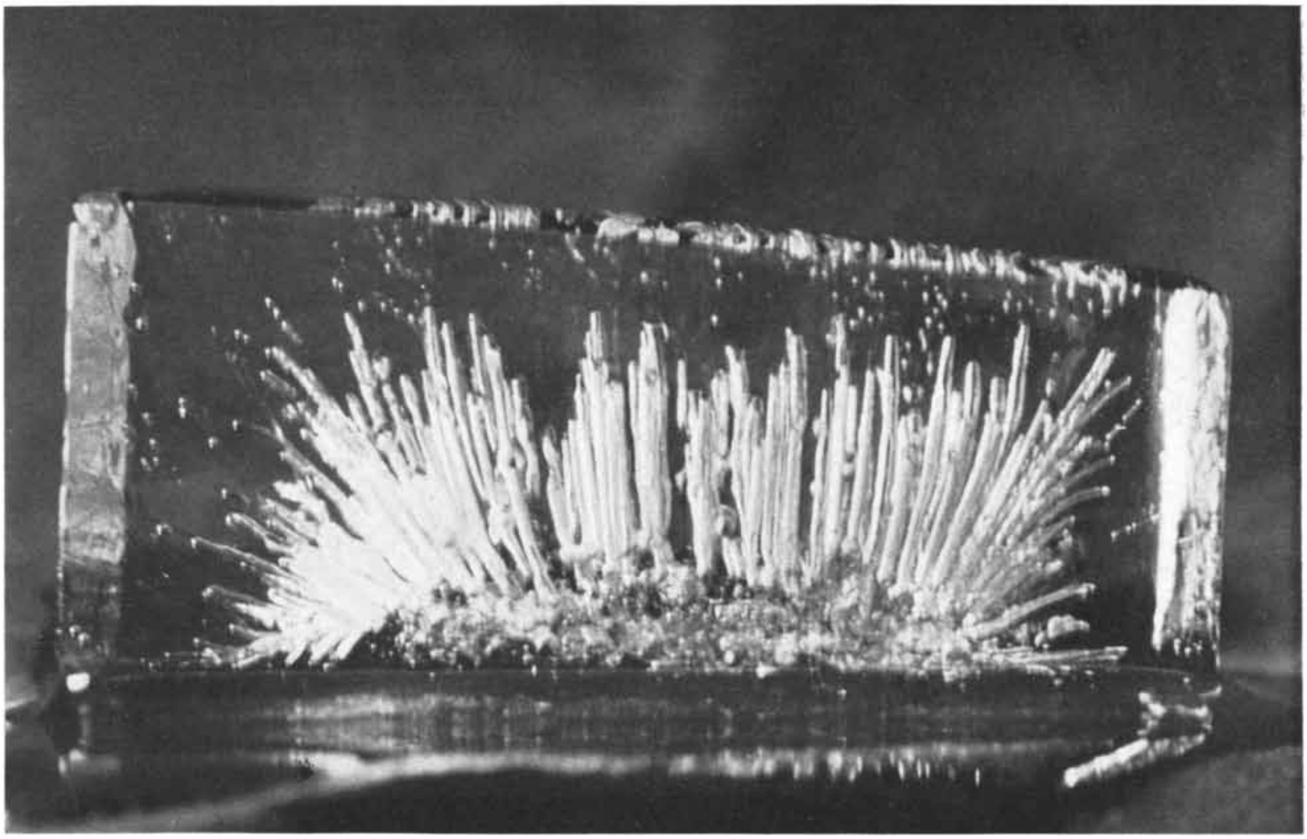
molecules are leaving the water and attaching themselves to the surface of the ice (that is, "freezing"), and some molecules are leaving the ice and wandering off into the water (that is, "melting"). The rates of these opposed processes vary with temperature and pressure (and with the curvature of the surface, as we shall see); at a given pressure there is only one temperature at which the rates are equal. With higher temperature, the melting process predominates; with lower temperature, the net process is that of freezing.

It is fairly certain that a very thin layer of water normally covers the surface of a piece of ice, even at temperatures somewhat below freezing. This explains the annoying propensity of ice cubes to stick together in a bucket. The exchange of molecules in the water layer on the abutting surfaces of two cubes can no longer maintain its natural equilibrium and the freezing process takes over.

If salt, or any other soluble substance, is dissolved in water, the freezing point is lowered. This is because the solubility of salt in ice is very low. The salt remains almost completely in the water and slows down the freezing part of the molecular exchange, largely by decreasing the availability of water molecules. The presence of salt, on the other hand, does not have much effect on the melting process. The result is a lowering of the temperature at which the two processes balance. When we scatter salt on ice or snow, the salt first dissolves in the water layer on the surface of the ice, forming a highly concentrated solution with a much lower freezing point. This "hypertonic" solution captures the molecules of water that continue to wander from the ice until it is diluted to the point where its freezing temperature is raised to that of the environment. In the "pre-electric" type of ice-cream freezer, the mixture of ice and salt absorbs the latent heat of fusion from its surroundings as the ice "dissolves" into the salt solution. This causes the temperature of the brine and the ice-cream mix to fall below the original temperature of the ice and the salt.

The existence of a sharply defined temperature of equilibrium necessarily assumes the presence of both ice and water. In the presence of ice, water cannot be cooled below the freezing point; the removal of heat causes an increase in the amount of ice and not a drop in temperature. If no ice at all is present, however, water can be "supercooled," that is, cooled to a temperature below the freezing point without freezing. Supercooled water will immediately begin to freeze when placed in contact with ice; the ice grows rapidly until the latent heat evolved by the freezing process has raised the temperature of the water and the ice to the freezing point. A familiar example of supercooling is the water quite commonly found in some of the compartments of a plastic ice tray in a refrigerator, while the water in the others has frozen. Dropping a bit of ice into one of these compartments will cause the water to begin freezing at once, showing it is supercooled.

Observations of this kind suggest that it is much more difficult to start the growth of ice than to cause it to continue once it has started. Here we encounter the factor of crystal shape. The equilibrium temperature is precisely zero degrees C. only when the surface of the ice is essentially flat. On a corner that juts outward there are more loosely bound surface molecules per unit volume of ice, and the melting process tends to predominate. Conversely, at corners that extend inward the surface-to-volume relationship is reversed, and freezing is in the ascendant. The temperature of equilibrium therefore depends on the curva-

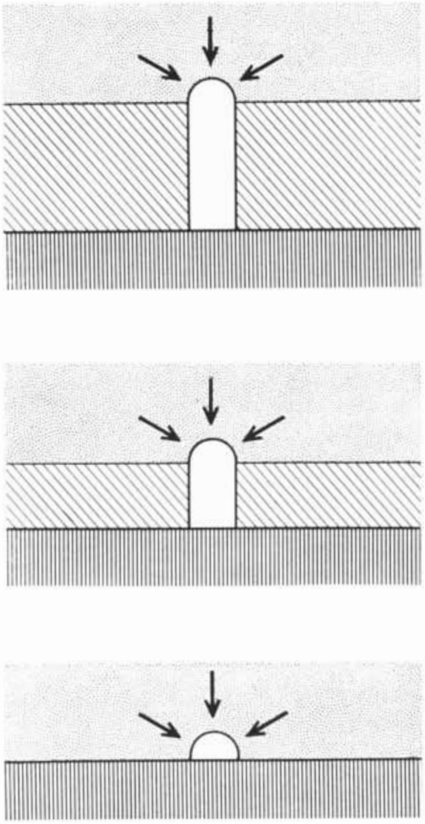


ICE WORMS form during the growth of an ice cube because the ice crystal (which, in the photograph above, grew from the bottom) rejects air that was dissolved in the water. The formation of an ice worm is diagrammed on the page at right (*read from bottom*).

ture of the surface. It follows that the temperature is lower for a small sphere of ice than for a large one. For each temperature there is a critical radius of curvature at which ice and water are in equilibrium [*see chart on page 114*].

An extremely small crystal of ice, then, may have an equilibrium temperature below zero degrees. The equilibrium, however, is metastable: any increase of size above the critical radius causes the ice crystal to grow further, while any decrease in size causes it to melt more rapidly and finally to disappear. To survive, a crystal must be above the critical size for the prevailing temperature; to exist at the freezing point it must have "infinite" radius, that is, its surface must be substantially flat.

It is the absence of any ice surface with a critical radius that permits water to remain liquid when it is supercooled. In their random motion, however, molecules frequently assume positions with respect to one another exactly as they would if bound together in a crystal of ice. The size and number of such "solid-like" clusters increase as the temperature goes down. Freezing will start spontaneously when the largest of these clusters, or nuclei, assumes a radius of curvature equal to the critical radius; such an embryo crystal has an even chance of exceeding the critical size and to grow. Spontaneous nucleation of this kind occurs in water at about —30 degrees C. It requires very special precautions to supercool water to this temperature, because freezing can start on nuclei whose formation is catalyzed by a suitable solid surface. Less supercooling is required to form a critical-sized nucleus on a solid surface than without such assistance, especially if the molecular arrangement of the solid is a fairly good match for that of ice. The nucleation catalyst may be the container in which the water is cooled, or it may be a suitable particle in suspension in the water. Ordinary tap water cannot be supercooled by more than about five degrees because of the presence of suspended particles which permit the formation of nuclei at that temperature. Similarly, in cloud seeding, the supercooled droplets of water that are too tiny to fall are made to freeze around nuclei provided by fine particles of silver iodide or of other substances. Once freezing is initiated, the drops grow and become large enough to fall as rain. It has recently been suggested that meteoric dust, which enters the atmosphere from space, may be effective as a cloud-seeding agent; there is some evidence of an association between abnormally high rainfall and the probable arrival in the upper atmosphere of unusual amounts of dust.



Diagonal hatching shows accrual of ice; the arrows, dissolved air diffusing into worm.

The nucleation of freezing is but a special case of a phenomenon that can be observed in many and various forms, in nature and in human society. The boiling of liquids, the condensation of vapors, and the establishment of a hive of bees, a herd of animals, an epidemic, a new political party or a new fashion in hats are all examples of events in which the survival and growth of the new entity depend upon the achievement of a critical size, at which the survival of the entity becomes as probable as its disappearance and above which its growth becomes increasingly likely.

As anyone must deduce who has observed ice cubes floating in a glass, ice has a lower density than water. The molecules of water in the crystal structure of ice assume positions farther apart from one another than they do in the liquid state. Water is apparently unique among substances in that it expands in volume during the last few degrees as it approaches freezing; while it is still in the liquid state, aggregates of atoms begin to assume a packing configuration resembling that of ice rather than that of water. In most other substances, of

DENDRITIC GROWTH of an ice crystal is shown from bottom to top in three stages. Ice grows in this snow-crystal-like fashion when it discharges its latent heat of fusion out into supercooled water rather than through a block or slab of ice that has already formed.

course, the solid is more dense than the liquid because the atoms become more closely packed in the crystal. Thanks to its peculiar departure from the rule, ice usually forms not on the bottom but on the surface of lakes; aquatic life can therefore survive the winter. However, ice sometimes forms at the bottom of a lake; this occurs when the cooling is due to radiation into a clear sky; the bottom radiates far more heat than the water (being "blacker") and so the water at the bottom is cooled much more rapidly than the water above. If this takes place faster than the water is mixed by convection, freezing starts at the bottom. On the other hand, because ice occupies a larger volume than the water from which it forms, a pipe or other container may be burst by the freezing of water confined in it.

Understandably enough, most people jump to the conclusion that the frost heaving of soil is caused by the same expansive force that bursts pipes. An interesting experiment performed by scientists of the U. S. Army Corps of Engineers indicates that this is by no means a full explanation. The scientists filled a cylinder six inches high with a suitable soil, stood it in water and subjected the top to subfreezing temperature. The length of the column of soil and ice increased to more than twice its original size. Such upward movement, often observed in highways, is much too great to be explained by the expansion of freezing water alone. The cross section of the experimental soil column showed what really happens. Water, drawn up from below, formed slabs known as "ice lenses"; these grew to a substantial thickness and pushed the superimposed material upward in doing so. Ice lenses of considerable extent and thickness form when full-scale frost heaving occurs.

The formation of these ice lenses is governed primarily by the critical role of geometry in the freezing process. First of all, the water in a small cavity in the ground freezes. The dense packing and the physical nature of the surrounding soil are such, however, that the ice cannot propagate into adjoining cavities. To grow between the particles, the radius of curvature of the advancing crystal surface would have to be so sharp that its freezing point would drop below the temperature of the environment. The ice can continue to grow only if the water layer on its surface is maintained by the flow of water from other compartments, usually below it. This water is supercooled, and it is able to exert a considerable force of expansion in the process of freezing, thereby increasing the size of the cavity and making it possible for the ice lens to grow in height and width.

The same mechanism explains the surfacing of large stones from below and the uprooting of fence posts. The ice lens forms in close contact with the stone or post; as it grows upward it carries the stone or post with it, leaving a space underneath into which enough soil will fall to prevent the stone or post from going back to its original position. The surrounding soil surface, however, subsides to its original level when the ice melts. Thus alternate freezing and thawing works fence post and stone out of the ground by a sort of ratchet effect.

The process that develops such impressive and sometimes destructive forces occurs one molecule at a time. When an ice crystal has attained the critical size and the freezing process has become dominant, then it continues to grow, adding molecules to its crystal structure, as bricks are added to a wall. The structure of the ice crystal has great regularity and symmetry. Because this highly organized structure cannot accommodate other atoms or molecules without very severe local strain, salt and practically every other solute in the water is rejected by the advancing surface of a growing ice crystal. The solute accumulates just ahead of the crystal surface, as can be seen in the photograph on the next page. Freezing may yet prove to be an inexpensive way to desalt sea water, since it takes less energy to bring the water down to zero degrees C. and freeze it than to raise it to 100 degrees and then vaporize it.

The freezing that preserves food must be "quick-freezing" because of the behavior of the solutes in the cellular and intercellular fluid of the plant and animal tissues. When ice forms in the aqueous solutions between the cells, it increases the concentration of solutes in the remaining fluid. The resulting osmotic pressure causes water to diffuse slowly out of the cells. The cells are dehydrated, and they do not return to their original condition upon thawing. Quick-freezing overcomes this difficulty because it allows much less time for water to leave the cells.

The rejection of solutes during freezing has another important effect which may play a profound role in the weather. When the water contains an impurity that is ionized, the positive and negative ions in the solution may be rejected unequally, or they may diffuse away from the interface between the ice and the water at unequal rates. The result is a separation of electric charges. A potential difference of more than 100 volts has been measured during freezing between an electrode embedded in the ice and one in contact with the water. Such separation of charges may generate the very high potentials that give rise to lightning. A thunderhead is always full of freezing raindrops. In the violent turbulence they may rise and fall through the cloud a considerable number of times, growing into hailstones. During freezing, the water and the ice would be oppositely charged. The water, carrying charge of one sign, would be whipped by the updraft from the surface of the ice and carried to the top of the cloud, while the heavier ice particles would tend to fall, either reaching the ground as hail or melting on the way down. Repetitions of this process could build up the extremely high potentials necessary to account for lightning.

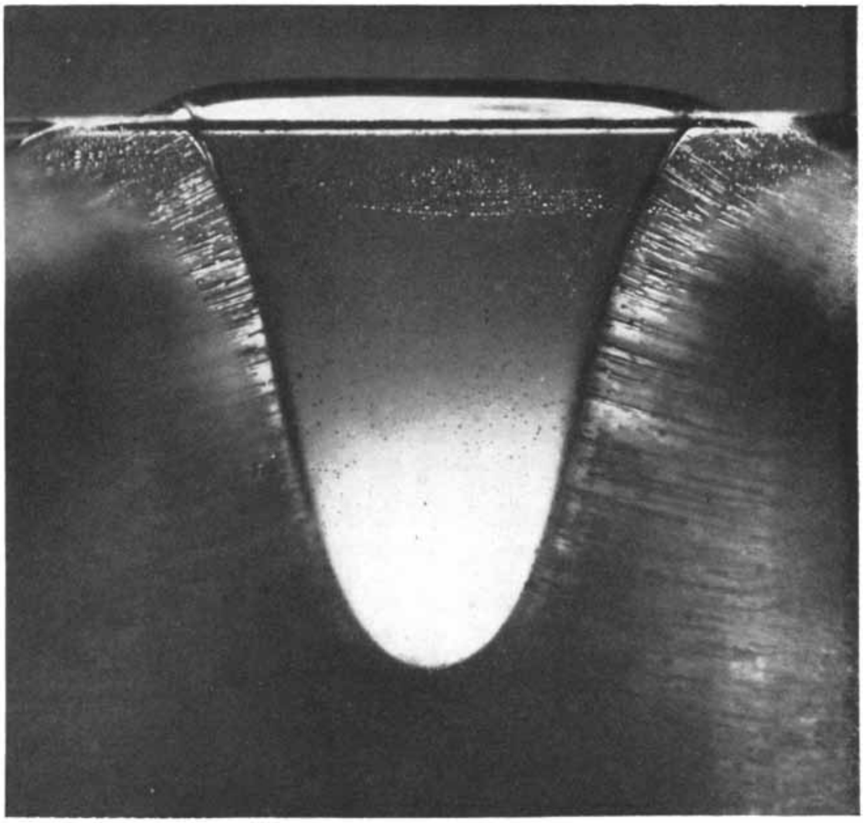
Air is another solute that is rejected by water ahead of the freezing process. It accumulates in the advancing interface until its concentration is high enough for bubbles to nucleate. Once a bubble has formed, it grows because air diffuses into it. If the interface continues to move forward, the bubble cannot grow laterally, and so it grows forward to form the cylindrical bubble sometimes known as an ice worm [*see photograph on page 116*]. Close inspection shows that ice worms never start at the surface of the ice, but always a little way in; this is because some freezing must occur before the air accumulating at the interface reaches sufficient concentration to cause the nucleation of a bubble. Here again growth occurs more easily than the nucleation that starts it.

The ice worms that grow in ice cubes frequently look like strings of pearls. This reflects the fluctuation in the freezing rate due to the intermittent operation of the refrigerator. When freezing is slow, more air diffuses into the bubbles and they grow larger; during periods of fast growth, there is less time for diffusion and the bubble decreases in cross section. Fast freezing suppresses the formation of ice worms. Because insufficient air diffuses into the bubbles to permit them to grow, the ice contains a large number of very small, round bubbles. On the other hand, very slow freezing permits the rejected air to diffuse away from the interface; because the concentration of air never reaches the nucleation point, neither bubbles nor ice worms appear. Ice grown in flowing water is also usually free of bubbles and ice worms; the continuous removal of the water prevents the build-up of a high concentration of dissolved air. Hence the absence of bubbles in the ice cubes produced by some commercial freezers.

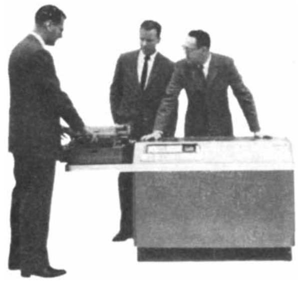
For freezing to take place continuously, the heat of fusion must somehow be carried away from the region where ice is forming. Normally, as in the growth of ice cubes or of ice on the surface of a lake, the heat is extracted by conduction through the ice that has already formed. The water-ice interface tends to remain flat, because any region of convex curvature is cooled less efficiently than the remainder, and its rate of freezing is retarded until a smooth interface is restored. However, if the ice crystal is growing in supercooled water, its growth takes an entirely different form. Because the latent heat of fusion flows outward into the supercooled liquid, cooling is more efficient at a convex region; convex regions therefore become even more convex. The latent heat produced by the growth of a convexity suppresses growth in the vicinity, and so a projection becomes an isolated spike [*see illustration on page 118*]. The direction in which such branching or "dendritic" growth may go in various substances depends on the characteristic molecular arrangement of the crystal. In the case of ice, the spike may grow in any one of six directions. Once a spike has formed, the supercooled environment may permit the growth of lateral secondary, ternary and even quaternary branching spikes, always in the proper crystallographic directions.

The resemblance between such dendritic ice crystals and snowflakes is more than coincidental; they are the result of similar processes. Dendritic crystals formed in supercooled water are pointed and branched because the latent heat is conducted away most efficiently at points. Snowflakes grow in a similar pointed and branched fashion because they grow in supersaturated water vapor, where the supply of water molecules is larger at points than at flat surfaces. The molecules that build up a snowflake can arrive at a point from any direction instead of from only one direction. Of course, since the dendritic crystal and the snowflake are both ice, they must conform to the same crystallographic plan. The detailed shape of snow crystals, however, has far more variety because there are two variables (temperature and humidity) in the vapor medium in which they grow; there is only one variable (temperature) for the crystals grown in supercooled water.

