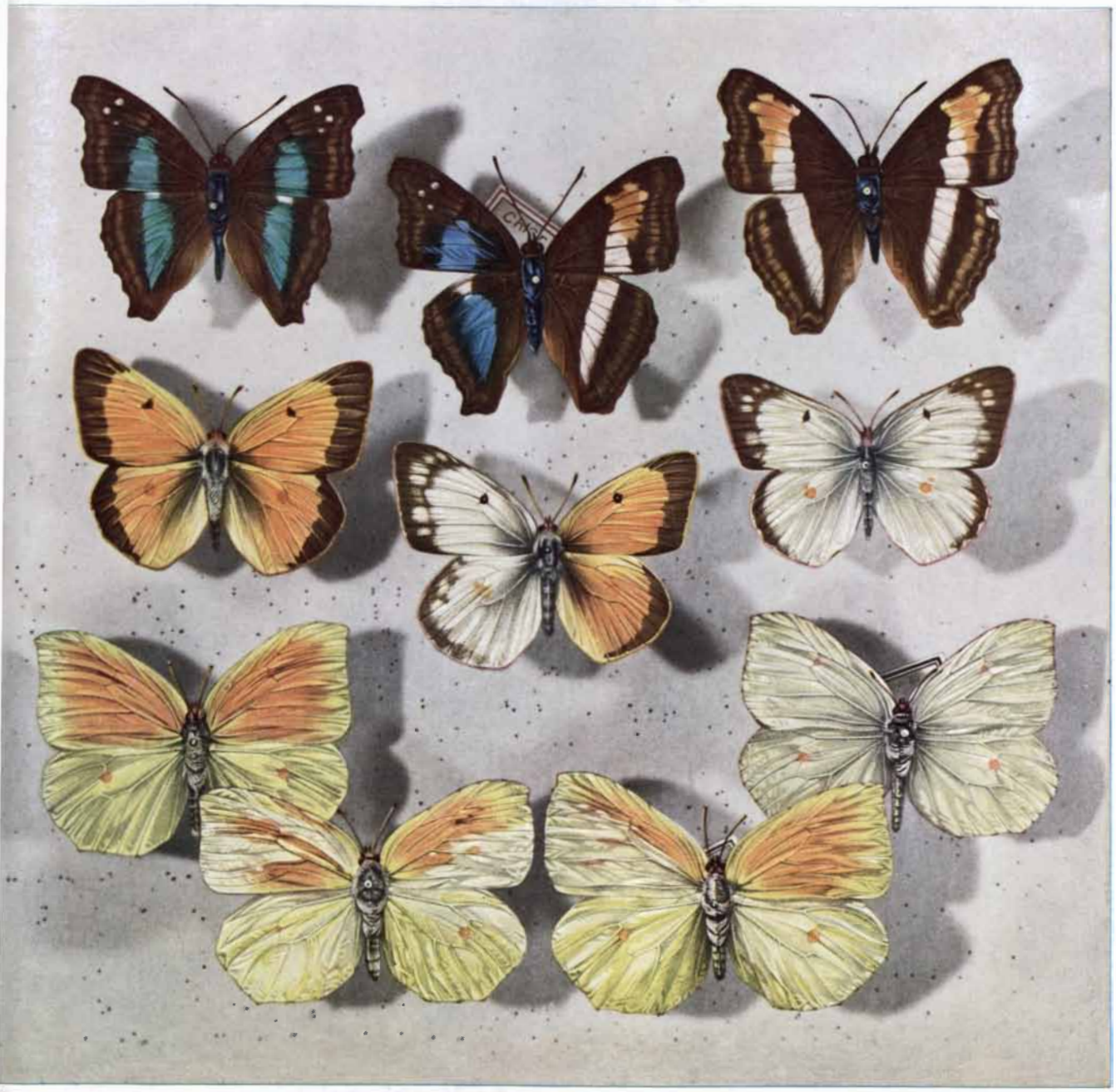
SCIENTIFIC AMERICAN



GENETIC MOSAICS

FIFTY CENTS

May 1960

Amazing new mower works under water

When underwater plants clogged irrigation ditches, farmers used to drag iron chains through them to get water to thirsty crops.

Now "chaining the ditch" has been replaced by Shell Chemical's new killer of aquatic weeds, *Aqualin*® herbicide. Added to irrigation water, Aqualin destroys submersed weeds and algae that choke off water flow . . . dead plants disintegrate and float away.

With Aqualin herbicide to help keep irrigation channels free from weeds and algae, Shell Chemical solves another problem for the modern farmer.