If supercooled water freezes dendriti-



EXCLUSION OF A SOLUTE from a growing mass of ice is shown in this photograph of the freezing of a solution of potassium permanganate. As the ice grows inward it includes water but excludes potassium permanganate, visible as a dark streak along the interface.



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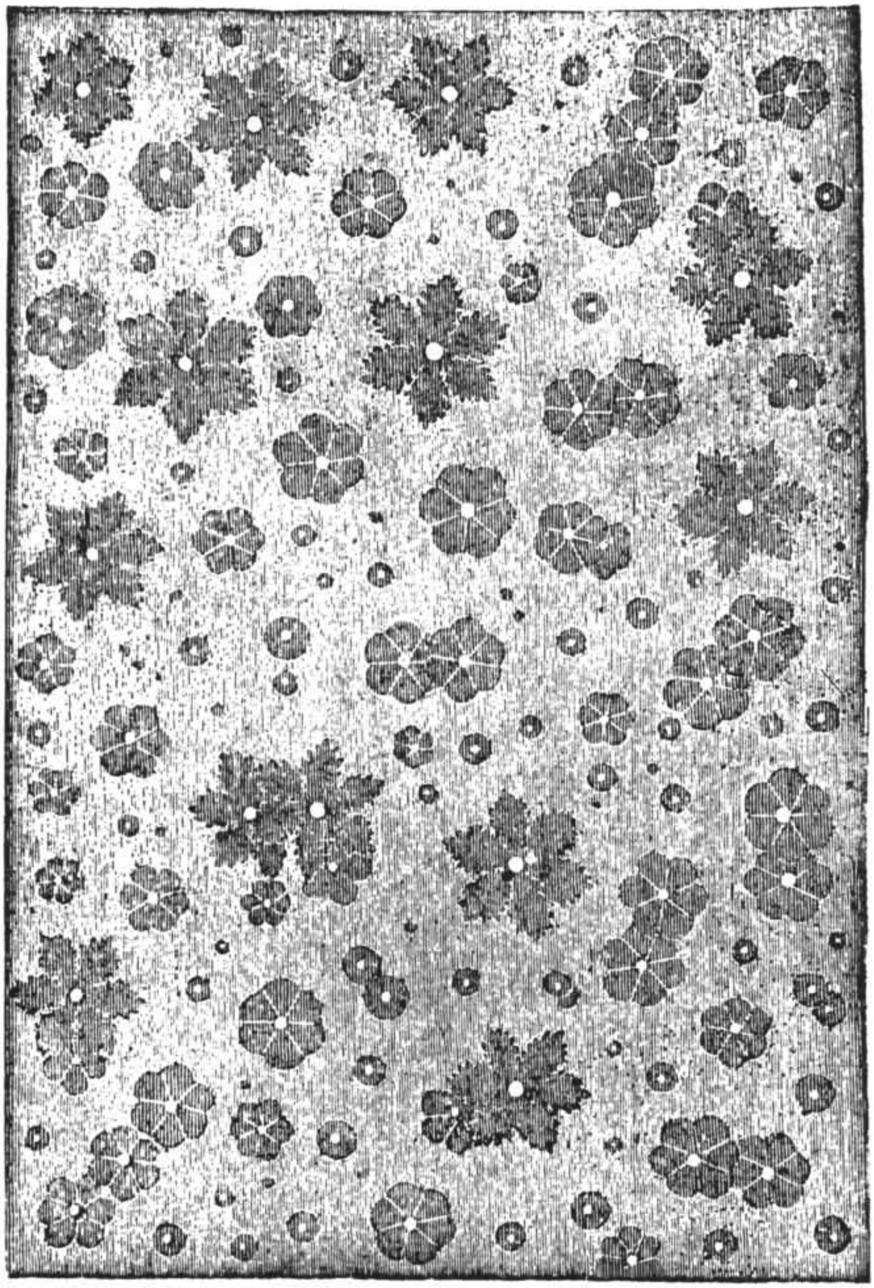


"ICE FLOWERS" evince dendritic melting, the converse of dendritic freezing. The flowers, which are water-filled chambers, result from the superheating of the interior of ice by infrared radiation. This woodcut is from John Tyndall's *The Forms of Water*, published in 1872.

cally, as a result of better heat transfer from points, it would be expected that superheated ice should melt dendritically. "Dendritic melting" indeed occurs when infrared radiation is focused into the interior of an ice crystal. Ice cannot be superheated at its surface without melting, because there is some water there already. But in the interior the nucleation principle comes into play again, and there is some superheating before melting. When melting at last begins, it proceeds dendritically, with the heat of fusion flowing inward to the growing points of the six-pointed "ice flower," which contains water [*see illustration above*].

Many of the diverse phenomena associated with the freezing of water can thus be understood in terms of a few fundamental ideas, which have been developed largely as a result of research on the solidification of molten metals, a subject of great industrial as well as scientific importance. The need to know for practical ends and the desire to know for philosophic motives always share in the increase of understanding.

PIDGIN LANGUAGES

These humble by-products of colonialism are still useful in contacts between peoples. Far from haphazard grammatically, they at times evolve into national languages called creoles

by Robert A. Hall, Jr.

Since the time of Columbus the course of history has largely been set by the growth of European commerce and power in the rest of the world. One much-misunderstood by-product of this historical process has been the birth, in nearly every Oriental, African and American region visited or colonized by Westerners, of a simplified form of speech, used in contacts with the native population: the so-called pidgin languages. Today, despite a certain amount of well-meant disapproval, the importance of some varieties of pidgin is increasing.

To those who speak European languages, pidgin sounds like a ludicrous mispronunciation of their own tongues; for that reason it is often castigated as a "bastard lingo" or "gibberish." Common parlance has made "pidgin" an opprobrious term for any formless speech, such as the broken-English "No tickee, no washee" attributed to Chinese laundrymen. I have even heard a professor apply the word to the language of his freshman students, simply because they wrote unimaginatively and overworked a few clichés. But investigations in Haiti, Melanesia and elsewhere have shown that real pidgin languages are far more than half-learned versions of European speech. They are languages in their own right. Their sounds and grammar have the internal consistency requisite to any stable system of communication. And whether we like them or not they are probably here to stay, for they have their own humble, but useful, function in society.

Pidgin is not the only form of mixed language. To understand the stages through which such forms of speech develop, we must make a three-way distinction between the "lingua franca," the "pidgin language" and the "creolized language." A lingua franca is any tongue serving as a means of communication among groups that have no other language in common; for example, English in India and the Philippines. A pidgin language is a lingua franca that in the course of its adoption has become simplified and restructured. The reduced language which results from this process is nobody's native language, but the languages of its speakers considerably influence its vocabulary and other features. Occasionally users of a pidgin language will cease to speak their native tongue and come to rely upon the pidgin entirely. In such a community children will grow up speaking pidgin as their sole language. When a pidgin is pressed into

PIDGIN AND CREOLE LANGUAGES are spoken at many points of contact between native peoples and colonial traders or rulers. Lingua Franca, the oldest known pidgin, service as a native language, its vocabulary must greatly expand to accommodate its users' everyday needs. A reduced language, when thus re-expanded, is called a creolized language (the creole languages of Haiti and other Caribbean areas are typical).

Pidgin and creolized languages have arisen many times in history. The earliest recorded pidgin, which has given its name to the whole genus of international languages, is the original Lingua Franca, based on southern French and the Ligurian dialect of Italian and used in the Middle Ages by western Europeans ("Franks") in the eastern Mediterranean. During the epoch of colonization, as Europeans came into contact with aboriginal populations, many pidgin forms of Portuguese, Spanish, French and English became common. It is said that there was, or is, a Pidgin Portuguese in every region colonized by Portugal. Separate varieties of Pidgin English arose in North America, China, West Africa, Australia and the Pacific; in the latter region subtypes have arisen in Hawaii, New Guinea and the Solomon Islands. Pidginized varieties of French are found in North Africa and New Caledonia.

Pidginization has occurred not only with European but also with non-European languages, as in the case of the "Chinook Jargon" based on the Chinook Indian language and spoken in fur-trading days in the U. S. Northwest. We may also cite Bazaar Malay in Southeast Asia, Swahili in Central Africa, the Pidgin Motu of Papua, Tupí-Guaraní (the so-called Lingua Gêral or "general language") in Brazil, and the Fanaga-Lò or "Kitchen Kaffir" in South Africa.

The best-known creolized languages derive from French and are spoken in Louisiana, Haiti, the Lesser Antilles, Réunion and Mauritius. English-based creole languages also exist: among them are the Gullah of the Sea Islands off South Carolina, the Taki-Taki of Dutch Guiana and the Negro English of the West Indies. Pidgin Spanish, strongly influenced by Portuguese, gave rise to the Papiamentu Creole of Curaçao and neighboring islands. The Afrikaans or "Cape Dutch" of South Africa, which is much simpler than Netherlands Dutch, may be another creolized language, arising out of an earlier Pidgin Dutch used between settlers and natives, and adopted by white children growing up in South Africa.

People who wish to denigrate pidgin languages sometimes point out that they are not written, the implication being that any unwritten language is an unlicked bear cub, an unintelligible jargon never submitted to the necessary discipline of the schools. This reflects a basic misunderstanding of the nature of language. Most of the languages spoken by men throughout history (and before it) have never been reduced to writing, but they are no less languages. On the other hand, many modern pidgin and creole languages are quite regularly written and are even used in newspapers and education. Languages, pidgin or otherwise, are orderly by definition. Writing is no more than an external representation of most (not all) of the structure of a language.

The most orderly representation of a language is a spelling based on its pho-

was based on French and Italian. Lingua Gêral, Chinook Jargon, Swahili, Fanaga-Lò and Indonesian have a non-European basis. Gullah and Taki-Taki stem from English, Papiamentu from Spanish and those which are here specified as creoles from French.

nemes, or functional units of sound. Nothing but confusion can result from attempts to render pidgin languages in a botched form of traditional English or French spelling. In this article I adhere strictly to phonemic spellings. For example, the Melanesian Pidgin English sentence meaning "I have three books" is "mi gat trifela buk," not "me got t'ree-fellow book." A Haitian Creole proverb meaning "He who gave the blow forgets, he who bears the scar remembers" would be "Bay-kal blié, pòté-mak sôjé," not the mock-French "Baille-calle 'blier, porter-marque songer." Readers interested in the derivation of the pidgin and creole words that I have spelled phonemically will find them in the tables beginning on this page. Phonemic spellings have been devised (mainly by missionaries) for a number of pidgin and creolized languages. This trend should be encouraged wherever possible, if only to enforce recognition of the fact that pidgin words and sounds are things in themselves and not bungled attempts to pronounce another language.

In general the phonemic systems of pidgin and creolized tongues show a certain amount of simplification. Vowel structure is often reduced to five vowels represented by "a," "e," "i," "o," "u" (pronounced as in Italian). Most French-based creoles have lost the group of French vowels pronounced with the lips rounded but with the tongue in the front of the mouth. In Haitian Creole the French word "culture" becomes "kilti" and "bleu" becomes "blé." Virtually all English-based pidgins lack the voiced and unvoiced sounds represented by "th" in English spelling: in Melanesian Pidgin "this" is "disfela" and "three" is "trifela." Similarly, the English "f" is replaced by "p," the "v" by "b" and the "sh" by "s." Thus "heavy" is "hebi" and "finish" becomes "pinis."

The pronunciation habits of a native

MELANESIAN PIDGIN	DERIVATION	SOURCE WORDS	MEANING
ARS	ENGLISH	ARSE	BOTTOM, BASE, CAUSE, REASON, SOURCE
BAGARIMAP	ENGLISH	BUGGER 'IM UP	WRECK, RUIN
BALUS	GAZELLE PENINSULA LANGUAGE		PIGEON; AIRPLANE
BILONG	ENGLISH	BELONG	OF, FOR
BUK	ENGLISH	BOOK	BOOK
DISFELA	ENGLISH	THIS + FELLOW	THIS
FAIT	ENGLISH	FIGHT	FIGHT
FAITIM	ENGLISH	FIGHT + 'IM	STRIKE, BEAT, HIT
FES	ENGLISH	FACE	FACE
GAMAN	ENGLISH	GAMMON	DECEIT; DECEIVE
GAT	ENGLISH	GOT	HAVE
GODAM	ENGLISH	GOD DAMN	GOLLY
GRAS	ENGLISH	GRASS	ANYTHING GROWING BLADE-LIKE OUT OF A SURFACE; GRASS
GUDFELA	ENGLISH	GOOD + FELLOW	GOOD
HAISIMAP	ENGLISH	H'IST + 'IM + UP	LIFT
HARDWOK	ENGLISH	HARD + WORK	WORK HARD
HAUS	ENGLISH	HOUSE	HOUSE; ROOM
HEBI	ENGLISH	HEAVY	HEAVY
HED	ENGLISH	HEAD	HEAD
I–	ENGLISH	HE	(PREDICATE-MARKER)
KALABUS	ENGLISH	CALABOOSE (FROM SPANISH CALABOZO)	JAIL
KARABAU	MALAY		WATER-BUFFALO
KIAU	GAZELLE PENINSULA LANGUAGE		EGG
KING	ENGLISH	KING	KING
KLIR	ENGLISH	CLEAR	CLEAR
LONG	ENGLISH	ALONG	TO, AT, WITH, BY

MELANESIAN PIDGIN	DERIVATION
MAUS	ENGLISH
MI	ENGLISH
MIFELA	ENGLISH
MONI	ENGLISH
NADARFELA	ENGLISH
OLSEM	ENGLISH
PATO	PORTUGUESE
PIKININI	PORTUGUESE
PINIS	ENGLISH
PLANTIM	ENGLISH
PLISBOI	ENGLISH
RAUS	GERMAN
REDI	ENGLISH
SAVE	PORTUGUESE
SI(N)DAUN	ENGLISH
SRANK	GERMAN
TALATALA	POLYNESIAN
TA(M)BU	POLYNESIAN
TINKTINK	ENGLISH
TOK	ENGLISH
TOKIM	ENGLISH
TRIFELA	ENGLISH
YU	ENGLISH
YUFELA	ENGLISH
YUMI	ENGLISH

MELANESIAN PIDGIN ENGLISH vocabulary in this chart includes all the words of this language mentioned in the text, together with their sources and meanings. Although condemned by the United Nations as a colonial relic, Melanesian Pidgin is essential language often carry over into a pidgin and survive, even for generations, in creoles. In the pidgin and creolized languages spoken in the Americas by the descendants of West African slaves the "r" at the end of a syllable is generally lost, as in the case of the Haitian "pòté" ("to carry," from the French "porter"). In Taki-Taki an older stratum of words has lost the "r" (*e.g.*, "gódo" for "gourd"), but newer borrowings from the English or Dutch retain the "r" (*e.g.*, "forku" for "fork"). The Cantonese Chinese merged "r" with "l," as in the Chinese Pidgin English "veli" ("very").

In Melanesian languages the con-

SOURCE WORDS	MEANING
MOUTH	MOUTH
ME	I, ME
ME + FELLOW	WE, US (NOT INCLUDING THE HEARER)
MONEY	MONEY
NOTHER + FELLOW	ANOTHER
ALL THE SAME	THUS, SO
PATO	DUCK
'EQUENINO (LITTLE)	CHILD
FINISH	ALREADY
PLANT + 'IM	BURY
POLICE + BOY	POLICE-BOY, NATIVE POLICEMAN
'RAUS (OUT!)	GET OUT
READY	READY
·ABE (HE KNOWS)	KNOW
SIT DOWN	SIT, BE LOCATED
SCHRANK	CHEST OF DRAWERS
(FRIEND)	PROTESTANT
TABU	PROHIBITION; FORBIDDEN
THINK-THINK	OPINION, THOUGHT
TALK	SPEAK; SPEECH
TALK + 'IM	SPEAK TO, ADDRESS
'HREE + FELLOW	THREE
YOU	YOU (SG.)
YOU + FELLOW	YOU (PL.)
YOU + ME	WE, US (INCLUDING THE HEARER)

to social unity on the multilingual island of New Guinea, and is now used in its schools.

STORI BILONG TESEUS NA ARIADNE

Pidgin languages are a serviceable and, indeed, expressive mode of communication: despite their small vocabularies (and the consequent need to use circumlocutions) they can convey information, or spin a yarn, as readily as other tongues. To bring home this point, as well as to provide teaching materials for the schools of Australian New Guinea, Robert A. Hall, Jr., the author of this article, has rendered a number of familiar myths and legends into Melanesian Pidgin. This is Hall's version of the myth of Theseus and Ariadne. It tells how Minos, King of Crete, exacted from Athens a tribute of seven youths and seven maidens ("meris"), to be fed to the bull-headed Minotaur, who dwelt in the celebrated Labyrinth; how Theseus, an Athenian prince, joined the party of victims and, abetted by the Cretan princess Ariadne, slew the Minotaur, escaping the Labyrinthine maze by winding up a magic thread; and how Theseus returned with Ariadne to Athens but by failing to display the agreed-upon sign of victory (a white sail) caused his father, King Aegeus, to kill himself from grief.

I-gat wanfela ailan i-stap, nem bilong em Krit. Disfela ailan i-klostu liklik long kantri (bigples) ol i-kolim Gris. I-no klostu tru, na i-no longwe tru. Spos man i-kirap long Niu Gini, na i-laik go long Niu Briten, aitink i-longwe olsem.

Nau longtaim bifo, i-gat wanfela king i-stap long ailan Krit; nem bilong disfela king, Minos. Disfela King Minos i-no gudfela king. Em i-strongfela moa, oltaim oltaim em i-laik fait. Nau long Gris i-gat wanfela siti (taun, bigfela ples) ol i-kolim Athens. King Minos i-krosim king bilong Athens na bigfela fait i-kamap. Minos i-kisim ol man bilong fait bilong em, i-brukim bigsolwata, i-go long Athens; ol i-mekim bigfela fait, winim ol man bilong Athens. King bilong Athens (nem bilong em Aigaios) i-mas tok: "Yufela winim mi finish." Minos i-tokim em: "Spos yu no laik mi kisim siti bilong yu, bagarimapim haus, pulim meri, kukim olgeda samting, orait, yu mas mekim olsem mi tok nau. Olgeda yia yu mas selim sevenfela strongfela, yangfela man, na sevenfela naisfela yangfela meri, i-kam long Krit, baimbai mi givim ol long Minotauros, bilong em i-kaikai."

Disfela Minotauros i-wankain bulmakau man nogud, i-olsem masalai, i-gat faia i-kamaut long nos bilong em, na i-save kaikai man. Minos i-putim Minotauros i-stap long bigfela haus tumas, ol i-kolim Labirintos, i-gat plenti handat rum, plenti pasij. Spos man i-go insaid long disfela haus, em i-no kan save fashin bilong kamaut gen, na i-lus olgeda, i-go nabaut nabaut nabaut, bihain Minotauros i-lukim, i-kaikai. Disfela bigfela haus Labirintos, bifo wanfela man i-gat save, nem bilong em Dedalos, i-wokim; mi tokim yufela finish long stori bilong Dedalos na pikinini man bilong em, Ikaros.

Orait, yufela kan tinktink, ol man bilong Athens i-no laikim disfela toktok bilong King Minos. Ol i-foldaun long ni bilong em, ol i-kraiaut: "Yu marimari long mifela!" Tasol Minos i-no laik marimari. Em i-tok: "Spos yufela no mekim olsem mi tok, orait, mi kam bak gen, kisim Athens, kilim olgeda man, pulim olgeda meri, bagarimapim tru olgeda samting." Orait, nau olgeda yia ol i-bungim olgeda yangfela man meri, ol i-kisim sevenfela yangfela man (i-no gat man i-strongfela moa) na sevenfela yangfela meri (i-no gat meri i-naisfela moa), bilong selim i-go long Krit, kaikai bilong Minotauros. Ol i-sel i-go long Krit nau, long blakfela ship i-gat blakfela sel.

Nau King Aigaios, king bilong siti Athens, i-gat pikinini man, ol i-kolim Teseus. Long taim Minos i-winim ol man bilong Atenai, aitink Teseus i-gat tenfela yia. Bihain, Teseus i-kamap bigfela, i-gat wanfela ten eit yia finish, na em i-tinktink long bel bilong em: "Mi strongfela man, mi laik go kilim Minotauros." Orait, taim bilong kisim yangfela man meri i-kamap finish, na olgeda yangfela man meri bilong ples i-bung finish, Teseus nau i-kirap, i-tokim papa bilong em, King Aigaios: "Nogud yu kisim sevenfela yangfela man. Yu kisim sikisfela tasol, na mi yet, mi nambaseven." Ol i-hirim disfela toktok bilong Teseus, ol i-kirap nogud, na King Aigaios i-tok: "Kalapa! Bilong wonem yu tok olsem, Teseus! Nogud yu go long Krit, baimbai Minotauros i-kaikai yu. Yu mas stap long ples hia, na bihain, taim mi dai finish, yu king bilong Athens."

Tasol Teseus i-no chenjim tinktink bilong em, na em i-tok: "Nogat! Mi laik go long Krit, kilim disfela bulmakau nogud Minotauros, na bihain mi kam bak gen." Aigaios i-kraiaut, i-olsem longlong man, tasol Teseus i-tok yet: "Spos mi no go, oltaim oltaim plenti gudfela yangfela man meri bilong Athens i-lus long kaikai bilong disfela bulmakau nogud. Spos mi go, baimbai mi kilim Minotauros finish, na mifela no mas selim yangfela man meri moa." Bel bilong King Aigaios i-hevi tumas, tasol em i-tokim Teseus: "Orait, yu go. Tasol spos yu winim Minotauros na yu kam bak, yu mas chenjim sel bilong ship, putim waitfela sel, baimbai mi save yu orait. Spos ship i-kam bak, i-katim blakfela sel yet, baimbai mi save yu dai finish."

Ol i-kisim sikisfela nadafela yangfela man, na sevenfela yangfela meri, na ol i-kirap nau i-go nau, brukim bigsolwata, na i-go i-go i-go i-go, bihain i-kamap long Krit. King Minos i-kisim ol, bringim ol i-kam long haus bilong em. Fashin bilong Minos i-olsem: ol i-kamap finish, Minos i-givim gudfela kaikai long ol, na long neksfela de em i-selim ol i-go long haus Labirintos, bilong Minotauros i-kaikai ol. Orait, distaim tu Minos i-rediim bigfela kaikai, na ol i-sindaun kaikai. Nau King Minos i-gat pikinini meri, nem bilong em Ariadne. Long disfela taim Ariadne aitink i-gat wanfela ten eit yia, olsem Teseus. Em i-lukim ol yangfela man meri, i-marimari long ol; na i-lukim Teseus, i-laik tru long em. Ariadne i-tinktink: "Mi laik tru long disfela yangfela man, mi no laik em i-dai. Mi laik helpim em." Bihain ol i-go slip, na Minos i-tokim ol: "Tumora mi selim yufela i-go insaid long haus Labirintos."

Long bignait, Ariadne i-go long rum Teseus i-slip long em. Teseus i-no slip yet, em i-tinktink long fashin bilong winim Minotauros. Ariadne i-kamap finish, i-tokim Teseus: "Mi laik tru long yu, na mi no laik Minotauros i-kaikai yu. Mi no laik tru long disfela fashin nogud bilong papa bilong mi. Mi laik ranwe long Krit. Mi bringim disfela tred, mi givim nau long yu. Morbeta yu fasim tred long do bilong haus Labirintos, na bihain yu katim tred i-go wantaim yu, na go go go go, yu letim tred i-foldaun long graun, baimbai i-makim rod bilong kam bak gen. Bihain, kilim Minotauros finish, yu lukim tred i-stap we, bihainim tred, na long disfela fashin yu kan kam bak autsaid gen. Mi wetim yu klostu long do, na baimbai mi tufela i-ranwe, wantaim ol nadafela yangfela man meri."

Teseus i-tok: "Tinktink bilong yu i-nambawan tru. Mi mekim olsem yu tok." Bihain, moningtaim i-kamap finish, ol i-go long haus Labirintos. Teseus i-tokim ol wantok bilong em: "Nogud yufela go longwe insaid. Morbeta yufela wet klostu long do, na mi go insaid. Bihain, kilim Minotauros finish, mi kam bak gen, na yumi kan ranwe." Ol i-wet klostu long do, na Teseus i-go insaid long haus Labirintos.

Em i-go nabaut nabaut nabaut. tasol i-tanim tred, letim foldaun long graun, bilong em i-kan luksave rod bilong kamaut gen. Bihain Teseus i-hirim bigfela nois, na Minotauros i-ran i-kam long em. Minotauros i-bigfela bulmakau man, i-gat faia i-kamaut long nos bilong em; spos disfela faia i-faitim man, man i-kuk kwiktaim tumas. Teseus i-stap klostu long do bilong wanfela rum. Minotauros i-resis i-kam long Teseus, na em i-abrusim Minotauros, i-haid long do bilong disfela rum. Minotauros i-no lukim Teseus, i-fofai long em, na Teseus i-kisim bainat, i-faitim Minotauros long hafsaid klak i-stap long em, kilim Minotauros i-dai.

Kilim Minotauros finish, Teseus i-bihainim tred, i-go bak long do bilong haus Labirintos. Ol i-wetim em, na ol i-askim em: "Yu kilim Minotauros?" Teseus i-tok: "Yes, mi kilim finish." Ol i-go autsaid nau, na Ariadne i-wetim ol. Ariadne i-tok nau: "Mi tokim ol boskru finish, rediim ship na wetim yumi. Morbeta yumi go hariap nau, baimbai papa bilong mi i-save Minotauros i-dai finish, na em i-kros tru long yumi." Teseus i-tok: "Yes, yumi olgeda i-go nau. Bihain, kamap long Athens finish, baimbai yumi tufela i-marit."

Orait, ol i-hariap i-go nau, go bak long ship, na ship i-katim ol i-go long Athens. Tasol sel i-blakfela yet, na Teseus i-lusim tok bilong papa bilong em, ol i-mas chenjim sel. Ol i-no tinktink long disfela samting, na ol i-no chenjim sel. Ship i-kamap klostu long Athens nau, na King Aigaios i-lukim, i-tok: "Sel i-blakfela! Teseus i-dai finish! A, kalapa mi! A! Mi dai nau!" Ai bilong King Aigaios i-tantanim long hed bilong em, na em i-foldaun i-dai tru. Liklik taim nau, Teseus i-kamap long Athens, ol i-tokim em: "Mifela lukim blakfela sel i-stap long ship, mifela tinktink Minotauros i-kaikai yufela olgeda. Papa bilong yu tu, em i-tinktink olsem, na em i-dai nau." Teseus i-sari tumas, em i-no tinktink long putim waitfela sel. Ol i-mekim bigfela seremoni bilong man i-dai, ol i-plantim King Aigaios. Plantim finish, Teseus i-king bilong Athens nau.

Na Ariadne i-olsem wonem? Samfela stori i-tok, em i-kam bak long Athens wantaim Teseus, na Teseus i-maritim em, na bihain Ariadne i-kwin bilong Athens. Tasol samnadafela stori i-tok, Ariadne i-no go long Athens. Ol i-kamap long wanfela ailan, nem bilong em Naksos, na ol i-stap liklik taim long disfela ailan. Bihain, Teseus na ol wantok bilong em i-gowe nau, tasol Teseus i-no tinktink long Ariadne, na Ariadne i-stap nating long ailan Naksos. Bihain wanfela bigdewel, nem bilong em Bakkhos, i-bigdewel bilong wain, em i-kam maritim Ariadne. Wonem stori i-tru? Mi no save.

Em tasol, stori bilong Teseus na Ariadne.

sonants "b," "d" and "g" often begin with a nasal sound: "mb," "nd," "ng." Those who speak Melanesian carry this peculiarity over into Melanesian Pidgin, where "tabu" ("prohibition" or "forbidden") is usually "tambu," and "sidaun" ("sit" or "be located") is frequently "sindaun." Many combinations of consonants are difficult for the Melanesian, and he will insert an extra vowel into sound clusters such as "kl," "pl," "br" and "ls"; thus "klir" ("clear") often sounds like "kalír" or "kilír," and "olsem" ("so" or "thus") like "olasem." The younger generation, however, is learning to omit these interpolated vowels.

The same linguistic snobs who make sport of unwritten pidgin and creolized languages are likely to declare that these tongues have no grammar. Behind this criticism, too, lurks a misapprehension of the nature of language. Every language has a grammar, that is, a stock of linguistic forms and principles for using them. All men, no matter how primitive in other respects, speak fully structured languages. Grammar is a far older and more firmly established invention than the grammar book. One critic has asked: "How can it be said that pidgin has a grammar when it has no tenses, cases or numbers?" It is true that many forms of pidgin lack these familiar features of European grammar, but they have other devices to make up for them.

Chinese Pidgin, for instance, adds the suffix "-pisi" ("piece") to all numerals, as in "tupisi man" ("two men") and "forpisi tebal" ("four tables"). In Chinese Pidgin the suffix "-said" indicates place where, and the suffix "-taim" indicates time when. Both are added to nouns and pronouns: "hi haussaid" ("at his house"), "doksaid" ("at the dock"), "maisaid" ("where I am"), "hwattaim?" ("when?"), "distaim" ("now"). In Melanesian Pidgin there are three suffixes that serve to indicate the form and function of words. The suffix "-fela," when added to the pronouns "mi" ("I" or "me") and "yu" ("you," singular), forms the plural: "mifela" ("we" or "us"), "yufela" ("you," plural). Another suffix, also pronounced "-fela" but distinct from the foregoing, characterizes demonstratives, indefinites, numerals and one-syllable adjectives: "disfela" ("this"), "nadarfela" ("another"), "tufela" ("two"), "gudfela" ("good"). The suffix "-im" shows that a verb is transitive: "tok" means "speak," but "tokim" is "speak to" or "address"; "fait" is "fight," but "faitim" means "strike," "beat," "hit."

Some pidgin and creolized languages employ grammatical devices that appear quite peculiar to the Western mind. In languages with West African elements, prefixes replace suffixes as indicators of grammatical relationships. Haitian Creole, for instance, has no verb tenses in our sense. Instead verbs are distinguished by a set of prefixes indicating the continuity or completion of the action performed: while "mwê châté" means "I sing," mwê ap-châté" means "I am singing" and "mwê fèk-châté" means "I have just sung."

Sometimes parts of speech, as well as the process of adding suffixes or prefixes, derive from the original native language of the speakers. Consider the pronouns of Melanesian Pidgin. Those who speak this language distinguish between "yumi" ("we" or "us," including the hearer) and "mifela" ("we" or "us," excluding the hearer). This reflects the distinction between the "inclusive" and "exclusive" first-person plural found in native Melanesian languages. Melanesian Pidgin also employs phrases formed of pronoun plus numeral, such as "mi trifela" ("the three of us") and "yu tufela" ("the two of you"). These correspond to special forms in Melanesian languages called "dual" (referring to two) or "trial" (referring to three).

Pidgins and creoles, with their simplified use of grammatical endings, rely heavily on word order to indicate the relationship between words. Simple juxtaposition serves to characterize many types of phrases; in Melanesian Pidgin, for example, a noun following another noun serves to tell some characteristic or purpose of what is referred to by the first noun: "haus moni" is "house for money," *i.e.*, "bank," and "tok gaman" is "talk characterized by deceit," *i.e.*, "falsehood." A similar combination occurs in Haitian Creole, but with the second noun indicating a possessor: "pitit rwa" means "children of a king," and "lakay mwê" means "house of me" or "my house." In Melanesian Pidgin possession is indicated by a phrase introduced by the preposition "bilong" ("of"): "pikinini bilong king" means "a king's children," and "haus bilong mi" means "my house." In Chinese Pidgin possession is shown simply by a noun or pronoun preceding the noun modified: "dat master poni" ("that master's pony") or "yu legan" ("your legs").

Those who speak Western European languages expect every full sentence to contain a predicate whose main element is a verb. But in Melanesian Pidgin and Haitian Creole (as in many other languages) the core of the predicate may

CHINESE PIDGIN	DERIVATION	SOURCE WORDS	MEANING
DAT	ENGLISH	THAT	THAT
DISTAIM	ENGLISH	THIS TIME	NOW
DOKSAID	ENGLISH	DOCK + SIDE	AT THE DOCK(S)
FAR	ENGLISH	FAR	FAR
FORPISI	ENGLISH	FOUR + PIECE	FOUR
HAUSSAID	ENGLISH	HOUSE + SIDE	AT THE HOUSE
HI	ENGLISH	HE	HE, HIM; SHE, HER; IT
HWATTAIM	ENGLISH	WHAT + TIME	WHEN?
LEGAN	ENGLISH	LEG + ?	LEG
MAISAID	ENGLISH	MY + SIDE	WHERE I AM
MAN	ENGLISH	MAN	MAN
MASTER	ENGLISH	MASTER	MASTER, EUROPEAN MAN
MO	ENGLISH	MORE	MORE
PONI	ENGLISH	PONY	PONY
–SAID	ENGLISH	SIDE	AT . . .
SPOILIM	ENGLISH	SPOIL + 'IM	ROTTEN
–TAIM	ENGLISH	TIME	(SHOWS TIME WHEN)
TEBAL	ENGLISH	TABLE	TABLE
TUPISI	ENGLISH	TWO + PIECE	TWO
YU	ENGLISH	YOU	YOU

CHINESE PIDGIN ENGLISH vocabulary includes all Chinese Pidgin words cited by the author. The words are English, but their pronunciation is influenced by Cantonese Chinese.

just as well be a noun, an adjective or an adverb. In Melanesian Pidgin "mi plisboi" means "I am a policeman," "Yu redi?" means "Are you ready?," "tinktink bilong mi olsem" means "my opinion is thus." In Haitian Creole "li bô" means "he is good," "ou gasô" means "you are a regular fellow," and "yo isit" means "they are here." Some grammatical forms belong especially to predicates, such as the Melanesian Pidgin third-person predicate-marker "i-" in "disfela man i-gudfela" ("this man is good") and "ol i-hardwok" ("they work hard"). Other examples are the Haitian Creole tense-markers "té-" (past), "va-" (future) and the negative particle "pa-": "li té-bô" ("he was good"), "yo va-isit" ("they will be here") and "ou pa-gasô" ("you're not a regular fellow").

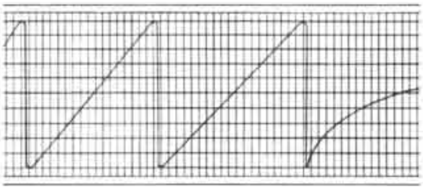
Naive observers have been struck by three supposed characteristics of pidgin vocabularies: their poverty, bastard origin and content of vulgar words. In all three of these respects, however, prevalent opinions concerning pidgin languages are erroneous. True, the ordinary pidgin language has a very small stock of words, say between 700 and 1,500, as contrasted with the 20,000 to 25,000 that even the most ignorant speaker of a "full-size" language knows. But though small, the pidgin vocabularies are not poor; the scarcity of individual words is counterbalanced by a wealth of combinations into which they may enter. These combinations often show considerable resourcefulness and ingenuity on the part of the speakers. The Melanesian Pidgin word "gras," for example, means not just "grass" but "anything growing bladelike out of a surface": "mustache" is "gras bilong maus." This restriction of vocabulary leads to semantic extensions and an increase of verbal allusiveness and color.

Curiously the vocabulary of any given pidgin language is usually less mixed in origin than that of the "full-sized" tongue on which it is based. Casual observers are struck by the presence of words from many sources in a pidgin language; Melanesian Pidgin, for example, has borrowings from German ("raus," meaning "get out"; "srank," meaning "chest of drawers"), from native languages ("kiau," meaning "egg"; "balus," meaning "pigeon" or "airplane"), from Malay ("karabau," meaning "water buffalo"), from Polynesian ("talatala," meaning "Protestant"). It even has a few Romance words ("save," meaning "know"; "pikinini," meaning "child"; "pato," meaning "duck"). But a count of the total lexicon reveals that roughly 80 per cent of the Melanesian Pidgin vocabulary is of English origin. In English itself over 50 per cent of the words are from French, Greek, Latin and other non-English sources!

The vocabularies of pidgin languages often contain words revealing the lower-class origin of their first European speakers (Melanesian Pidgin "plantim," meaning "bury"; "kalabus," meaning "jail"), or their nautical calling (Melanesian Pidgin "haisimap," meaning "lift"; Haitian Creole "viré," meaning "turn" or "veer"). Other words seem, to fastidious Europeans, downright indecent: for example, the Melanesian Pidgin "ars," meaning "bottom"; "bagarimapim," meaning "wreck" or "ruin"; "godam," meaning "golly." In native cultures, however, European taboos are not relevant. Moreover, the meaning of the words themselves is often so greatly extended as to lose all inelegance. Thus "ars" not only means "bottom" but also "base," "cause," "reason," "source." The phrase "long ars bilong" is "because of," structurally an exact parallel to the French "à cause de."

The important feature of pidgin vocabularies is their ability to grow and their adequacy to the needs of the situations where they are used. When a pidgin becomes creolized, the vocabulary expands greatly, especially through borrowings from the language of the dominant nation in the region (*e.g.*, Dutch in Taki-Taki and Papiamentu).

How do pidgin languages arise? Usually they spring from situations of casual contact, where a means of easy, informal communication is desired between a dominant foreign group and a subservient native population. No emphasis is laid on "correctness" or completeness. Members of the dominant group often assume that their interlocutors are childlike and must be addressed as children. Hence baby talk and similar simplifications enter into the original

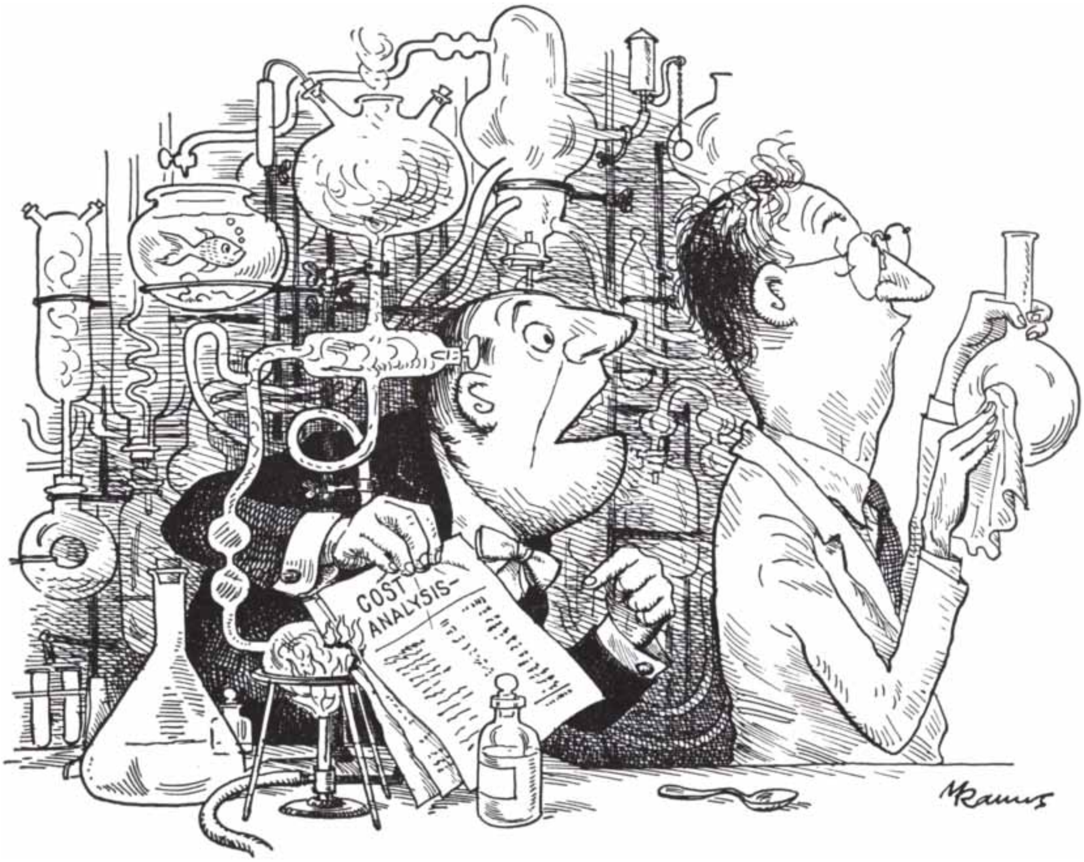


formation of a pidgin. Europeans are quick to assume that the native's first, broken imitation of the foreign speech represents his optimum performance; they reply in the same broken style. When the process of language learning is arrested at this stage, and the use of the resultant simplified structure and vocabulary is institutionalized, a pidgin has been born.