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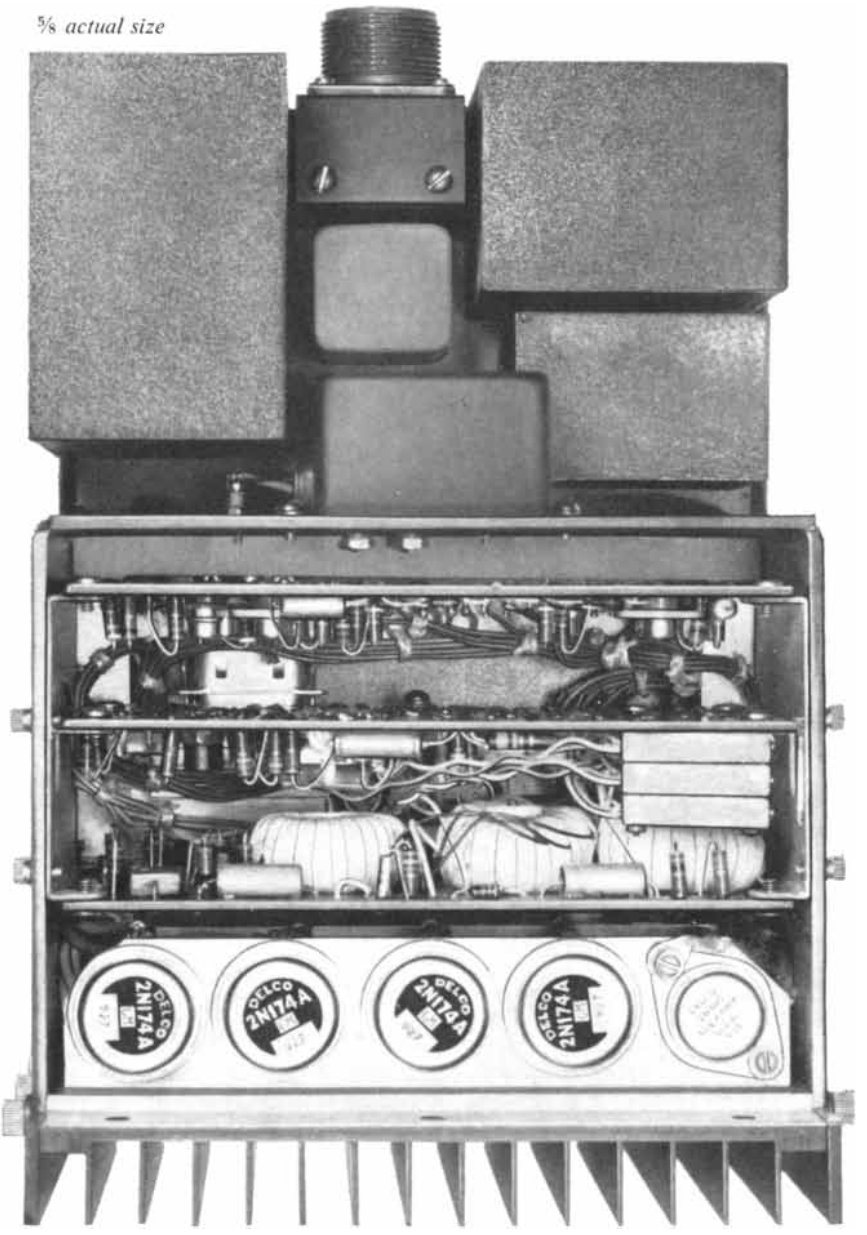
NEW YORK

SHELL



FROM DELCO RADIO NEW IDEAS FOR DEFENSE

HIGH CAPACITY STATIC INVERTERS WITH NO MOVING PARTS

Delco Radio's high capacity Static Inverters and Converters fill a critical need in missile guidance and control—offering extremely reliable, very highly regulated power of precise frequency. The Static Inverters use direct crystal-frequency control and digital logic circuits to produce accurate, single or polyphase power output. They have no moving parts. There is nothing that can get out of adjustment. Electrical characteristics are: High Capacity—150 to 4,000 volt-amperes. High Efficiency—65 to 90% depending on power and control (precision and regulation) required. Accurate Phase Angle Control—to 0.5 degree. Precise Frequency Control—up to 6 parts per million maximum variation under all load and environmental conditions. Voltage Amplitude Control—to ±1% no load to full load. Low Distortion—typically 2% total harmonic distortion. Delco Radio has developed and produced power supplies for missiles such as the Air Force's Ballistic Intermediate Range Thor, Intercontinental Titan, and the pilotless aircraft Mace. For further information on military electronics, write to our Sales Department. *Physicists and electronics engineers: Join Delco Radio's search for new and better products through Solid State Physics.*

PIONEERING PRECISION PRODUCTS THROUGH SOLID STATE PHYSICS

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INDEPENDABILITY
RELIABILITY

Division of General Motors • Kokomo, Indiana

THESE MEN BUILT THE PERMACHON . . . NOW, WHAT CAN THEY DO FOR YOU?

These are some of the men responsible for developing the Westinghouse Permachon, an amazing new television camera tube with a "memory". The Permachon "freezes" whatever it sees, and stores the image to allow detailed study or photographing.

Its applications are exciting. The Permachon will replace photo-finish equipment by eliminating the wait for film development. Television shows can be "frozen" while the director studies the staging of a scene. It can store fluoroscopic X-ray pictures, aid immeasurably in air-traffic control, and permit detailed study of weather radar scopes.

The talented team of engineers who developed the Permachon pick up their paychecks from Westinghouse, but they're really working for you. They belong to a special group of Westinghouse "idea men", available to you at any time, for creative engineering and advice on any product. Call on them next time you need help. In a hurry? Write, wire, or telephone right now: Westinghouse, Elmira, N.Y. Phone: REgent 9-3611.

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

Westinghouse Electronic Tube Division, Elmira, N.Y.

Established 1845 **SCIENTIFIC AMERICAN** May, 1960 Volume 202 Number 5

ARTICLES

DEPARTMENTS

PUBLISHED MONTHLY BY SCIENTIFIC AMERICAN, INC., 415 MADISON AVENUE, NEW YORK 17, N. Y. SECOND CLASS POSTAGE PAID AT NEW YORK, N. Y., AND AT ADDITIONAL MAILING OFFICES. SUBSCRIPTION RATE $6 PER YEAR.

THE COVER

In the painting on the cover are specimens of three species of butterfly. Four of the specimens are rare "gynandromorphs": mosaics of male and female tissue [*see page 118*]. At top left is the normal male of *Chlorippe seraphina;* at top right is the normal female. Between them is a gynandromorph of the same species. Its left side has male coloration; its right side, female coloration. At middle left is the normal male of the sulfur butterfly (*Colias eurytheme*); at middle right is the normal female. Between them is a gynandromorph of that species. At bottom left is the normal male of *Gonepteryx cleopatra linnaeus;* at bottom right is the normal female. The two specimens between them represent a different kind of gynandromorph in which the male and female tissues are irregularly distributed. Gynandromorphs result from differences in the hereditary constitution of the cells that make up an organism. The change in constitution occurs either at the time of fertilization or after the organism has begun to develop. The specimens of *G. cleopatra linnaeus* are in the American Museum of Natural History; the other specimens are in the Peabody Museum of Yale University.

THE ILLUSTRATIONS

Cover painting by Rudolf Freund

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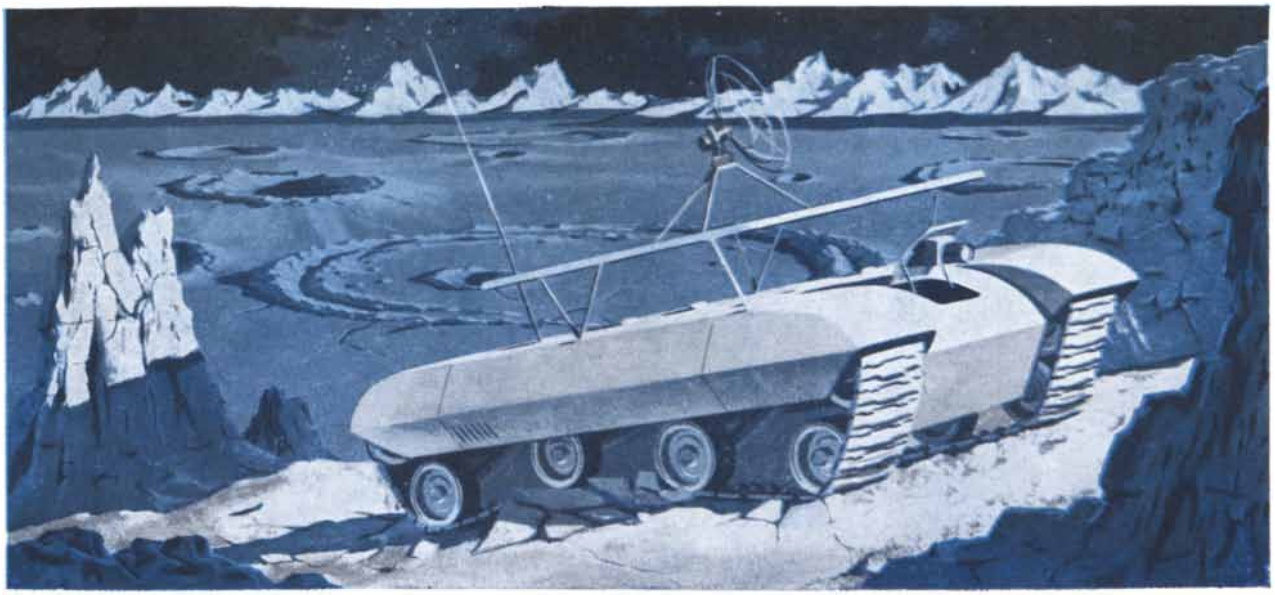

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solving the exotic problem in systems design

WESTERN GEAR Systems Management can give you a useful assist on your major programs. Thinking about exploratory gear for the moon—or to probe the secrets of the deep? Even if your exotic problem isn't quite that far out or quite that deep today, now is a good time to acquaint yourself with the men of Western Gear's Systems Management group. From conception to co-ordination of engineering activities, they can provide the invaluable assistance that speeds you to the solution of the exotic problem.

Need propulsion gear that achieves "impossible" sound levels? A gear drive that functions at a fierce 1000°F? A drive rated at several horsepower that fits in the palm of your hand? Rotative speeds approaching that of sound? Backed by deep-strength in R & D, the imaginative men of Western Gear's Systems Management Division have a way of making realities out of today's—or tomorrow's—impossibilities. To consult them on your exotic product or system, call on our sales engineer or write Systems Management Division, P.O. Box 182, Lynwood, California.