Pidgin languages do not always derive from this kind of master-and-servant relationship. Indeed, they may arise between groups (of traders, for example) that have more or less equal status. But when a pidgin survives beyond the ini-

HAITIAN CREOLE	DERIVATION	SOURCE WORDS	MEANING
AP-CHÂTÉ	FRENCH	APRES (AFTER) + CHANTER (SING)	BE SINGING
BAY	FRENCH	BAILLE	GIVE
BLÉ	FRENCH	BLEU	BLUE
BLIÉ	FRENCH	OUBLIER	FORGET
BÔ	FRENCH	BON	GOOD
CHÂTÉ	FRENCH	CHANTER	SING
FÈK-CHÂTÉ	FRENCH	[NE] FAIT QUE CHANTER (ONLY SINGS)	HAVE JUST SUNG
GASÔ	FRENCH	GARÇON (BOY)	YOUNG MAN; (REGULAR) FELLOW
ISIT	FRENCH	ICI	HERE
KAL	(?)		BLOW
KILTI	FRENCH	CULTURE	CULTIVATION
KÔPLÉZÂS	FRENCH	COMPLAISANCE	COMPLAISANCE
KÔTÂPLASYÔ	FRENCH	CONTEMPLATION	CONTEMPLATION
LAKAY	(?)		HOUSE
LANWIT	FRENCH	LA NUIT (THE NIGHT)	NIGHT
LI	FRENCH	LUI (HIM)	HE, HIM; SHE, HER; IT
MAK	FRENCH	MARQUE	MARK
MWÊ	FRENCH	MOI	I, ME
NÂ	FRENCH	DANS(?)	IN
OU	FRENCH	VOUS	YOU
PA–	FRENCH	PAS	NOT
PASÉ	FRENCH	PASSER	PASS
PITIT	FRENCH	PETITE	CHILD, CHILDREN
PÔTÉ	FRENCH	PORTER	CARRY
RWA	FRENCH	ROI	KING
SÔJÉ	FRENCH	SONGER (THINK, DREAM)	REMEMBER
TÉ –	FRENCH	ÉTAIT (WAS)	(PAST TENSE MARKER)
VA–	FRENCH + WEST AFRICAN	VA (GOES) + VA– (SIGN OF FUTURE)	(FUTURE TENSE MARKER)
VIRÉ	FRENCH	VIRER (VEER)	TURN
YO	FRENCH	(DIALECTAL?)	THEY, THEM; (NOUN PLURALIZER)
ZETWAL	FRENCH	LES ÉTOILES (THE STARS)	STAR

HAITIAN CREOLE vocabulary shows the French origin of most Haitian words cited. Once a contact language between French and Negroes, it is now the native tongue of Haiti.



"Percy, we've got to face the big problem," exclaimed Edgelow the exasperated executive of Extra Efficiency Drug Co. "Production costs on our multivitamin products must come down."

"Humm, yes, the big problem. These assistants of mine just never will learn to keep an orderly laboratory," answered Percival while polishing his paraphernalia.

"Percy — the big problem," interjected Edgelow.

"Oh yes! You know Pfizer has a new form of vitamin B_{12}—it's called STABLETS* — the most stable form ever produced — allows for a 50% reduction in overages. It's quite likely that the use of STABLETS would reduce our costs substantially. Now please allow me to continue my cleaning."

"Percy you're a prince — and so is Pfizer, clean away to your heart's desire" sighed Edgelow in utter relief.

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TAKI-TAKI	DERIVATION	SOURCE WORDS	MEANING
FÓRKU	ENGLISH	FORK	FORK
GÓ	ENGLISH	GO	GO
GÓDO	ENGLISH	GOURD	GOURD
MI	ENGLISH	ME	I, ME
SA–	ENGLISH	SHALL	(FUTURE TENSE PREFIX)
TORN	DUTCH	TORN	TOWER

TAKI-TAKI is spoken by descendants of runaway slaves in Surinam (Dutch Guiana). A creole like Haitian, it too is a native tongue based on pidgin, in this case Pidgin English.

tial stage of contact, when it persists for decades or centuries in intergroup dealings, we can assume that one group wishes to maintain social distance from the other. In the case of Chinese Pidgin English a standoffish attitude characterized both sides, for the Chinese more than matched the Europeans in their sense of national superiority. If only two language groups are involved, the side that feels it suffers loss of status because it speaks pidgin may come to insist on learning the other side's full language; this happened in China after 1900. But where those who speak many native tongues share a single pidgin, questions of status may be outweighed by an overpowering need for a means of communication. In New Guinea, with its multiplicity of tongues, Melanesian Pidgin has become a linguistic cement; without it labor relations and economic life would be impossible.

It is often assumed that a European language furnishes the pidgin vocabulary, while the "native" language supplies the pidgin grammatical structure. Chinese Pidgin English is sometimes called "Chinese spoken with English words." This notion is inexact. Close examination reveals that each form of pidgin adheres to the dominant language in grammar as well as vocabulary. The grammatical categories and types of phrase and clause in Taki-Taki, Chinese Pidgin and Melanesian Pidgin are English; those of the various creoles are North French; those of Papiamentu are Spanish. However, elements of all kinds—sounds, inflections and types of word order—can and do invade pidgin from the native tongues of the subservient group. I have already mentioned elements of Melanesian, Chinese and West African pronunciation in certain pidgins and creoles. With respect to inflection the Chinese Pidgin suffix "-pisi" is clearly a translation of the Chinese itemizer or numeral classifier meaning "piece," and such a phrase as "Ning-Po mo far" ("beyond Ning-Po") reflects the native Chinese word order.

The creolization of a pidgin language can happen either voluntarily (as in certain modern villages in New Guinea), or involuntarily (as when Caribbean plantation owners deliberately separated slaves of the same language, in order to minimize the danger of conspiracy and revolt). In either case the children of the group speak pidgin as their first language. Thus they extend its range to meet everyday needs, either by developing its inner grammatical resources or by borrowing from outside sources, as Haitian and other creoles have done from French. Creolized languages are often subject to snobbish condemnation. This causes insecurity in their speakers, who in their anxiety commit malapropisms. For example, a Haitian Creole storyteller once said of his characters: "Yo pasé lanwit nâ-kôplézâs zétwal yo" ("they passed the night in the complaisance of the stars"); when what he meant was "kôtâplasyô" ("contemplation").

To date most creolized languages have remained on the level of despised vernaculars. Sometimes, though, a pidgin can become creolized and then, through the accidents of history, attain the status of a universally recognized national language. This is what happened in the case of Indonesian. On Java and elsewhere in the former Dutch East Indies a pidginized form of Malay, known as Bazaar Malay, was widely used as a trade language. With the help of extensive borrowings from Classical Malay, Bazaar Malay became the linguistic vehicle for the new Indonesian nationalism; as such, it was renamed "Bahasa Indonesia" ("Indonesian Language"). Now a generation of native speakers is arising, and Indonesian is developing a national standard, an official literature, and all the other appurtenances of a world language.

In recent years a new school of criticism has begun to condemn pidgin and creole languages because they often function as "status" languages, the use of which sets off a given group as socially inferior. For this reason the United Nations in 1954 called on Australia to "eradicate" pidgin from New Guinea, saying: "Melanesian Pidgin is not only not suitable as a medium of instruction, but has characteristics derived from the circumstances in which it was invented which reflect now outmoded concepts of the relationships between indigenous inhabitants and immigrant groups."

The structures of pidgin languages, although reduced in contrast to "major" languages, are nonetheless clear and consistent once they are analyzed and described in their own terms. The lowly social origin of some vocabulary items is not a justifiable reason for condemnation or ridicule; otherwise we should have to ban such English words as "moist," "petulant" or "crepitate" because they come from inelegant Latin terms. The well-meaning diatribes of anti-colonialists lose sight of the fact that, although pidgins often do serve as means of discrimination, this is not a necessary or essential part of their function. On the other hand, even if it were possible to "abolish" a language by some totalitarian fiat, a slow, costly and immensely difficult process of reeducation would be required. Once creolized, pidgin has become a native language, with full rights to consideration and respect.

To remove the stigma associated with such terms as "pidgin" or "creole," it has been suggested that these languages be re-baptized with names such as "Neo-Melanesian," "Langue Haitienne" or, for Taki-Taki, "Sranan-Tongo" ("Surinam language"). This might be a wise concession. At any rate, it is evident that no amount of puristic or anti-colonialistic condemnation will "eradicate" pidgin or creolized languages. We should be duly respectful of the role of pidgin as a source of social cohesion in multilingual regions. Quite possibly some current forms of pidgin are future national languages in embryo. In all likelihood new pidgins will continue to arise when the situation calls for them, and will either die out when the need is gone, or acquire longer life through the creative process of creolization.

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MATHEMATICAL GAMES

"Brain-teasers" that involve formal logic

by Martin Gardner

A brain-teaser that calls for deductive reasoning with little or no numerical calculation is usually labeled a logic problem. Of course such problems are mathematical in the sense that logic may be regarded as very general, basic mathematics; nevertheless it is convenient to distinguish logic brain-teasers from their more numerous numerical cousins. Here we shall glance at three popular types of recreational logic problems and discuss how to go about tackling them.

The most frequently encountered type is sometimes called by puzzlists a "Smith-Jones-Robinson" problem after an early brain-teaser devised by the English puzzle expert Henry Dudeney. It consists of a series of premises, usually about individuals, from which one is asked to make certain deductions. A recent American version of Dudeney's problem goes like this:

1. Smith, Jones and Robinson are the engineer, brakeman and fireman on a train, but not necessarily in that order. Riding the train are three passengers with the same three surnames, to be identified in the following premises by a "Mr." before their names.
2. Mr. Robinson lives in Los Angeles.
3. The brakeman lives in Omaha.
4. Mr. Jones long ago forgot all the algebra he learned in high school.
5. The passenger whose name is the same as the brakeman's lives in Chicago.
6. The brakeman and one of the passengers, a distinguished mathematical physicist, attend the same church.
7. Smith beat the fireman at billiards.

Who is the engineer?

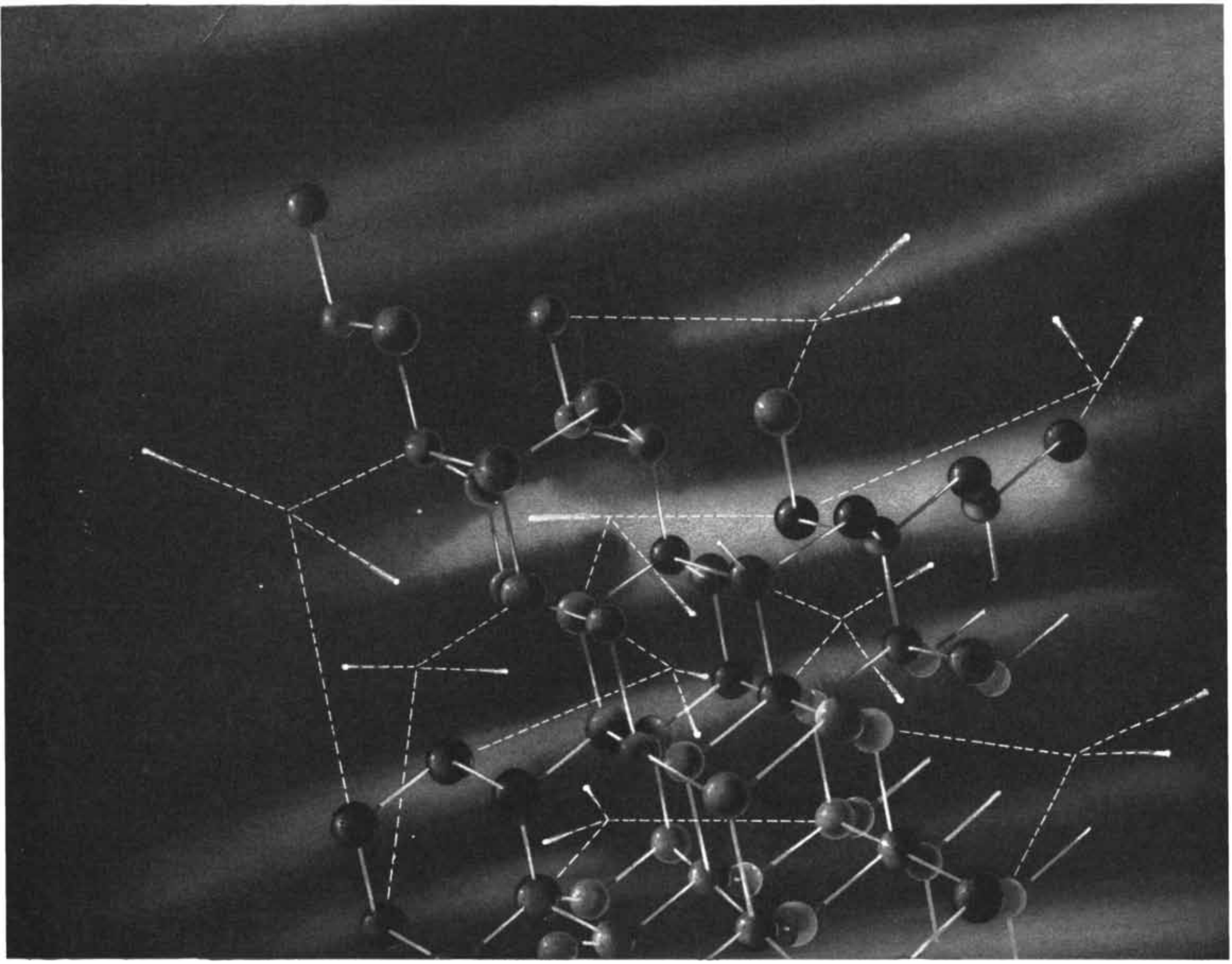
It is possible to translate this problem into the notation of symbolic logic and solve it by appropriate techniques, but this is needlessly cumbersome. On the other hand, it is difficult to grasp the problem's logical structure without some sort of notational aid. The most convenient device to use is a matrix with vacant cells for all possible pairings of the elements in each set. In this case there are two sets and therefore we need two such matrices [*see illustration below*].

Each cell is to be marked with a "1" to indicate that the combination is valid, or "0" to indicate that it is ruled out by the premises. Let us see how this works out. Premise 7 obviously eliminates the possibility that Smith is the fireman, so we place a "0" in the upper right corner cell of the matrix at left. Premise 2 tells us that Mr. Robinson lives in Los Angeles so we place a "1" in the lower left corner of the matrix on the right, and "0's" in the other cells of the same row and the same column to show that Mr. Robinson doesn't live in Omaha or

	ENGINEER	BRAKEMAN	FIREMAN
SMITH			
JONES			
ROBINSON			

	LOS ANGELES	OMAHA	CHICAGO
MR. SMITH			
MR. JONES			
MR. ROBINSON			

Two matrices for the "Smith-Jones-Robinson" problem



The nature of electron transport in a solid

An active program is under way at IBM to investigate various mechanisms that influence the conduction of electrons in solids. One project of interest is the work being done by Dr. Seymour H. Koenig of the Watson Research Laboratory at Columbia University, involving the behavior of electrons when their mean energy is greater than would be indicated by the temperature of the solid.

At a few degrees above absolute zero, the application of even a small electric field to a sample of germanium will grossly affect equilibrium of the conduction electrons and increase their average energy by a factor of twenty-five or more. The characteristics of these "hot" electrons are being studied to determine the processes that occur as they move through the lattice, "cool," and return to equilibrium. By measuring the detailed behavior of the electrical conductivity, often in time intervals measured in milli-microseconds, important information relating to the interaction of electrons with the germanium lattice can be obtained.

These investigations at the Watson Research Laboratory in New York City are adding to our understanding of basic solid state phenomena at low temperatures as well as yielding some interesting and unexpected device possibilities.

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	ENGINEER	BRAKEMAN	FIREMAN
SMITH		0	0
JONES	0	1	0
ROBINSON		0	

	LOS ANGELES	OMAHA	CHICAGO
MR. SMITH	0	1	0
MR. JONES	0	0	1
MR. ROBINSON	1	0	0

The matrices in use

Chicago and that Mr. Smith and Mr. Jones do not live in Los Angeles.

Now we have to do a bit of thinking. Premises 3 and 6 inform us that the physicist lives in Omaha, but what is his name? He cannot be Mr. Robinson, nor can he be Mr. Jones (who has forgotten his algebra), so he must be Mr. Smith. We indicate this with a "1" in the middle cell of the top row in the matrix at right, and "0's" in the remaining empty cells of the same row and column. Only one cell in the matrix is now available for the third "1," proving that Mr. Jones lives in Chicago. Premise 5 now permits us to identify the brakeman as Jones, so we place a "1" in the central cell of the left-hand matrix and "0's" in the other cells of the same row and column. The appearance of our matrices at this stage is shown in the illustration above.

The remaining deductions are obvious. Only the bottom cell of the fireman's column is available for a "1." This puts a "0" in the lower left corner, leaving vacant only the top left corner cell for the final "1" which proves that Smith is the engineer.

Lewis Carroll was fond of inventing quaint and enormously complicated problems of this sort. Eight are to be found in the appendix of his *Symbolic Logic*. One monstrous Carrollian problem (involving 13 variables and 12 premises from which one is to deduce that no magistrates are snuff-takers) was fed to an IBM 704 computer by John G. Kemeny of Dartmouth College. His Rand Corporation report No. P-966 (September 7, 1956) tells how the computer was programmed. The machine solved the problem in about four minutes, although a complete printing of the problem's "truth table" (a matrix showing the validity or invalidity of every possible combination of true and false values for the variables) would have taken 13 hours!

For readers who care to try their luck on a more difficult Smith-Jones-Robinson problem, here is a new one devised by Raymond Smullyan, now working for his doctorate in mathematics at Princeton University.

1. To celebrate the Armistice of the First World War, three married couples had dinner together. The following facts relate only to these six, and only their first and last names are involved.

2. Each husband is the brother of one of the wives; that is, there are three brother-sister pairs in the group.

3. Helen is exactly 26 weeks older than her husband, who was born in August.

4. Mr. White's sister is married to Helen's brother's brother-in-law. She (Mr. White's sister) married him on her birthday, which is in January.

5. Marguerite White is not as tall as William Black.

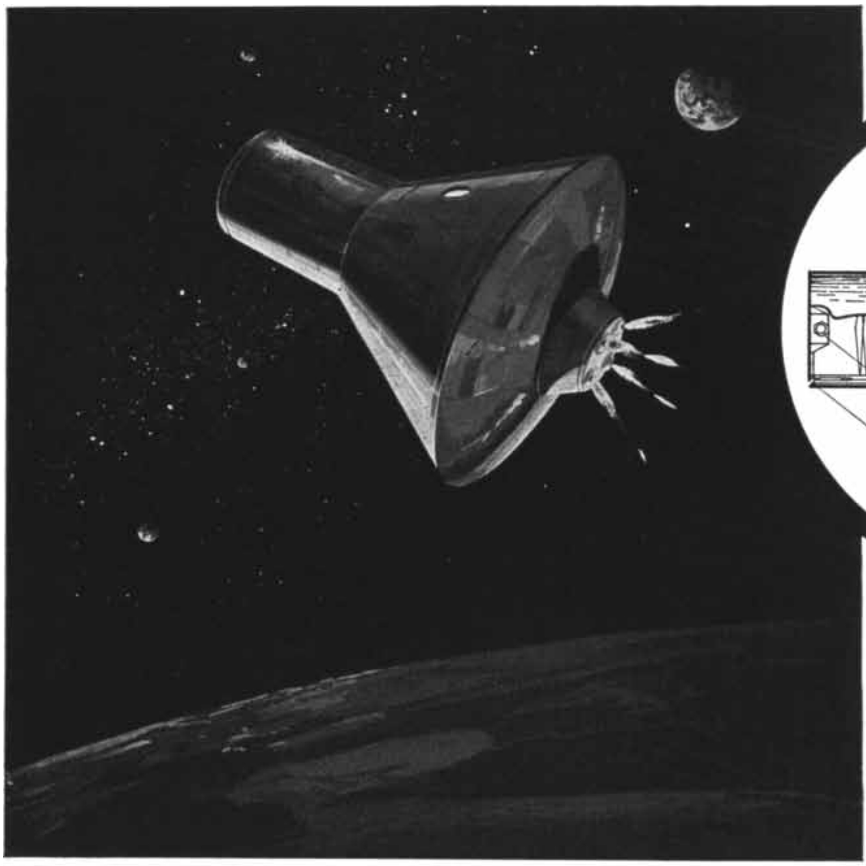
6. Arthur's sister is prettier than Beatrice.