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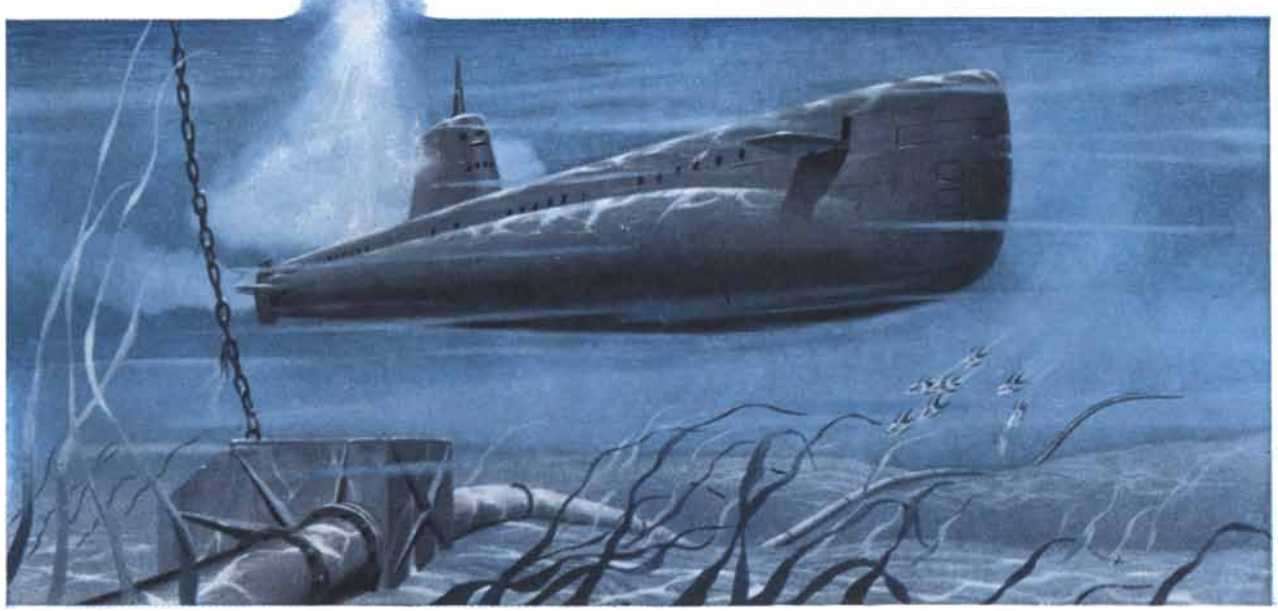
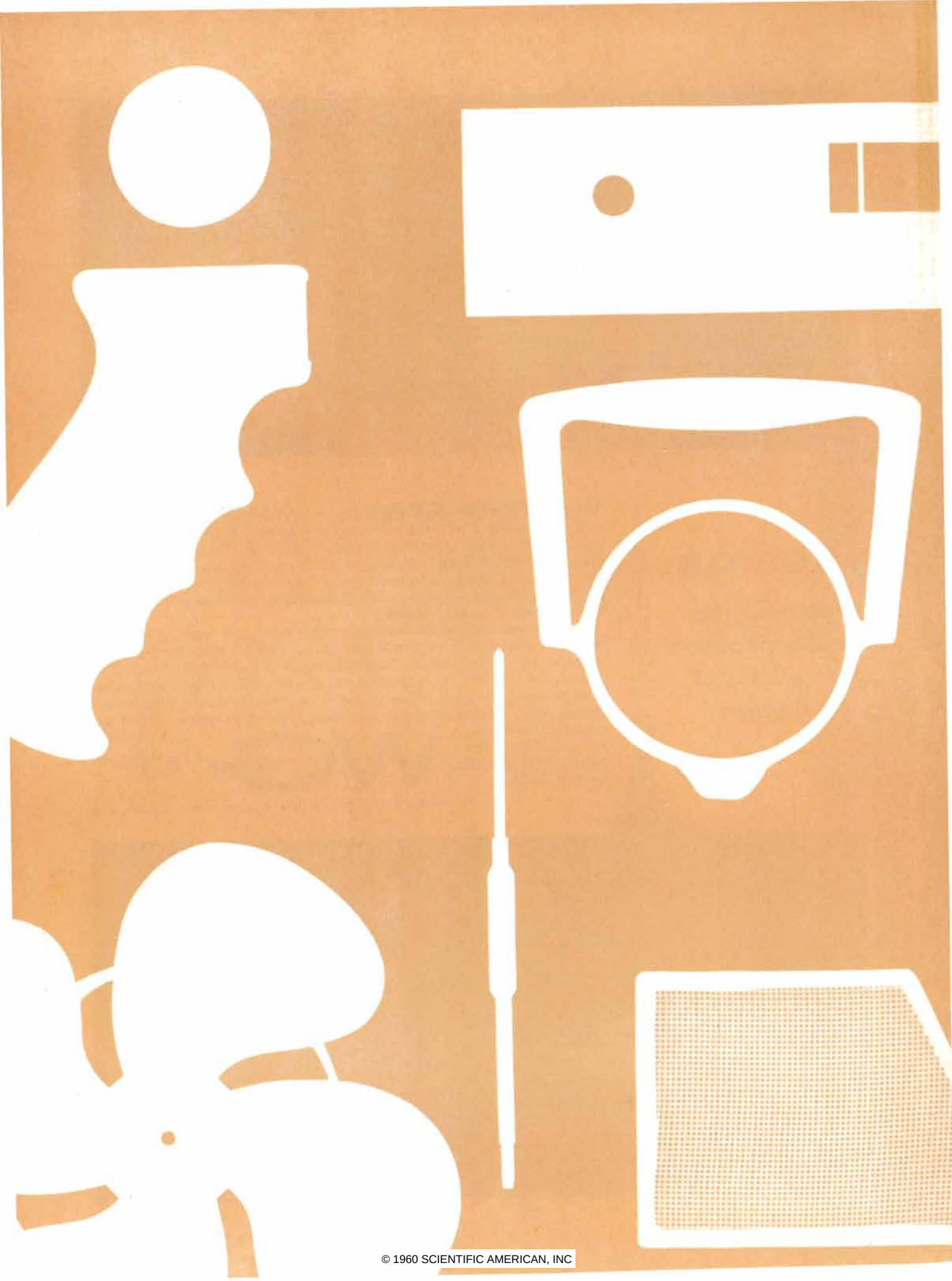




What 3 things do these parts have in common?

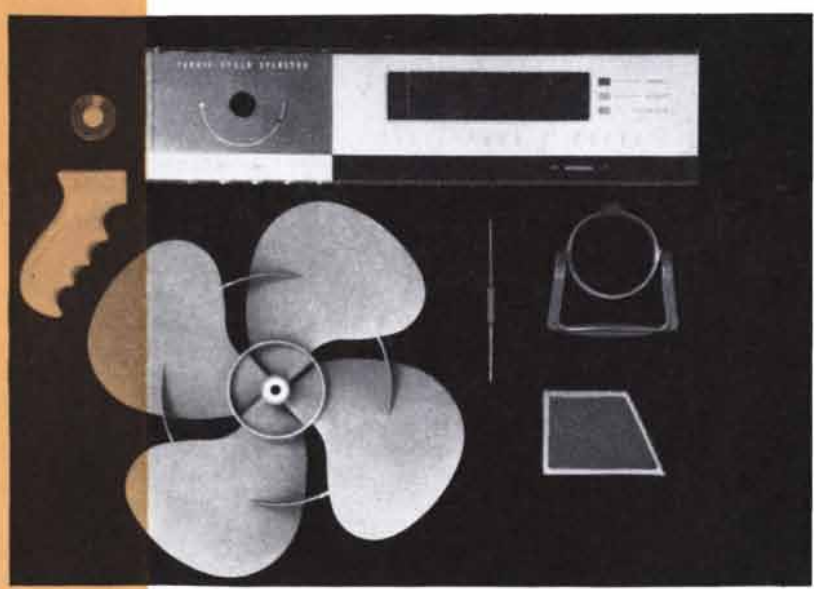
They perform better. Yet they cost less. And they are all molded of plastics.

The exhaust fan blades have a molded-in metal bearing, and are unaffected by corrosive fumes. The washing machine filter not only costs less to make, it also licked a rust problem. The one-piece phonograph spindle cap simplified a complicated assembly, while maintaining tolerances of +.003 and −.000.

The jewelers' screw driver, the pistol grip tool handle, the dryer control panel, and the milk bottle handle are all low cost product improvements, made possible by the ever-widening choice of plastics materials and the growing efficiencies of custom molders.