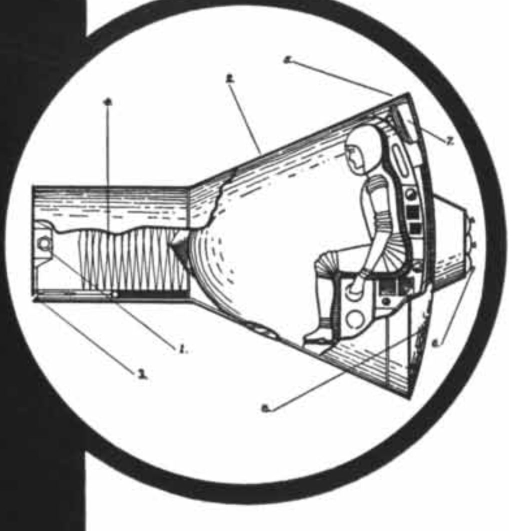
7. John is 50 years old.

What is Mrs. Brown's first name?

Another familiar type of logic poser may be called the "colored-hat" variety after the following best-known example. Three men—A, B and C—are blindfolded and told that either a red or a green hat will be placed on each of them. After this is done, the blindfolds are removed; the men are asked to raise a hand if they see a red hat, and to leave the room as soon as they are sure of the color of their own hat. All three hats happen to be red, so all three men raise a hand. Several minutes go by until C, who is more astute than the others, leaves the room. How did he deduce the color of his hat?

C asks himself: Can my hat be green? If so, then A will know immediately that he has a red hat, for only a red hat on his head would cause B to lift his hand. A would therefore leave the room. B





1. Horizon Scanner
2. Entrance Hatch
3. Pitch & Yaw Jets
4. Packed Parachute
5. Roll Jets
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NASA National Aeronautics and Space Administration would reason the same way and also leave. Since neither has left, C deduces that his own hat must be red.

As George Gamow and Marvin Stern point out in their delightful little book *Puzzle-Math,* this can be generalized to any number of men who are all given red hats. Suppose there is a fourth man, D, who is more astute than C. He reasons that if his hat is green, then A, B and C are in a situation exactly like the one just described. After several minutes the most astute member of the trio will surely leave the room. But if five minutes go by and no one leaves, D can deduce that his hat is red. If there is a fifth man more astute than D, he will decide that his hat is red after a time-lapse of, say, 10 minutes. Of course all this is weakened by the assumption of different levels of astuteness and by vagueness about the length of the various time-lapses.

Less ambiguous are some other colored-hat problems such as the following, also invented by Smullyan. Three men—A, B and C—are aware that all three of them are "perfect logicians" who can instantly deduce all the consequences of a given set of premises. There are four red and four green stamps available. The men are blindfolded and two stamps are pasted on each man's forehead. The blindfolds are removed. A, B and C are asked in turn: "Do you know the colors of your stamps?" Each says: "No." The question is then asked of A once more. He again says: "No." B is now asked the question, and replies: "Yes." What are the colors of B's stamps?

A third class of popular logic puzzles involves truth-telling and lying. The classic example concerns an explorer in a region inhabited by the usual two tribes; the members of one tribe always lie, the members of the other always tell the truth. He meets two natives. "Are you a truth-teller?", he asks the tall one. "Goom," the native replies. "He say 'Yes'," explains the short native, who speaks English, "but him big liar." What tribe did each belong to?

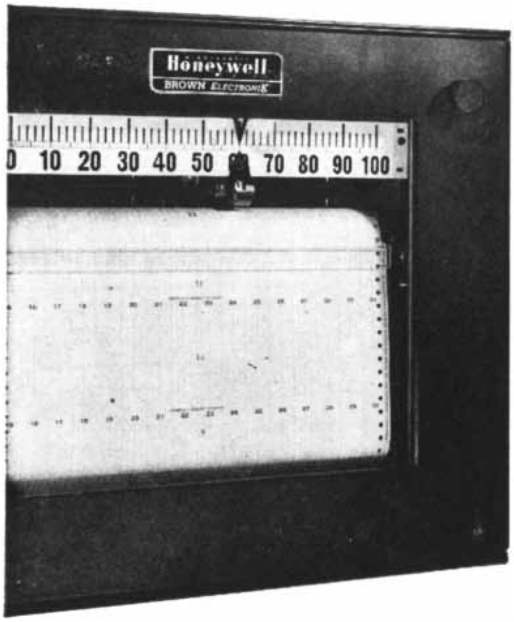
A systematic approach would be to jot down the four possibilities—TT, TL, LT, LL—then eliminate the pairs that are inconsistent with the premises. A quicker solution is reached if one has the insight to see that the tall native must answer "Yes" regardless of whether he lies or tells the truth. Since the short native told the truth, he must be a truth-teller and his companion a liar.

The most notorious problem of this type, complicated by probability factors and semantic obscurity, was dropped casually by the British astronomer Sir Arthur Eddington into the middle of the sixth chapter of his *New Pathways in Science.* "If A, B, C, D each speak the truth once in three times (independently), and A affirms that B denies that C declares that D is a liar, what is the probability that D was speaking the truth?"

Eddington's answer of 25/71 was greeted by howls of protest from his readers, touching off an amusing controversy that was never decisively resolved. The English astronomer Herbert Dingle, reviewing Eddington's book in *Nature* (March 23, 1935) dismissed the problem as meaningless and symptomatic of Eddington's confused thinking about probability. Theodore Sterne, an American physicist, replied (*Nature,* June 29, 1935) that the problem was not meaningless, but lacked sufficient data for a solution. Dingle responded (*Nature,* September 14, 1935) by contending that, if one granted Sterne's approach, there were enough data to reach a solution of exactly 1/3. Eddington then re-entered the fray with a paper entitled "The Problem of A, B, C and D" (*The Mathematical Gazette,* October, 1935), in which he explained in detail how he had calculated his answer.

The difficulty lies chiefly in deciding exactly how to interpret Eddington's statement of the problem. If B is truthful in making his denial, are we justified in assuming that C said that D spoke the truth? Eddington thought not. Similarly, if A is lying, can we then be sure that B and C said anything at all? Fortunately we can side-step all these verbal difficulties by making (as Eddington did not) the following assumptions: (1) All four men made statements. (2) A, B and C each made a statement that either affirmed or denied the statement that follows. (3) A lying affirmation is taken to be a denial and a lying denial is taken to be an affirmation.

The men lie at random, each averaging two lies out of every three statements. If we represent each man's true statement by T and his two lies by L1 and L2, we can construct a table of 81 different combinations of T's and L's for the four men. We must then decide which of these combinations are made impossible by the logical structure of the statement. The number of possible combinations terminating in T (that is, ending with a true statement by D), divided by the total number of possible combinations will then be our answer. Next month we will explain the solution to this as well as to the two problems left unanswered earlier.



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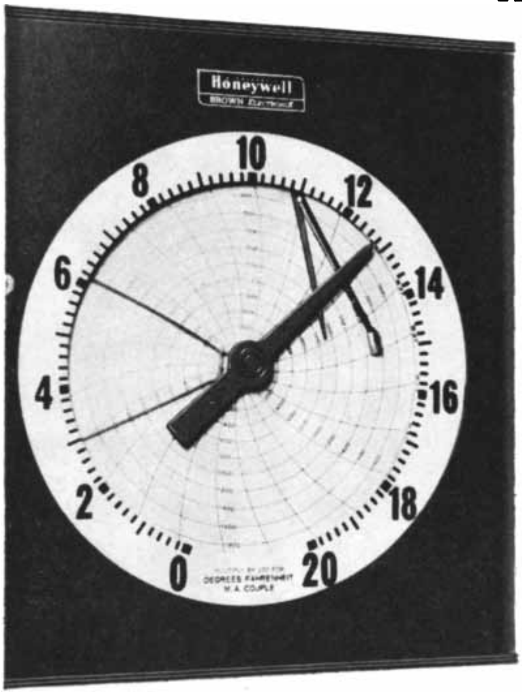

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THE AMATEUR SCIENTIST

Mostly about unearthing the fossils of dinosaurs

Conducted by C. L. Stong

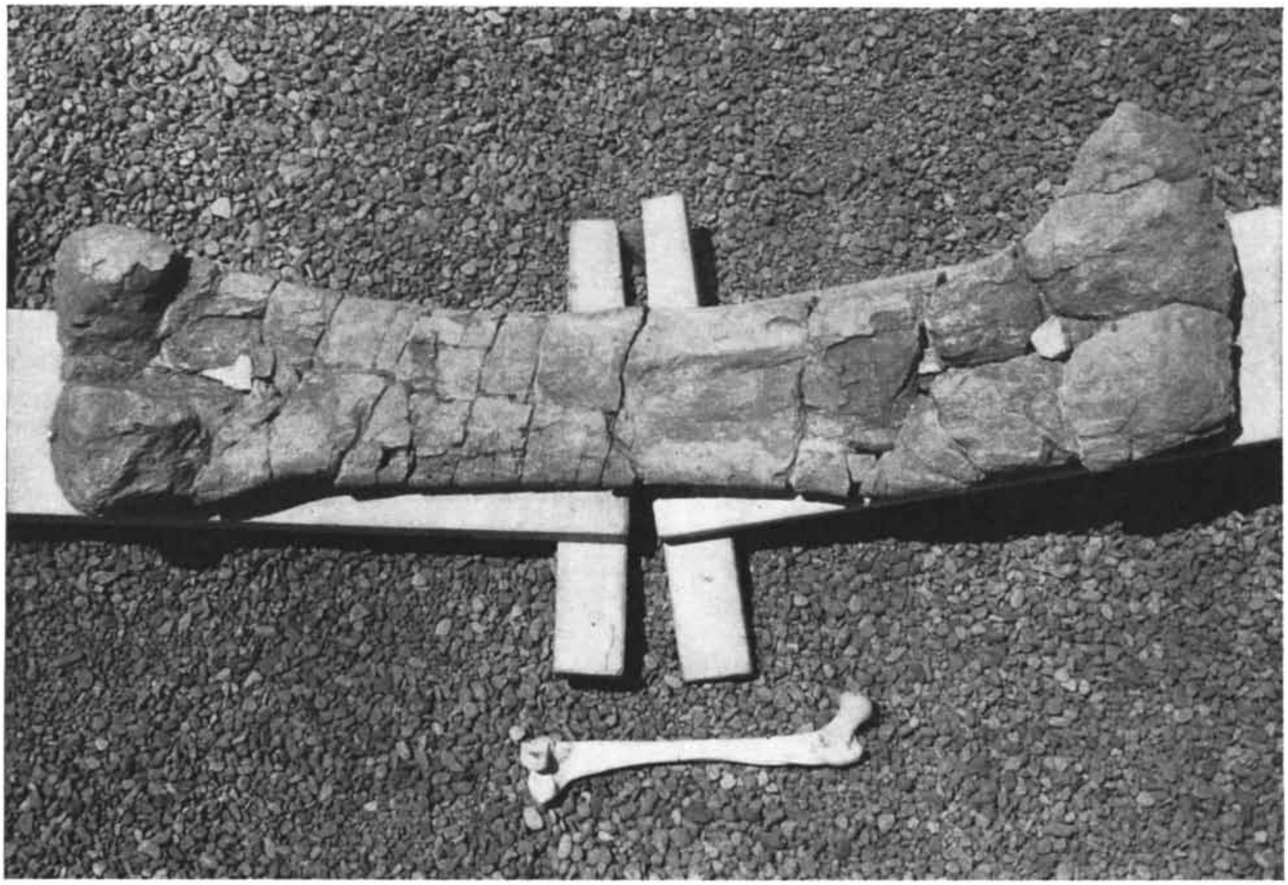
Among the most popular exhibits at any museum of natural history are the skeletons of dinosaurs. Of the millions of Americans who enjoy such exhibits, few realize that they can hunt and find such bones with no more equipment than the family automobile and some inexpensive tools which one can carry on one's back. According to Cresson H. Kearny, a petroleum geologist of Montrose, Col., the surface of many western states abounds with fragments of dinosaur bones, and on public lands U. S. citizens can gather as many as they want.

"Here is one national resource," writes Kearny, "in no danger of short supply. The best hunting grounds for dinosaur bones are the areas of soft sediments where erosion constantly brings specimens to the surface. Millions more are doubtless hidden within the rocks. If one is in fairly good physical condition and likes to hike, here is an undeveloped avocation which for me is more satisfying than catching stocked trout in a stream teeming with tourists. In dinosaur-bone country you can sometimes walk for days without seeing another human being, and you can enjoy not only the hunt for bones but also the grandeur of wilderness. Furthermore, if the amateur bone-hunter studies a bit, and then uses common sense in evaluating and handling his finds, he can render substantial help to paleontologists.

"Recently two amateur uranium prospectors found the largest leg bone—the left humerus of a Brachiosaurus—ever reported. Mrs. Eddie Jones of Delta, Col., and her husband were examining the Morrison formation, a deposit which has become famous for its fossils of large dinosaurs. Suddenly her Geiger counter began to click rapidly, although all she could see underfoot was the bluish shale of the Morrison. When the Joneses dug down a few inches they found a slightly fractured but complete fossil bone seven feet one inch long and 26 inches across at the broadest end [*see illustration below*]. As is often the case, the organic material of the fossilizing bone had concentrated-uranium minerals that had moved in dilute solutions through the almost impervious shale. A number of uranium minerals readily replace carbonaceous material, such as old driftwood or bone. It is remarkable how much 'hotter' a fossil bone can be than the surrounding rock.

"Unfortunately the Joneses did not realize that their bone was destined to set a new record for size and would

Cresson H. Kearny provides a scale for a huge Brachiosaurus bone found by Mrs. Eddie Jones of Delta, Col.



Leg bone of a Brontosaurus is compared to the femur of an American Indian

ultimately attract proportionate scientific interest. Furthermore, they were afraid that rival prospectors, then busy staking claims in the area, might find and take it. So they drove their jeep up to the find and carted away, like so much ore, over five hundred pounds of the biggest pieces, almost breaking their springs in the process. Back home in Delta, some 14 miles away, they roughly aligned the various chunks on the front porch for their neighbors to see.

"One night several weeks later I chanced to be passing through Delta on a geological trip and heard about the find. When I visited the Jones home in the evening, I actually tripped over the pieces of a specimen such as I had dreamed about since my first visit as a boy to the great dinosaur halls of the American Museum of Natural History.

"So it came about that one Sunday I put the Joneses' Brachiosaurus humerus together for them. Later, while on a trip to the East, I told paleontologists at both the American Museum of Natural History and the Smithsonian Institution about this bone, one far larger than any they possessed. When I described its size by gesturing toward the ceiling, however, I received only skeptical smiles. Finally I submitted a photograph of the bone, myself and a yardstick. That did the trick.

"Both the Smithsonian and the American Museum soon asked the Joneses for their bone, but the Smithsonian asked first. This spring we had the satisfaction of watching Peter Vaughn of the Smithsonian and two assistants skillfully cover each fragment with wet paper and then wrap it with a layer of burlap soaked in plaster of Paris. The next day the paleontologists packed the hardened packages in wooden crates filled with shavings and shipped them off to Washington. Before long the Joneses' Brachiosaurus humerus will be displayed against a column in the Smithsonian to help visitors picture one of the largest animals ever to walk the earth.

"What is the scientific significance of this huge bone? According to Edwin H. Colbert of the American Museum, the largest dinosaur bone previously found is the Brachiosaurus humerus excavated in Colorado by the Chicago Natural History Museum some 50 years ago. It is a little over six feet, eight inches long. This humerus once supported a Brachiosaurus which weighed about 100,000 pounds. The Joneses' seven-foot one-inch humerus must have belonged to an animal that weighed some 120,000 pounds! The head of the animal, judging by the height of a reconstructed Brachiosaurus skeleton in the Berlin Museum, must have towered 44 feet above the ground. This must surely approach the engineering limits for a land animal.

"Although the relatively common Brontosaurus is often cited to represent immensity among land animals, the rarer Brachiosaurus was a much larger animal. Both monsters were saurischians, one of the two orders of dinosaurs. Like dinosaurs of the other order (the ornithischians), the saurischian dinosaurs were descended from the small, agile, carnivorous Thecodonts of the Triassic Period of some 200 million years ago. The Thecodonts ran on powerful hind legs; their front limbs were adapted for grasping. Yet Brachiosaurus, which evolved and became extinct during the Jurassic Period of about 150 million years ago, was a ponderous herbivorous reptile that not only walked on all four feet but also carried most of its weight on front legs decidedly longer and larger than its hind legs. Above its shoulders rose a towering neck which supported a small head with jaws

and teeth so insignificant that it is hard to understand how the animal could have eaten enough to grow a body of so many tons. No doubt it spent most of its time in fresh-water lakes filled with plant life. Obviously Brachiosaurus was highly specialized for an aquatic existence; its nostrils pointed upward out of a sort of turret on the top of its head. Probably when Brachiosaurus was hiding from the worst predator of the period, the Allosaurus, its head looked like a small log floating in a muddy lake.

"The mighty leg bones of Brachiosaurus were barely adequate to support its weight. As the animals evolved their size increased, and more individuals in each generation died because their leg bones had broken under the strain. Their weight went up as the cube of their linear dimension, whereas the strength of their bones could increase only with the square of this dimension. Eventually Brachiosaurus became too specialized to cope with the changes in its environment, and it died out millions of years earlier than other dinosaurs did.

"All animal skeletons are made of material with essentially the same strength, whether the animal be a dinosaur or a mouse. This strength increases with the cross-sectional area of bone. Those dinosaur bones which did not have to bear heavy loads took advantage of engineering opportunities for light construction. When it came to supporting dead weight, however, the huge land dinosaurs found no solution other than solid columns of bone, as straight as possible to minimize bending stresses. The photograph on page 144 dramatizes this point; it compares the five-foot two-inch femur of a Brontosaurus and the corresponding leg bone of a six-foot American Indian. If the two structures were cut at right angles to their long axes, the leg bone of the Indian would of course have a hole in the center, but the dinosaur femur would be solid. The marrow of such solid bones is represented by large cells distributed throughout the bone.

"The problems of biological engineering suggested by the skeletons of large dinosaurs have given rise to some ingenious speculations. For example, the paleontologist W. D. Matthew believed that these animals could not walk unless they were partly supported by water. He wrote: 'The imperfect joints of the limb and foot bones were covered during life with thick cartilage, like the joints of whales, sea lizards and other aquatic animals. If the full weight of the animal came on these imperfect joints, the cartilage would yield and the ends of the bones would grind against each other, thus preventing the limb from moving without tearing the joint to pieces. The massive, solid limb and foot bones weighted the limbs while immersed in water, and served the same purpose as the lead in divers' shoes, enabling the Brontosaurus to walk about firmly and securely underwater.'

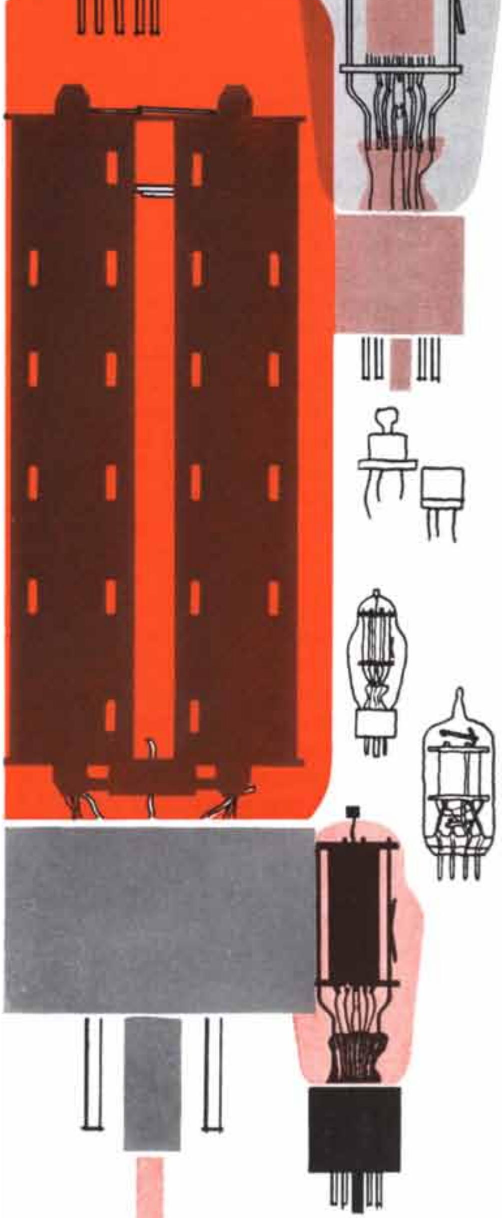
"It was with considerable interest that I measured the joint areas and cross sections of both the Joneses' Brachiosaurus humerus and the femur of the six-foot Indian. I counted as effective only those areas of the joint which were loaded when the leg was in a straight position. The lower, smaller joint of the Brachiosaurus humerus has a corrected bearing area of 153.3 square inches, as contrasted to a similarly corrected bearing area of 1.84 square inches for the ball of the Indian's femur. If the Brachiosaurus had weighed 120,000 pounds, and if this one humerus joint took the whole weight, then the stress per square inch on the effective surface of the leg joint was 783 pounds.