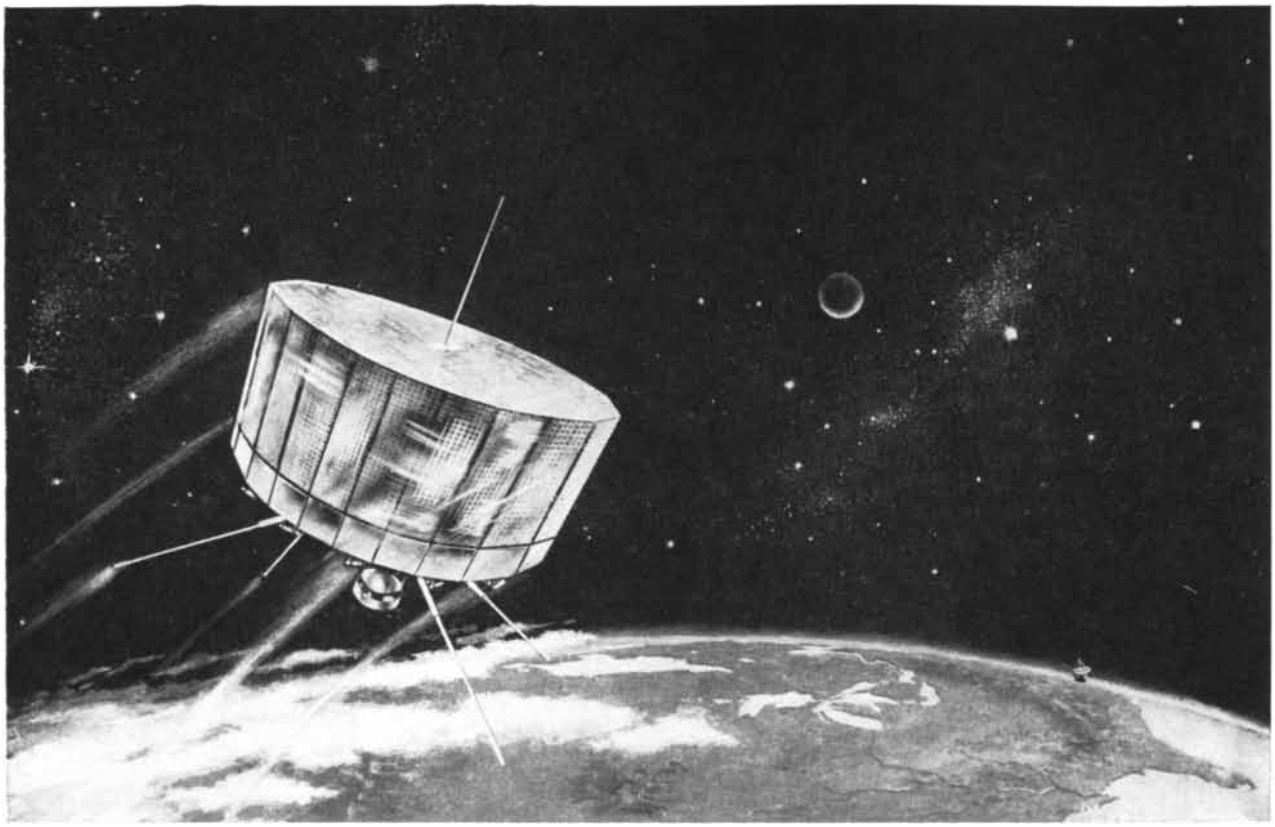
Think of the custom molder of plastics as the "manufacturer's manufacturer." His engineering staff measures the product for plastics. His tool-makers build the master molds to close tolerances. His manufacturing facilities produce the most complex parts with consistent quality, at rates to meet the tightest schedules and budgets.

Monsanto, supplier of plastics molding compounds to leading custom molders, has prepared a special report on "How To Buy Custom Molded Plastics." Write for your free copy to Monsanto Chemical Company, Plastics Division, Room 710, Springfield 2, Mass.



MONSANTO PACE-SETTER IN **PLASTICS**

Monsanto



TIROS satellite orbiting towards ground station in Eastern United States.

RCA-BUILT "TIROS" SATELLITE REPORTS WORLD'S WEATHER FROM OUTER SPACE

As you read these lines, the most remarkable "weather reporter" the world has ever known hurtles around our globe many times a day, hundreds of miles up in outer space.

The TIROS satellite is an orbiting television system. Its mission is to televise cloud formations within a belt several thousand miles wide around the earth and transmit a series of pictures back to special ground stations. Weather forecasters can then locate storms in the making . . . to help make tomorrow's weather forecast more accurate than ever.

The success of experimental Project TIROS opens the door to a new era in weather forecasting—with benefits to people of all lands. This experiment may lead to advanced weather satellites which can provide weathermen with hour-by-hour reports of cloud cover prevailing over the entire world. Weather forecasts, based on these observations, may then give ample time to prepare for floods, hurricanes, tornadoes, typhoons and blizzards—time which can be used to minimize damage and save lives.

Many extremely "sophisticated" techniques and devices were required to make *Project TIROS* a success—two lightweight satellite television cameras, an infra-red horizon-locating system, complex receiving and transmitting equipment, and a solar power supply that collects its energy from the sun itself. In addition to the design and development of the actual satellite, scientists and engineers at RCA's "Space Center" were responsible for the development and construction of a vast array of equipment for the earth-based data processing and command stations.

Project TIROS was sponsored by the National Aeronautics and Space Administration. The satellite payload and ground station equipment were developed and built by the Astro-Electronic Products Division of RCA, under the technical direction of the U. S. Army Signal Research and Development Laboratory.

The same electronic skills which made possible the success of man's most advanced weather satellite are embodied in all RCA products—RCA Victor black & white and color television sets, radio and high-fidelity systems enjoyed in millions of American homes.

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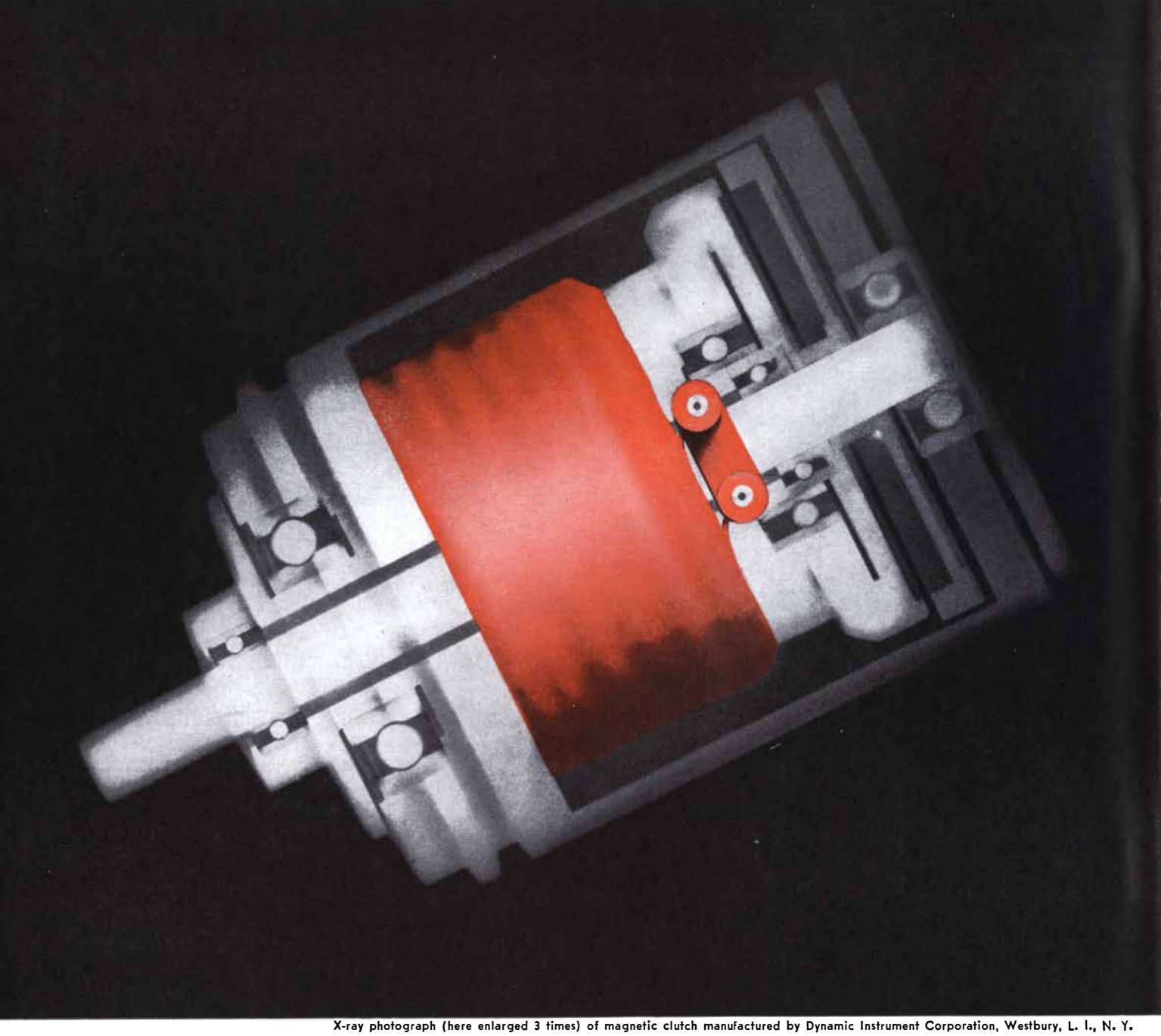

X-ray photograph (here enlarged 3 times) of magnetic clutch manufactured by Dynamic Instrument Corporation, Westbury, L. I., N. Y.

THE INSIDE STORY: magnetic-clutch terminals that hold tight

The feed-through terminals on magnetic clutches and clutch brakes don't have an easy time of it. With very little space for attachment, conventional terminals are prone to pop out and rotate under torque. Terminals must withstand 500 volts potential between the case and terminal, and operate continuously at 400°F. The answer? New, melt-processible TEFLON FEP-fluorocarbon resin. The two terminals are molded together of FEP resin and inserted from the inside of the case. This new member of the family of TEFLON fluorocarbon resins provides all the necessary insulating, thermal, mechanical and fabrication properties. Inside the potted case, where temperatures run higher, wires are insulated with TEFLON TFE resins for utmost reliability.

In addition to the properties demonstrated in this application, TEFLON resins — both FEP and TFE — offer remarkably low friction and almost universal chemical inertness.

If you would like to find out more about how TEFLON fluorocarbon resins make possible improved mechanical and electrical designs, send for your copy of a booklet describing in detail the unique engineering properties of these resins. Write to: E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room T395, Du Pont Building, Wilmington 98, Del. *In Canada:* Du Pont of Canada Limited, Box 660, Montreal, Quebec.

DU PONT REG. U. S. PAT. OFF.