"Now let us assume that the Indian weighed 200 pounds, and, for purposes of argument, that he was carrying a burden weighing 800 pounds. (Of course this is a mighty heavy load, but I have seen professional porters carry such loads in China.) If the entire weight were supported by one leg, the stress on the joint would be 543 pounds per square inch. The British biologist J. B. S. Haldane stated that the human leg would fail (with a fracture of the femur) under a load 10 times body weight; I have loaded my Indian with only four times his body weight. So if we grant that the cartilage of a Brachiosaurus was as strong as that of a man, and it may well have been stronger, then this largest of land animals could even have stood on one leg without wrecking its joints!

"Our dinosaur was in even better shape with respect to the strength of its leg bone: when it stood on one leg, its humerus, with a minimum cross section of 76.7 square inches, withstood a stress of 1,565 pounds per square inch. The solid bone of our Indian's femur had a cross section of .55 square inch; when he stood on one leg and carried a burden of 800 pounds, the stress on the bone was 1,820 pounds per square inch. Thus it seems probable that the Brachiosaurus could walk easily and safely from lake to lake without injuring its legs.

"Any student of the earth will find pleasure in reconstructing the world of the great dinosaurs of the Morrison formation in western Colorado and eastern Utah. On the Uncompahgre Plateau the evidence is especially clear. The first


5,000!



horizon with abundant dinosaur remains is the lower part of the Brushy Basin formation, which constitutes the uppermost member of the Morrison. The Brushy Basin member is mostly a series of variegated bluish and purplish bentonitic shales and clays, deposited largely in quiet fresh-water lakes in a flat Jurassic world. But near the bottom of the Brushy Basin are numerous sandstone beds, often cross-bedded and showing other indications of having been laid down by swift streams that transported poorly sorted gravels along with driftwood (now petrified in interesting green and brown colors) and dinosaur bones (especially those of Brontosaurus). Then the earth sank over a large area embracing what is now most of the Uncompahgre Plateau, and the region became a quiet, muddy fresh-water lake that was the home of the Joneses' huge Brachiosaurus. Some 200 feet of fine clay was deposited in this lake, so it must have existed for a long time.

"This quiet refuge for overspecialized giants was ruined when, at the beginning of the Cretaceous Period some 125 million years ago, the gravels and sands of the widespread Dakota sandstone blanketed the whole series of lake-deposited clays and shales of the Brushy Basin, bringing in deciduous leaves, now fossilized, that tell of new uplands and a changing world in which Brachiosaurus failed to survive.

"It is easy to see how a swift river, bearing coarse gravels as well as the bones of dinosaurs that had died farther upstream, often broke up the skeletons of even the largest animals. It is difficult to understand, however, how the giant humerus of the Joneses' Brachiosaurus came to be buried all by itself, for it certainly came to rest on the bottom, and far from the shore, of the lake. Perhaps the carcass floated into the lake and decomposed. The heavy humerus could then have broken away and sunk, to be petrified, collect uranium minerals and ultimately be found by an energetic lady with a Geiger counter.

"What would seem to be the best hunting ground for the amateur collector of dinosaur bones extends in a wide belt from Colorado to Alberta. State geological maps make it easy to find areas where Jurassic and Cretaceous sediments outcrop. A little local inquiry should lead one to areas where fossil bones have actually been discovered. The amateur should steer clear of areas such as Dinosaur National Monument, where dinosaur bones are found in hard conglomerate or sandstone. In these areas bones can be got out only by means of difficult mining operations, including the use of rock drills and dynamite.

"The prospector who seeks big fossils should get away from roads and farms. He must learn to use his eyes and to form a mental image of what a dinosaur bone looks like. He should remember that the early explorers of the West, including a number of good geologists, must have walked over numerous specimens without recognizing them as fossils. As a pioneer geologist once wrote in regard to the discovery of dinosaur fossils in the West, 'Most great discoveries are due to a state of mind rather than to accident.'

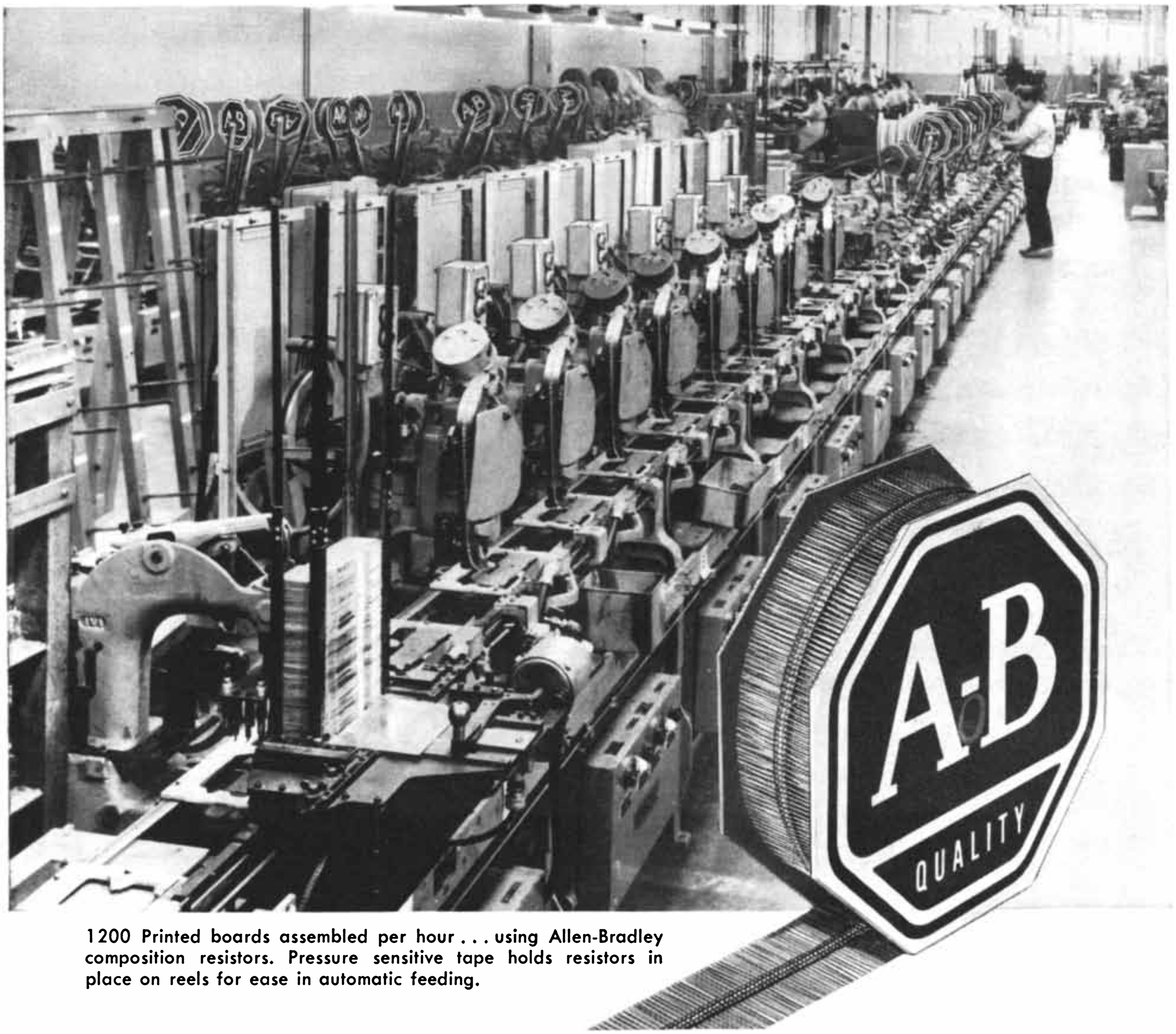
"The beginner should read extensively about dinosaurs and the art of finding and collecting them. An excellent reference is *The Dinosaur Book*, by Edwin H. Colbert. Visits to museums and talks with paleontologists are also helpful. The differences in form and color which distinguish a fossil from the rock in which it is found are subtle and easily escape the eye. One acquires the knack of spotting fossils quickest by exploring with a worker experienced in the field.

"How to get the specimen out of the ground also presents a problem. A light shovel, a sharp miner's pick and a prospector's hammer are the basic tools. A chisel, a supply of quick-drying plastic cement and a small brush are often very useful. The professional paleontologist always shellacs bones before he moves them, and then applies a protective cocoon of plaster of Paris and fabric. This technique may be impractical for the amateur who merely wants to take a bone home. In the case of larger bones, cocooning results in heavy packages that must be transported by a truck.

"Rare specimens deserve to be got out in the best professional manner. If they prove too much to handle, leave them in place and inform a paleontologist of their whereabouts. Always submit photographs and scaled sketches. Fossil bones that have petrified into hard rock can be got out and restored at home by another technique, even when broken into many pieces.

"This method is illustrated by the manner in which my son and I collected the first dinosaur bones he had found, when he was only 11. While hunting for petrified wood in the old river channel of the lower Brushy Basin member of the Morrison, he saw what he first thought was a strangely white petrified tree limb. To his delight, it proved to be the end of a dinosaur leg bone. He soon had the pieces all numbered, wrapped in paper and ready to go into our car, a half mile away.

"One bone often leads to another, and



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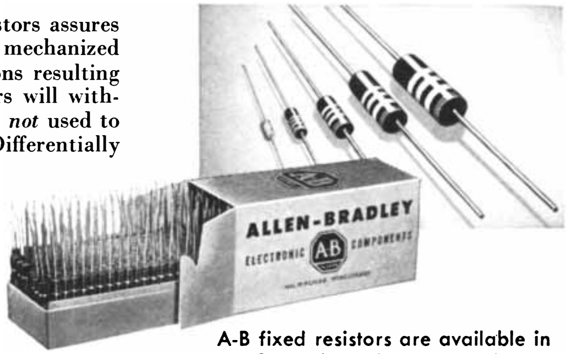

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RADIO, ELECTRONICS, AND TELEVISION COMPONENTS in this instance the next proved to be a hard but badly fractured Brontosaurus femur weighing about 250 pounds. Had we covered it with plaster of Paris, our package would have been so heavy that we would have been compelled to build a road up to our excavation.

"On our next trip to the area we first removed the overburden and placed atop the bone a measuring rod somewhat longer than the specimen. A mark was made on each major fragment of the bone and a sketch was drawn of the undisturbed fragments, along with the scale, including the distance between the marks. The fragments were next labeled, numbered serially and carefully removed for carting away. After we had got the pieces home, the indexed sketch enabled us to reassemble them quickly.

"An added complication was introduced by the fact that many of the fragments were shattered into dozens of smaller pieces. We solved this problem by cementing the smaller pieces together with quick-drying plastic cement before removal. These cemented chunks, which weighed a pound or so, were also labeled, and after being wrapped in newspaper were placed in our dog's pack. (The dog was a Saint Bernard.) My son did most of this work, and in the process learned something of the less pleasurable side of science, especially when a windstorm blew sand in his eyes. Then he and our Saint Bernard carried the big femur across terrain that would stop a tank. In the process the dog doubtless established a record for the largest bone brought home by his kind.

"The lighter you travel when prospecting, whether for uranium or dinosaurs, the more ground you can cover and the more likely you are to hit pay dirt. A plywood pack-board of the Army type, a waterproof bag, a light sleeping bag, a nylon poncho, a couple of canteens, about 12 pounds of ready-to-eat dry food and a few light tools will enable you to hunt for five days in areas far from roads. Until you start collecting fossils you will have complete freedom of movement, thus making it easy for you to get into virgin dinosaur country.

"My son and another boy are shortly leaving for just such a five-day hunt for dinosaurs. They are going into the area of the upper Morrison outcroppings in a remote part of the Uncompahgre Plateau, where they will be up to 10 miles from the nearest jeep road. During the hunt they will probably not see another human being. We recently received a letter from a paleontologist informing us that the small dinosaurs of the Morrison are now the only known species that

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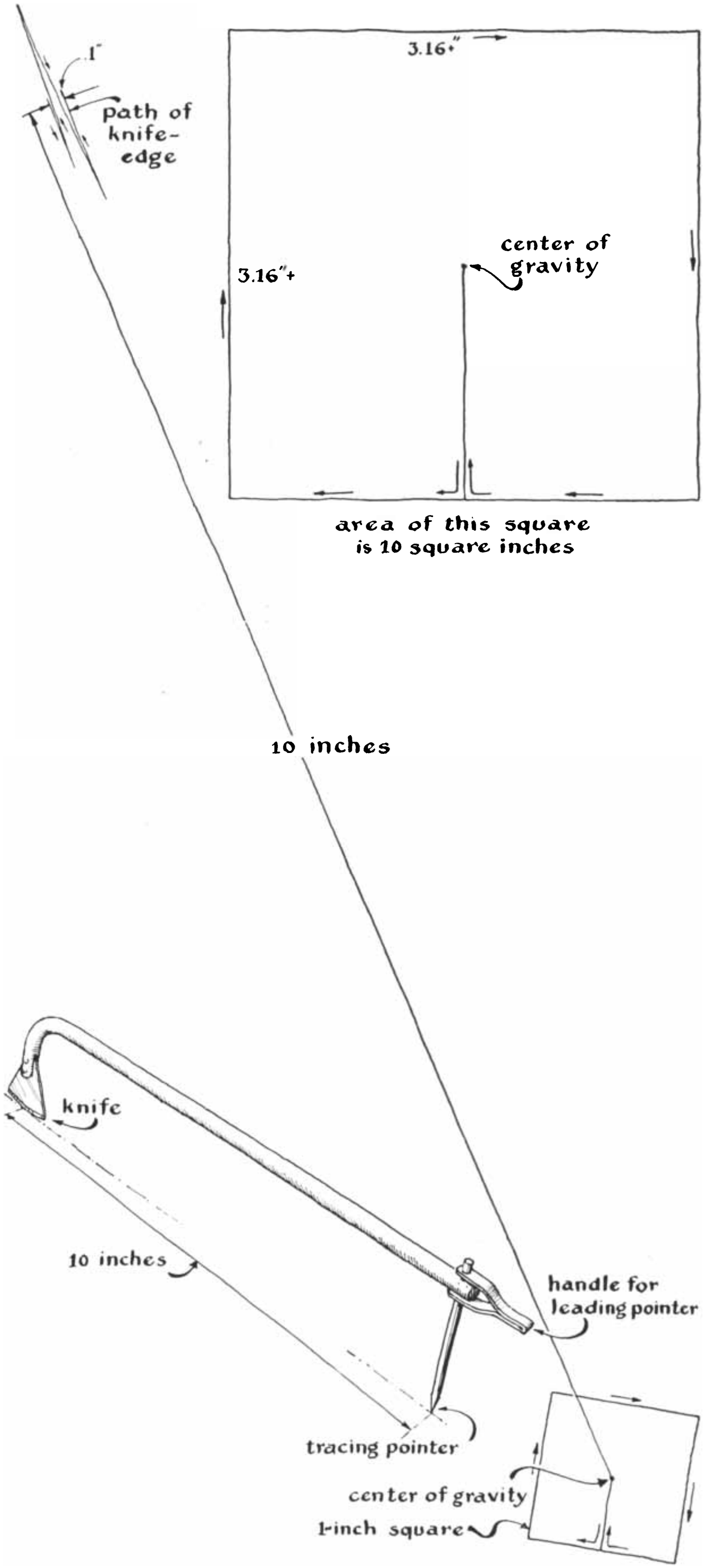

A hatchet-type planimeter to measure irregular areas

have not been extensively collected and studied. The boys, assisted by a Geiger counter, will accordingly concentrate on small dinosaurs and try to bring back skulls and pelvises—bones prized even by our foremost museums.

"In contrast with British amateurs, thousands of whom diligently collect well-known though insignificant fossils, relatively few Americans take an active interest in hunting our fossil treasures. This strikes me as most unfortunate. But after all, as my old professor of geology at Oxford once remarked, 'Americans are a young people living in a young country and still have time.' "

Walter Hobson, a mechanical engineer of Philadelphia, submits the design for a planimeter to measure the area of an irregular shape. His planimeter, of the hatchet type, was constructed in the 1900s, and has been used extensively for map work as well as for measuring the irregular areas encountered in problems of mechanical design. Details of construction are given in the drawing at left. The only critical dimension is the distance between the tracing point and the point at which the rounded knife-blade makes contact with the paper, which should be 10 inches. The tracing point is first set on the estimated center of the figure to be measured. The blade is pressed into the paper at any convenient point, and a straight line is drawn from the tracing point to the point where the blade touches the paper. The tracing point is moved along the straight line to its intersection with the figure, then around the figure and finally along the straight line to the point of origin. The knife is kept upright and in light but firm contact with the paper during the tracing operation. The motion of tracing causes the knife to make a zigzag excursion away from the line, as shown at upper left in the illustration. Measure the distance between the final position of the knife and the line and multiply it by 10. The product is the area in square inches of the figure.

René A. Wurgel, who described a novel method of mounting a diagonal mirror in a small telescope in this department last November, calls attention to an error in the associated drawing. The brass rings which support the mirror should be attached to the main tube of the telescope by two bolts instead of four, as illustrated. This permits the rings to be turned for collimation. Wurgel also suggests that the rings be made of relatively thin material, *i.e.*, on the order of .025 inch thick.

BOOKS

Four approaches to the problem of preventing a third world war

by James R. Newman

THE CAUSES OF WORLD WAR THREE, by C. Wright Mills. Simon & Schuster ($3.50). NO MORE WAR!, by Linus Pauling. Dodd Mead & Company ($3.50). INSPECTION FOR DISARMAMENT, edited by Seymour Melman. Columbia University Press ($6). PEACE OR ATOMIC WAR?, by Albert Schweitzer. Henry Holt and Company ($1.50).

Where there is an ear for reasoned argument these books will do a service. They are quite different books by quite different men, but they share a common concern: the continued existence of the human species. A sociologist examines the forces thrusting the world toward war; a chemist assesses the effects of radioactive fall-out; a group of scientists and engineers surveys the feasibility of an inspection system for disarmament; a physician pleads for an end of the nuclear-arms race. The tone of the books is also quite different. One sounds like a trumpet, one is cautious and analytical, one is restrained but remorseless, one is eloquent but gentle. All, however, reflect a deep awareness of man's peril: the probable annihilation of the human race in the event of another war.

One may differ with Mills's analysis of the causes of the next war, but it cannot be denied that he is a man of courage and of conscience. He has written an angry essay. It is none the worse for that; a torch must burn to give light. He confronts three main questions. Do men make history, and so make wars? Are we drifting blindly into the final catastrophe, or are certain decisions and policies thrusting us toward it? Assuming that it lies within our power to avert war, what ought we to do?

Take the first question. It is often said that certain great events such as wars are inevitable. Men are trapped by circumstances; fate makes the decisions. This ancient idea, gradually transformed into the belief that the Deity has fixed a great plan which determines every sparrow's fall is, among thinking men at least, obsolete. Nature is hard but not malicious; the stars are indifferent. Irresistible forces, it may be admitted, shape the universe, but man can see and judge and know and create and decide for himself. His freedom is bounded, but within its small sphere it is sovereign. The "thinking reed" is both the weakest and the strongest thing in nature. There is, however, another conception of fate that is not obsolete. It is in fact, Mills says, indispensable for adequate reflection on human affairs. According to this conception history is "the summary and unintended result of innumerable decisions of innumerable men." The men do not form an identifiable class; the decisions are not in themselves consequential enough for the results to have been foreseen. Like crowds of particles the decisions collide, coalesce and add up to the blind result—the historical event, which, as it were, is autonomous. This is the fate Karl Marx had in mind when he wrote in *The Eighteenth Brumaire of Louis Bonaparte*, "Men make their own history, but they do not make it just as they please."