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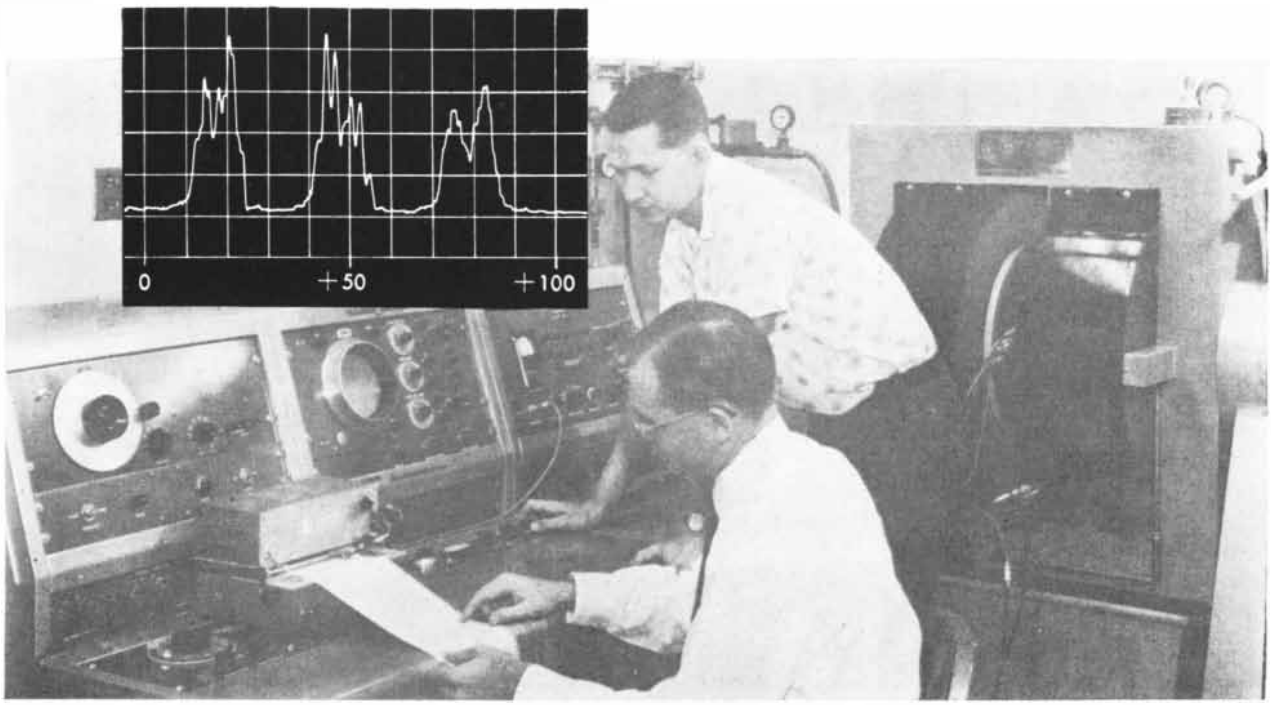
FLUOROCARBON RESINS

TEFLON is Du Pont's registered trademark for its family of fluorocarbon resins, including TFE (tetrafluoroethylene) resins and FEP (fluorinated ethylene) resin.

BETTER THINGS FOR BETTER LIVING...*THROUGH CHEMISTRY*

CREATIVE INSIGHT



The ability to apply basic physical principles and utilize new-found scientific knowledge has characterized Varian accomplishments ever since its klystron tube inaugurated the era of microwave electronics. An example is the Varian NMR Spectrometer, which applies the phenomenon of nuclear magnetic resonance to determine the subtlest details of molecular structure.

The original Nobel-Prize-Winning discovery permitted observance only of broad single peaks which, while useful in identifying isotopes, yielded no clear chemical information concerning the molecule. The Varian 60 megacycle high resolution NMR Spectrometer which evolved from this phenomenon is capable of observing spectral differences of one part in 100,000,000, providing a signal consisting of dozens of sharp peaks representing, for example, hydrogen atoms situated in the various chemical environments within the molecule.

Other examples of Varian's creative insight and foresight are the Vaclon Pump which uses an electro-magnetic interaction to achieve vacuums to a trillionth of an atmosphere . . . the 100 kc Electron Paramagnetic Resonance (EPR) Spectrometer which uses unpaired electrons as "spies" to probe the basic mechanisms of chemistry (and life) . . . and a miniaturized magnetometer using proton precession to measure the earth's magnetic field from a globe-circling Vanguard Satellite.

This creative insight and Varian's "science of practicality" — the ability to put prototypes of complex equipment into quantity production — have accounted for Varian's rapid growth and its reputation for products of unequalled performance and reliability.

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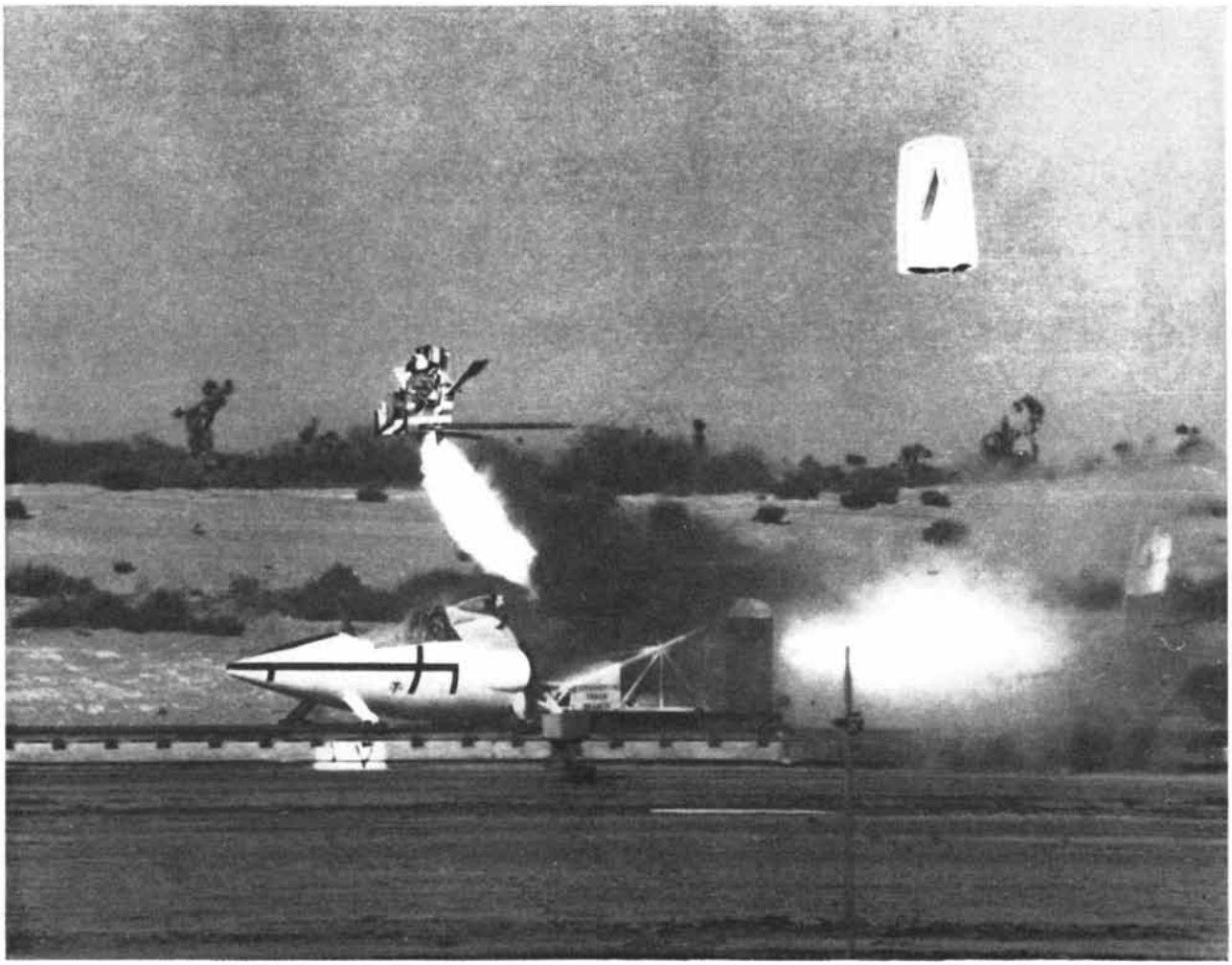
WHEN YOU WANT TO SPLIT SECONDS