Thus understood, fate is not, in Mills's words, a universal constant. It depends upon social structure and especially upon the concentration of power. Fate is a name we give to power so diffused and fragmented that we cannot discern the mechanics of its use; it is a name like probability, which baptizes our ignorance. But in a society where power is visibly concentrated, history is not drift or fate. It is the sum of the vital decisions made by the groups of men which hold power. What they do—or fail to do—makes history; what others do is of little account: the others are the "utensils" of history-makers and the "objects" of history-making.

Given this diagnosis, we shall with Mills take it for granted that a handful of "high and mighty" of the U.S.S.R. make history; but what about the U. S.? Mills's thesis, already set forth in *The Power Elite*, is here reaffirmed. In our country history is made, he says, by a small group of men: "the high military, the corporation executives, the political directorate." This is the top level. The middle level is composed of "a drifting set of stalemated forces," and at the bottom is a passive, increasingly powerless "mass society." The power elite makes the decisions even though the formal democratic machinery has been relegated to the middle groups. The "great public" votes and even elects, but to what purpose? Of the men it elects only a few help make decisions, and then only when they are admitted to the elite.

Mills now warms to his argument. The power elite (in the U.S.S.R. as well as in the U. S.) is possessed by the "military metaphysic" that the constant threat of violence and the maintenance of a "balance of fright" are the essentials to a condition of peace. Many of the elite also believe that a war economy is the indispensable underpinning of economic prosperity. They are committed therefore to the arms race, which may in itself be the immediate cause of World War III. Political apathy of "publics" and moral insensibility of "masses" in both communist and capitalist worlds allow the economic and military causes of war to operate. Leading intellectual, scientific and religious circles are either confused and permissive, or join in the cold war. Few intellectuals put pressure on the elite to change its policies; fewer still set forth alternatives. In framing this indictment Mills is careful to say that the thrust to war is not an elite "plot," either here or in the U.S.S.R. The elite of each country has its "war parties" and its "peace parties," and both elites have what Mills calls "crackpot realists." They are men so rigidly focused on the next step "that they become creatures of whatever the next step brings"; they are also men who cling rigidly to general principles and who "join a high-flying moral rhetoric with an opportunist crawling among a great scatter of unfocused fears and demands." Practical next steps and round, hortatory principles, but no program: this is the main content, in Mills's view, of today's struggles of "politics."

Steadily we move towards the abyss. What is to be done? Mills's appeal is addressed mainly to intellectuals. They must stop fighting the cold war. They must make contact with their opposite numbers "among those now officially defined as our enemy." ("With them, we ought to make our own separate peace.") They must help educate one another. They must also remedy the default of religion and help awaken the public conscience; for religion itself is "morally dead" in the U. S., and ministers of God, who are responsible for the moral cultivation of conscience, "with moral nimbleness blunt conscience, covering it up with peace of mind." Scientists should honor publicly those, like the 18 German physicists, who have made their declarations for peace and against working on the new weaponry. Scientists should attempt "to deepen the split among themselves and to debate it." They should denounce secrecy. They should refuse to become members of a "Science Machine" under military authority. They should refuse to make weapons and boycott all research projects directly or indirectly relevant to the military. These are among the steps that Mills says would begin the practice of a professional code. The scientist, by adopting such a code, would reject "fate," for he would thereby declare his resolve to take at least his own fate into his own hands.

Mills's book is primarily a polemic and a sermon. It is, as intended, provoking as well as provocative. Patriotic groups will not clasp his thesis to their bosoms, and many disinterested students of society and power will differ strongly with his analysis of the causes of war. No open-minded person, however, will mistake this for the work of a hack or pitchman for the official lines of either side. Mills is his own man.

Linus Pauling, though gentler, is also his own man. His book is a powerful statement of the case for nuclear disarmament.

That war is today an insane method of solving disputes is a truth so obvious that it is hard to prove. Men are apt to acknowledge it, as they acknowledge their mortality, and then go about their business. But the proposition that we all have to die some day is not the same as that we all have to die the same day. Until now it had always been assumed that, though men were mortal, man would endure. This assumption, as Pauling shows, has become questionable.

Five chapters of his book discuss fallout. They give one of the clearest summaries of the problem I have seen. While there is considerable disagreement as to what constitutes "safe" limits of radiation with respect both to somatic and genetic injury, no responsible scientist doubts that wide "margins of uncertainty" (these words are from the United Nations report on radiation) surround all estimates. Before the subject became a hot military and political potato, it was accepted that even small amounts of radiation produce mutations, and that almost all mutant genes are bad. But because quantitative estimates of population exposure and of effects are so wide-ranging, it is easy for those who for official reasons wish to minimize the danger to becloud and confuse the issues. It cannot be foretold whose genes will be altered, or in what way, so let's all stop worrying and keep our fissionables dry.

The physicist Edward Teller, who has sought and gained wide publicity for his views, is Pauling's prime example of a public misinformer. Teller regards radiation from nuclear tests as a negligible threat to world health. World-wide fallout is, in his phrase, "as dangerous as being an ounce overweight." So far as possible genetic damage is concerned, Teller has stated that "radiation in small doses need not necessarily be harmful—indeed may conceivably be helpful." This puts fallout in roughly the same category as Lydia Pinkham's remedy. His views on radiation are of course essential to his general political position. He is convinced that the bigger the bombs the better the chance for peace. If the next war kills everyone, the world will again be peaceful; but this is not, I think, what Teller has in mind. He pins his hopes to "clean" bombs, which would leave survivors. Continued tests are needed, he says, to develop such bombs, and the tests themselves are harmless. Another reason he gives for not suspending tests is that atomic explosions can be concealed; we could never be sure therefore that an international agreement prohibiting tests would not be secretly violated by the Soviets. Because of his eminence as "father of the H-bomb," Teller's opinions have carried considerable weight. Lately their prestige has waned, Pauling's arguments having contributed to this result.

The statement that fallout is as dangerous as being an ounce overweight Pauling characterizes as "ludicrous." It is based, he says, on a gross statistical blunder and represents a 1,500-fold underestimate of the hazard. One of Teller's points is that the people of Tibet, though exposed to much more intense cosmic radiation than people who live at lower altitudes, are as healthy as we are (or, at any rate, used to be). Pauling replies that the Tibetan exposure to increased amounts of cosmic radiation should produce an increase in the incidence of seriously defective children from 2 per cent—the average U. S. figure—to 2.3 per cent. But since there are no medical statistics for Tibet, Teller's statement is simply out of the blue. (He advanced it in a magazine article in order, as he said in a television debate with Pauling, merely to "quiet excessive fears.") Another of Teller's assertions is that the radiation danger to the average person is 10 times as great from luminous-dial wrist watches as from fallout. Pauling demolishes this statistic. Teller, it may be felt, is better at bombs than at arithmetic.

Pauling gives examples of official misstatements. Merril Eisenbud, an Atomic Energy Commission official, wrote an article in 1955 which stated that "the total fallout to date from all tests would have to be multiplied by a million to produce visible, deleterious effects except in areas close to the explosion itself." He was later asked by a chairman of a Congressional subcommittee if he remembered how much radioactivity had fallen on the city of Troy, N. Y., following a test held in Nevada a few days before. Eisenbud estimated the amount as "something under .1 roentgen" and finally settled on .01 roentgen. Ralph Lapp, who was present at the hearing, pointed out that a million times .01 roentgen is 10,000 roentgens. Whereupon one of the Senators observed that this amount would have the "visible and deleterious" effect of killing everybody in the region.

Commissioner Willard F. Libby of the A.E.C. said in 1955 that "the fallout dosage rate as of January 1 of this year could be increased 15,000 times without hazard." This is not as cheering as Eisenbud's figure, but cheering enough. Pauling is less reassuring. He notes that 10 hours after the detonation of a small fission bomb at the Nevada test site, the level of gamma radiation at St. George, Utah, was .004 roentgen per hour, which is .1 roentgen a day. Multiplied by 15,000, this gives an exposure of 1,500 roentgens—a dose that will produce death within a few days from radiation sickness.

Pauling's own estimates of the effects

of fallout are somber. He predicts an annual death rate of 8,000 if tests continue at the present rate. Moreover, 15,000 seriously defective children will be born each year whose defects must be attributed to the tests (this number does not include embryonic and neonatal deaths and stillbirths). It is possible, he admits, that his estimates are 10 times too large or 10 times too small. Perhaps then only 1,500 children will have to be sacrificed annually to the maintenance of peace; on the other hand, if the figures are too small, 150,000 children may be required. Even if no more tests are carried out, a lethal legacy of radioactive carbon 14 already released into the atmosphere will be handed on for thousands of years. According to Pauling's calculations, based to a large extent on data provided by Libby and others, the quantities of this long-lived isotope discharged in the period 1952 to 1958 will ultimately produce about one million seriously defective children and about two million embryonic and neonatal deaths, "and will cause many millions of people to suffer from minor hereditary defects." Our generation will be remembered.

When in April of last year Pauling first called attention to the menace of bomb-produced carbon 14, he was sharply criticized by three geneticists in a letter to *The New York Times* for making "erroneous" and "exaggerated" statements that "only add to the public's confusion and do not contribute to the solution of the problem." Libby dismissed Pauling's warning by saying that the effect of carbon 14 from nuclear tests "is equivalent to an increase in altitude of a few inches." But the ridicule backfired when the A.E.C.'s Division of Biology and Medicine issued a document, "The Biological Hazard to Man of Carbon 14 from Nuclear Weapons," whose conclusions agree quite closely with Pauling's. This document was unaccompanied by a press release and no enterprising reporter nosed it out. Lapp brought it to public attention in a letter to *The New York Times.*

Like Mills, Pauling makes a general appeal for peace and for international agreements on the cessation of bomb tests and on disarmament. His words are a *cri de coeur*, sustained by moral authority and reason. But there is little evidence that such pleas, uttered by those who know most about the dangers involved in a nuclear war, have persuaded leaders of states of the necessity of making radical changes in their policies. The argument is often heard that those responsible for the safety of the state are in a hopeless dilemma, for even if they are sincere in wanting peace and favor disarmament it is impossible to frame enforceable disarmament agreements. If no inspection system is workable, as Teller and others have claimed, what is the practical value of test bans and treaties to outlaw weapons?

There are at least two replies to this argument. One is that of the noted German physicist Max von Laue. "Suppose," he said, "I live in a big apartment house and burglars attack me; I am allowed to defend myself and, if need be, I may even shoot, but under no circumstances may I blow up the house. It is true that to do so would be an effective defense against burglars, but the resulting evil would be much greater than any I could suffer. But what if the burglars have explosives to destroy the whole house? Then I would leave them with the responsibility for the evil, and would not contribute anything to it."

The other reply is less noble, but is no less to the point in countering the untruthful and misleading statements that have made men skeptical about the possibility of enforcing disarmament.

It is given in the Melman book, a cooperative study made at Columbia University, which provides a searching examination of inspection techniques. One of the contributors, the Columbia physicist Jay Orear, effectively refutes the claim that atomic tests can be "bootlegged." He demonstrates that a comparatively small number of monitoring stations uniformly distributed throughout the U.S.S.R. and the U. S., using the combined techniques for picking up acoustic waves, seismic waves, electromagnetic radiation and radioactivity, would constitute an adequate inspection system for test suspension. This, together with a provision that U.N. inspectors "be invited to all large chemical explosions, should make it possible," Orear says, "to detect all nuclear tests unless they are of such ultra-low yield as to be in the class of World War II blockbusters." This view is substantially the same as the one adopted by the U. S. and the U.S.S.R. at the Geneva Conference of Experts held last summer.

Some 20 papers, together with an excellent general summary by Melman, make up the Columbia report. They deal with inspection of several major classes of activities: the production of heavy weapons of a conventional type, such as tanks, artillery and trucks; ship and submarine building; aircraft, missile and fissionable-material manufacture; the preparation of biological-warfare weapons. Anyone who has thought about the problem quickly realizes that inspection of the manufacture of heavy weapons and naval vessels is relatively easy. The sheer mass of metal that must be moved and processed, the size of the plants and yards, the large labor force required—all facilitate controls. One cannot hide a whale in the backyard. Inspectors with access to major factories can ensure against large-scale evasions: the Columbia group estimates that 5,000 to 10,000 inspectors are needed for 493 ordnance and accessories plants in the U. S. This number seems high, especially in view of the multiple approach recommended for every inspection assignment; but at least it represents a feasible operation that would not interfere with normal industrial activity. Monitoring the development of biological weapons presents greater difficulties. Because their dependability as mass killers is uncertain, biological weapons are unlikely to be the first choice of countries with large stores of atom bombs; but small countries with limited laboratory and manufacturing facilities may, it is suggested, avail themselves of what is called the "poor man's atom bomb"— dispensers of virulent material. "Continuous and close attention" should therefore be given these weapons.

These, however, are essentially secondary matters. The main worry is inspection of the production of fissionables and missiles. In addition to Orear's analysis of clandestine bomb-testing, the book contains reports on the possibility of using established radiation-protection services in an inspection scheme embracing the manufacture of nuclear explosives, on the possible "theft" of fissionable materials, on inspection of missile components, propellants and guidance systems, on the "amenability of the air-borne propulsion systems industry to production inspection."

The contributors weave a pretty tight net. It is hard to imagine how any militarily significant evasion of a disarmament agreement could slip unnoticed through the inspection system here envisaged. The analysis is based entirely on publicly available information; no attempt was made to gain access to "secrets." In Melman's opinion this self-imposed limitation has given the report a "conservative bias"; that is, "more access and more knowledge might have revealed more strategic control points for inspection" and thus made possible the elimination of many points now regarded as essential.

The basic assumption is that between

200 and 400 large missiles could be used "to devastate effectively" any one of the larger land areas of the earth. A useful inspection system must cope with possible efforts to produce these weapons in clandestine ways and also with the problem of hidden inventories of arms produced before the inspection system was instituted. In Congressional hearings some years ago J. R. Oppenheimer and other witnesses made the point that enough fissionable material to devastate a city the size of New York could be toted around in a violin case. The purpose of this testimony was to point up both the danger of atomic weapons and the desperate necessity for nations getting together to prohibit their manufacture and use. But this somewhat overheated illustration had unfortunate results. Those who accepted it at face value became convinced that no inspection system would work, that disarmament was altogether unfeasible and that the only prudent course for the U. S. was to amass an enormous stockpile of weapons. The Columbia report presents a more rational perspective. The contributors do not minimize the dangers, nor do they claim that any inspection system, however searching, is without loopholes; but the report offers convincing evidence that a comprehensive scheme can probably be framed, which would make secret rearmament so extraordinarily difficult "as to be virtually impossible." An inspection system is, after all, an alarm system. It is intended to give timely warning not of minor infractions but of illegal activities on a substantial scale, for these alone carry the threat of a decisive surprise attack.

The multiple-inspection approach recommended by the Columbia group includes, among other things, aerial reconnaissance (useful to detect the production rather than the existence of missiles); analysis and auditing of government budgets; monitoring stations; checks on the whereabouts and activities of engineers and scientists; surveillance of plants producing airframes, chemicals and fissionables; inventory validation. The contributors have tried hard to foresee how ingenious men might contrive to fool the inspectors. This carries the analysis pretty far. When serious consideration is given, for example, to testing—in connection with inventory validation—the alteration of records and the age of papers and inks, the reader begins to feel as if Dick Tracy had taken over. But these are minor aberrations, more than counterbalanced by a knowledgeable and sensible treatment of the various aspects of a tricky business.

It is no small thing to question, as this book does, the validity of the ruling notion of deterrence. It is widely held, and not only by Mills's "elite," that genocidal weapons offer a reasonable guarantee of peace because no nation would deliberately commit suicide. But neither history nor social psychology unequivocally supports this opinion. People do not vote on going to war, and children are never asked. Deterrents may not deter because the deliberate judgment that is essential to the "if-we-kill-them-they'll-kill-us-so-let's-not-kill-them" sequence rarely comes into play. Small causes may have large effects; moreover the dropping of even a single nuclear weapon is manifestly more provocative than slicing off Jenkins's ear or assassinating an archduke. An accident can set a catastrophic nuclear war in motion, and as nuclear weapons are increasingly available and dispersed in more hands, the probabilities of such an accident must necessarily increase. "One aberrant, psychotic person or person gone momentarily out of control," Melman writes, "could explode nuclear weapons at a random place, or over any populated area. A space satellite could be mistaken for a ballistic missile." And when many countries possess nuclear weapons, if a warhead were set off in one city, it might be impossible to identify the aggressor and therefore even to threaten retaliation. Thus the major assumption of the mutual-deterrence strategy falls to the ground.

The best possible system of inspection techniques has weaknesses. A "foolproof" inspection system is a politician's catchword. The Melman report recognizes this truth and suggests a design to compensate for the inevitable gaps in inspection. This design, called "inspection by the people," counts upon the help of plain citizens of every country to enforce international agreements. Secret rearmament requires the participation of a large number of persons; among them there are certain to be some who are not in sympathy with the evasion efforts and who might therefore be expected to report them to the international inspectorate. Such persons must be encouraged and protected. If channels of communication from the population to the inspecting organization are always kept open, news of clandestine violations—the use of certain machines, the production of materials, the operation of prohibited processes—will almost certainly trickle through. A constant appeal urging the theme that "the international agreement is mankind's shield against mutual extermination and that a violation of this *progress report on Aeronutronic*

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OFFICE OF ADVANCED RESEARCH • SPACE TECHNOLOGY DIVISION • COMPUTER DIVISION • TACTICAL WEAPON SYSTEMS DIVISION agreement is thereby a crime against humanity" would, in Melman's view, evoke a cooperative response in every country and make untenable the position of any government, or group of officials, found guilty of breaking the law.

Can it not be said that this is the most important conclusion of the Columbia study? In a sense it links together the different approaches of Mills, Pauling, Schweitzer and others who warn and strive to educate the world before it is too late. For after assessing the causes of war, analyzing the various strategies, designing meticulous disarmament and inspection schemes, one faces the irreducible truth that we can live together or die together. It is too much to expect men all at once to throw away their weapons and embrace. But a beginning must be made, and that beginning depends, as the authors of the Melman report tell us, on conceding to each other what moral capacity we have, on having faith even in the enemy's awareness of his humanity.

"We cannot," says Schweitzer in a moving appeal broadcast from Norway last year and reprinted in his little book, "continue in this paralyzing mistrust. If we want to work our way out of the desperate situation in which we find ourselves, another spirit must enter into the people. It can only come if the awareness of its necessity suffices to give us strength to believe in its coming. We must presuppose the awareness of this need in all the peoples who have suffered along with us. We must approach them in the spirit that we are human beings, all of us, and that we feel ourselves fitted to feel with each other; to think and to will together in the same way. . . ."

Short Reviews

A HISTORY OF TECHNOLOGY, VOL. IV. THE INDUSTRIAL REVOLUTION, C. 1750–C. 1850, edited by Charles Singer, E. J. Holmyard, A. R. Hall, Trevor I. Williams. Oxford University Press ($26.90). As this splendid history moves down to modern times, both the achievement and the dilemma of the editors become more evident. The first volume spanned half a million years; the second, about two millennia; the third, two and a half centuries; and now the fourth covers the hundred years which embraced what is generally known as the Industrial Revolution. It hardly needs to be said that the present volume is worthy of its predecessors, a treat to the mind and eye. The rich variety of topics considered, the effective organization of the book, the general clarity of the exposition, the excellence and abundance of the illustrations deserve unstinted praise. Skill, learning, taste, scholarly devotion combine in these pages to yield a triumph of historical literature. Yet, as the editors themselves point out, they faced severe difficulties in preparing this installment of their survey. Primarily, of course, they had to cope with the familiar historiographer's paradox: the more there is to say, the less can be said. Thus, for example, while almost every scrap of information about technological history before 500 B.C. could be sifted and weighed, the treatment of the 18th and 19th centuries, which saw a tremendous increase in the pace of discoveries and application, necessarily involved hard problems of selection and sampling, with many topics having to be omitted and many others scanted. Moreover, as the picture becomes sharper it also becomes more complex, and the historian of science has to take on responsibilities beyond those of the digger-compiler. To many members of the profession this more challenging task is quite uncongenial, for it is cozier to work within the confines of old books and parchments than to be forced to chart a new course, to trace the development of ideas, to establish fresh historical perspectives. And there is certainly a greater risk of being proved wrong in expressing a view on the effect of Black's notion of latent heat on the development of the steam engine, or of Ampère's mathematical researches on the rise of the electrical industry, than in showing that Galileo was mistaken when he said Copernicus was a priest, or that Desargues and not Roemer was the first to advocate epicycloidal teeth for gears. A second difficulty confronting the editors lay in the fact that machines and processes had, by the time of the Industrial Revolution, ceased to be simple. A plow, a pump, a potter's wheel are easier to understand than a steam engine, a scutching and lap machine, or Earnshaw's free detent escapement. The contributors were therefore obliged to find a satisfactory compromise between over-simplification and suffocation by detail. In the main they have succeeded, so that the average reader not only gains a sense of the astonishing sweep of technological advance, but learns a good deal about the wonderfully ingenious devices and principles which poured forth during the period and revolutionized man's way of life. Among the conspicuously effective chapters are those on metal- and coal-mining; the extraction and production of iron, steel and nonferrous

Dr. John F. Brown, Jr., graduated from Brown University in 1947 and received his Ph.D. at Massachusetts Institute of Technology in 1950. Since then he has been an organic chemist at the General Electric Research Laboratory, where he now serves as manager of the reaction-studies unit.

Lock-and-key chemistry

General Electric's Dr. John F. Brown, Jr., seeks ways to put molecules together in specific patterns

"It is distressing," says chemist John F. Brown, Jr., "to know that even the lowliest amoeba is much better at performing chemical syntheses than the chemist is. The big difference between nature's chemistry and man's is the ability—or lack of it—to fit things together precisely."

At the General Electric Research Laboratory, Dr. Brown and his associates are exploring a variety of unusual techniques for making organic molecules fit together as a key fits a lock. An example is their work with canal complexes, strange organic crystal structures much like a honeycomb. When the "honey" is polymerized—linked together—the regular walls of the honeycomb serve as "molecular templates," forming a polymer with precise and ordered structure.

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metals; the steam engine; watermills; the chemical industry; gas for light and heat, the textile industry; precision mechanics, building and civil-engineering construction; roads; canals; telegraphy. Each of these presentations is lucid, interesting, well-planned. The final chapter discusses the beginning of the change from craft to science as a basis for technology. One of the major questions in surveying this period is how to separate and distinguish the interacting elements of technological growth. In some industries and activities scientific understanding contributed to development; in others accumulated experience and the imagination of gifted craftsmen rather than scientific theory were the major factors. ("Until 1850," L. J. Henderson said, "the steam engine did more for science than science did for the steam engine.") The contributors have tried to identify these different elements, a task essential to a proper historical analysis; unfortunately they have not been able to discuss at any length the even more important questions of the social, economic and political circumstances surrounding the advance of technology.

LOGIC MACHINES AND DIAGRAMS, by Martin Gardner. McGraw-Hill Book Company, Inc. ($5). A brief history of the methods and machines that men have designed to solve problems of formal logic. Until comparatively recently such devices were either mere intellectual toys or were intended to facilitate the study of the principles and mechanics of reliable inference. But with the development of automata and computers many technical problems have arisen that involve difficult logical transformations. Thus, for example, electronic calculators often need a built-in logic unit to direct their operations. Gardner describes the absurd invention of the Spanish mystic Raimon Lull, which by a generous stretch of imagination might be regarded as a primitive logic machine; the famous logic diagrams of John Venn; the related work in symbolic logic of Augustus De Morgan, Charles Peirce and Lewis Carroll; the Stanhope Demonstrator, Jevons's Logic Machine, the Marquand Machine—ingenious but crude engines that were capable of answering the sort of question that any experienced logician could have answered more quickly out of his head; and the electrical logical machines, which first appeared about 10 years ago. This is an interesting book on an intriguing subject, but the author seems to have been undecided as to the audience he was aiming at, with the result that the treatment of certain topics presupposes an acquaintance with graduate mathematics, while other parts of the exposition are at a quite elementary level.

THE DECIPHERMENT OF LINEAR B, by John Chadwick. Cambridge University Press ($3.75). The late Michael Ventris described the decipherment of Linear B, the strange and baffling writing inscribed on the clay tablets found at Mycenean cities in Greece and Crete, in the first two chapters of the book he wrote jointly with Chadwick (*Documents in Mycenean Greek*), which was reviewed in these columns two years ago. The story is here told again for the general reader with most of the technical details omitted, but in other respects more fully so as to present the background and to give some notion of the actual steps of the decipherment. It was a remarkable feat, combining trial and error, inspired guesswork and logic, an intellectual assault which would have dazzled even Sherlock Holmes's condescending brother Mycroft. Chadwick makes a most interesting and valiant effort to make it understandable, a task whose difficulty may be judged from the fact that not a few experts resisted Ventris' decipherment because he was unable to explain to them how he had got his results. Still, even the "Greek-less" reader will enjoy following Ventris' conduct of the campaign, and an imperfect grasp of how each advance follows from the preceding one will not mar one's satisfaction over the final triumph.

THE WORLD OF BUTTERFLIES AND MOTHS, by Alexander B. Klots. McGraw-Hill Book Company, Inc. ($15). A leading U. S. entomologist describes the forms and colors of butterflies and moths, their ancestry and relationships, how they moult and grow, their egg-laying habits, their larvae and pupation, their diet and relations with plants and animals, their specialized senses, social behavior, courtship and mating, their distribution, their place in man's economy. The book is illustrated with 180 photographs, 37 in color. Some of the black-and-whites are excellent but the color photographs are, with a few exceptions, mediocre.

A FIELD GUIDE TO REPTILES AND AMPHIBIANS OF EASTERN NORTH AMERICA, by Roger Conant. Houghton Mifflin Company ($3.95). Another compact guide in this useful series. The text gives the essential facts for the amateur naturalist, and there are more than 1,100 illustrations (400 in color) of species of turtles, crocodiles, alligators, lizards, snakes, salamanders, newts, frogs and toads found in the U. S. and Canada east of the 100th meridian.

LIVING BIRDS OF THE WORLD, by E. Thomas Gilliard. Doubleday and Company ($12.50). A readable, authoritative and representative survey of the world's birds by the associate curator of birds in the American Museum of Natural History. Almost 1,500 of the 8,600 species of birds are described as to general characteristics, relationships, distribution and habits; 400 photographs, of which more than 200 are in color, support the ample text. Among the remarkable creatures and characteristics reported by Gilliard are these: The Madagascar elephant bird, now extinct, that laid a two-gallon egg and weighed 1,000 pounds; the coot that carries half a ton of rocks to build an island on which to lay its eggs; the skimmer that marks the water with a file of glowing animal life to lure its prey; the frogmouth that mimics a flower and eats the insects that come to visit it; the birds that live in groups with migratory locusts; the use of mass fainting as a defense; the birds that paint their plumage with a pink pigment during the nuptial season. This is the best all-around book of its kind in English, and a bargain in today's market.

LISTENING IN THE DARK, by Donald R. Griffin. Yale University Press ($7.50). Based on the Trumbull Lectures delivered at Yale University, this book presents a full account of the researches on echolocation in animals. The first scientific studies of how bats find their way in the dark were made by the 18th-century Italian naturalist Lazaro Spallanzani. After many brilliant experiments he advanced the hypothesis that the sound of the bat's wing as it moved through the air was reflected from obstacles, stimulated the bat's ear and formed the basis of its ability to navigate. He was, however, unable fully to confirm this idea. At the beginning of the present century Sir Hiram S. Maxim, without knowing of Spallanzani's work, made a similar suggestion. The English physiologist H. Hartridge furthered understanding of the problem in putting forward the possibility that bats might use sounds of high frequency and short wavelength; and Griffin himself, in a long and masterly series of investigations, finally solved the question by demonstrating that bats in flight emit pulses of high-frequency sound, whose echoes enable them to locate their insect prey and "hear their way." Griffin re-

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counts the work of earlier investigators, describes in great detail the combined zoological, neurophysiological and acoustical studies that led to the discovery of echolocation, and considers the bearing of this discovery on the remarkable ability of the blind to sense obstacles and avoid collisions. (It is quite possible, he makes clear, that this ability can be further developed by devising methods based on what has been learned about bats.) This is a fine book that, despite many technical chapters, holds much of interest for the ordinary reader. It tells a fascinating natural-history story, but more than that, it gives a remarkably clear picture of a complete episode of the creative process in science: the false starts, the clever but inadequate hypotheses that have to be reshaped again and again, the long, wearisome field observations and laboratory experiments, the breakthrough to a fresh insight, and the many new questions raised by each forward step that provide the impetus to further study and breathe life into science.

THE BIRDS OF THE BRITISH ISLES, VOL. VII, by David Armitage Bannerman. Oliver and Boyd (63 shillings). This delightful work, which when complete will be the most authoritative and comprehensive guide to British birds, now passes the half-way stage with a volume devoted to 32 species of diving ducks and dabbling or surface-feeding ducks. The subjects include the mallard, gadwall, teal, garganey, wigeon, pintail, shoveler, pochard, goldeneye, eider, scoter, goosander, merganser and smew, and the white-eyed, tufted, ring-necked, buffle-headed, long-tailed, harlequin and scaup ducks. The essays are readable, leisurely, unwearied and amazingly wide-ranging in their coverage of sources; the late George E. Lodge's paintings are as lovely as ever. Bannerman is simply a marvel in spinning off this great book in his retirement after 40 years of prodigious professional industry at the British Museum; and, if this were not enough, he has recently completed jointly with his wife another work: *The Birds of Cyprus.* "Our days," he says, "have not been idle, and we have learned a great deal that we did not know before."

Notes

STUDIES ON FOSSIL VERTEBRATES, edited by T. Stanley Westoll. Essential Books ($5.60). A collection of essays on vertebrate paleontology presented to D. M. S. Watson, noted zoologist and

comparative anatomist, on the occasion of his retirement from the University of London.

THE BACKGROUND OF ASTRONOMY, by Henry C. King. George Braziller, Inc. ($5). A brief popular history of astronomy from its obscure beginnings in the Near East to its position at the close of the 16th century in Western Europe.

THE EARTH AND ITS GRAVITY FIELD, by W. A. Heiskanen and F. A. Vening Meinesz. McGraw-Hill Book Company, Inc. ($12.50). An advanced monograph on the earth's gravity field and related subjects, that presents, among other things, new conclusions about the way the earth tends toward equilibrium and the character and size of the deviations from this equilibrium, based on researches carried out by several workers, particularly by the authors, during the last three decades.

A TREATISE ON THE ANALYTIC GEOMETRY OF THREE DIMENSIONS, by George Salmon. Chelsea Publishing Company ($4.75). A reissue of the seventh edition of Volume I of a noted mathematical work. Chelsea continues year after year to reprint in attractive format useful but out-of-print mathematics books, and to offer them at a reasonable price, a program that deserves notice.

FROM APE TO ANGEL, by H. R. Hays. Alfred A. Knopf, Inc. ($7.50). A somewhat galloping but not uninteresting history of social anthropology from Schoolcraft, Morgan, Lubbock, Tylor and Frazer to Malinowski, Boas, Bateson, Benedict, Dollard, Mead, *et al.* Too much is jammed into these 400 pages; even the most colorful and varied material is hard to take in such a rush.

THE MARCH OF ARCHAEOLOGY, by C. W. Ceram. Alfred A. Knopf, Inc. ($15). A colorful picture-book counterpart of the author's *Gods, Graves and Scholars.* A number of the illustrations are very good, and the relatively brief, easy text that is keyed to the pictures will enable even the tired reader to follow some of the major sequences of archaeological discovery without strain.

LINEAR OPERATORS, PART I: GENERAL THEORY, by Nelson Dunford and Jacob T. Schwartz. Interscience Publishers, Inc. ($23). The first part of a comprehensive survey of the general theory of linear operators, together with a survey of the application of this theory to the diverse fields of more classical analysis.

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BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful.

REACTOR FUEL ELEMENTS

MANUFACTURE OF FUEL PLATES FOR EXPERIMENTAL BOILING WATER REACTOR. R. E. Macherey, C. H. Bean, N. J. Carson, Jr. and J. R. Lindgren in Argonne National Laboratory Report ANL-5629, 1957.

MANUFACTURE OF THE ThO_2-UO_2 CERAMIC FUEL PELLETS FOR BORAX-IV. J. H. Handwerk, C. L. Hoenig and R. C. Lied in Argonne National Laboratory Report ANL-5678, 1957.

NUCLEAR REACTOR METALLURGY. Walter D. Wilkinson and William F. Murphy. D. Van Nostrand Company, Inc., 1958.

THE CIRCULATORY SYSTEM OF PLANTS

ABSORPTION AND TRANSLOCATION OF PLANT REGULATING COMPOUNDS. John W. Mitchell and Paul J. Linder in *Atomic Energy and Agriculture*. American Association for the Advancement of Science, 1957.

THE TRANSLOCATION OF MINERALS IN PLANTS. O. Biddulph in *Mineral Nutrition of Plants*. The University of Wisconsin Press, 1951.

THE TRANSLOCATION OF ORGANIC NUTRIENTS IN PLANTS. C. A. Swanson in *Atomic Energy and Agriculture*. American Association for the Advancement of Science, 1957.

THE PERCEPTION OF THE UPRIGHT

PERCEPTION AND PERSONALITY: A SYMPOSIUM. Edited by Jerome S. Bruner and David Krech. Duke University Press, 1950.

PERSONALITY THROUGH PERCEPTION. AN EXPERIMENTAL AND CLINICAL STUDY. H. A. Witkin and others. Harper & Brothers, 1954.

ALFRED RUSSEL WALLACE

ALFRED RUSSEL WALLACE: LETTERS AND REMINISCENCES. James Marchant. Harper & Brothers, 1916.

DARWIN'S CENTURY. Loren Eiseley. Doubleday & Company, Inc., 1958.

MY LIFE: A RECORD OF EVENTS AND OPINIONS. Alfred Russel Wallace. Dodd, Mead and Co., 1905.

A VOYAGE UP THE RIVER AMAZON, INCLUDING A RESIDENCE AT PARÁ. William H. Edwards. D. Appleton & Co., 1847.

ENTEROVIRUSES

THE COXSACKIE GROUP. Joseph L. Melnick and Edward C. Curnen in *Viral and Rickettsial Infections of Man*. J. B. Lippincott Co., 1952.

THE ENTEROVIRUSES. *American Journal of Public Health*, Vol. 47, No. 12, pages 1,556-1,566; December, 1957.

A STUDY OF CERTAIN NONPOLIOMYELITIS AND POLIOMYELITIS ENTEROVIRUS INFECTIONS. William McD. Hammon, David S. Yohn, Ernest H. Ludwig, Rose A. Pavia, Gladys E. Sather and Lambert W. McCloskey in *The Journal of the American Medical Association*, Vol. 167, No. 6, pages 727-734; July 7, 1958.

METAMORPHOSIS, POLYMORPHISM, DIFFERENTIATION

THE PHYSIOLOGY OF INSECT METAMORPHOSIS. V. B. Wigglesworth. Cambridge University Press, 1954.

HOW WATER FREEZES

THE FORMS OF WATER. John Tyndall. Interscience Publishers, Inc., 1872.

GROWTH AND PERFECTION OF CRYSTALS. Edited by R. H. Doremus, B. W. Roberts and David Turnbull. John Wiley & Sons, Inc., 1958.

NUCLEATION. J. H. Hollomon and D. Turnbull in *Progress in Metal Physics*, Vol. 4, pages 333-386; Pergamon Press, 1953.

PIDGIN LANGUAGES

HANDS OFF PIDGIN ENGLISH! Robert A. Hall, Jr. Pacific Publications Pty., Ltd., 1955.

MATHEMATICAL GAMES

101 PUZZLES IN THOUGHT AND LOGIC. Clarence Raymond Wylie, Jr. Dover Publications, Inc., 1957.

QUESTION TIME. Hubert Phillips. Farrar and Rinehart Incorporated, 1938.

THE AMATEUR SCIENTIST

AN INTRODUCTION TO THE STUDY OF FOSSILS. Hervey Woodburn Shimer. The Macmillan Company, 1933.

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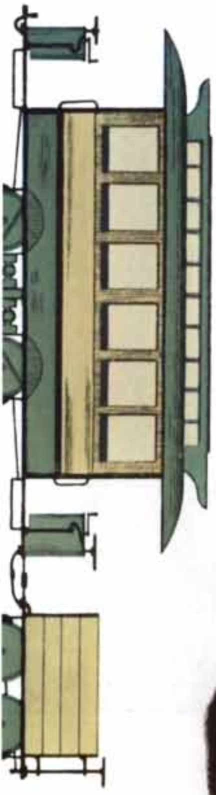

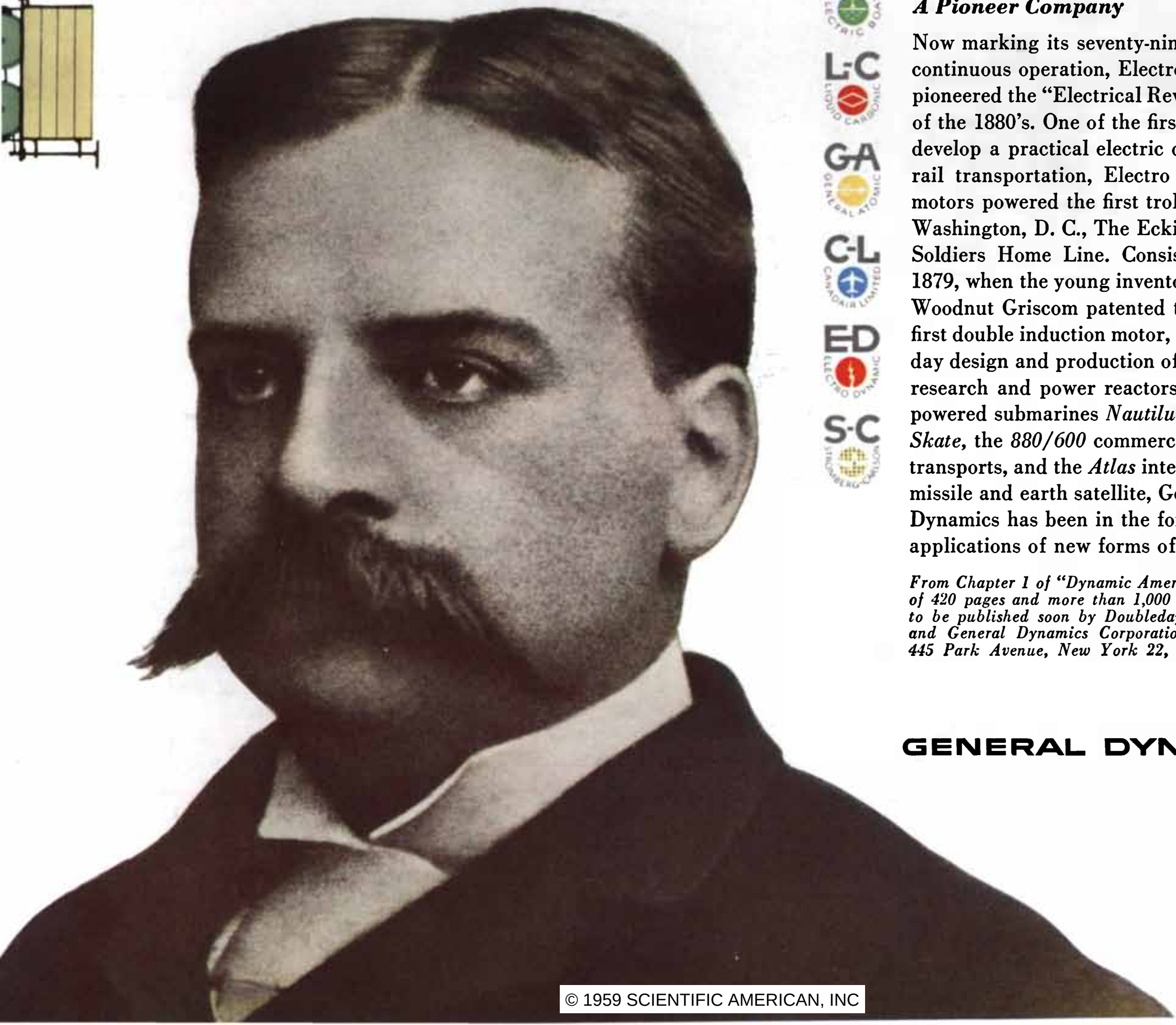

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