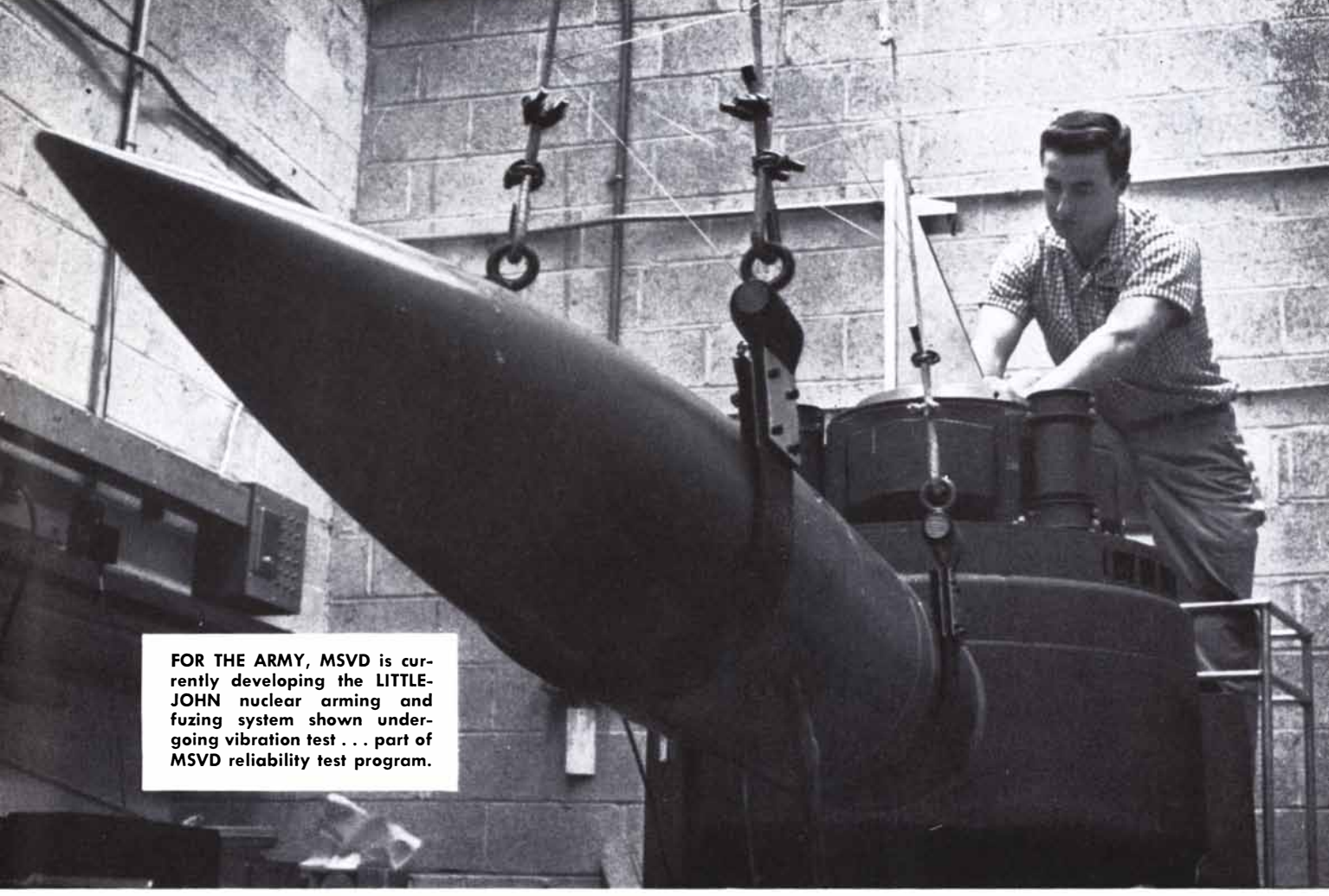
You may be designing a new aircraft ejection seat . . . or a better high speed camera . . . or a more accurate precision timing device. *Whatever* you design, if it calls for precision ball bearings, Fafnir has what you need. For example, if your product needs miniature bearings, the Fafnir line includes all popular types and sizes . . . flanged and unflanged bearings, shielded types (with one or two shields), as well as unshielded bearings — all available in bore sizes from $\frac{3}{32}$" (.0937) to $\frac{1}{4}$" (.2500). For miniature ball bearings — for *any* precision ball bearings you need — look to Fafnir. Write The Fafnir Bearing Company, New Britain, Connecticut.

Fafnir Precision Miniature Ball Bearings were among the first to be manufactured of extra-clean, vacuum-melt 440C stainless steel to insure a minimum of impurities, and to eliminate chances of pits or imperfections in balls and races. The ultimate results are super-sensitive bearings offering low torque values.



SUPERSONIC TESTING OF AUTOMATIC EJECTION SEAT FOR NORTH AMERICAN'S X-15

FAFNIR
BALL BEARINGS



FOR THE ARMY, MSVD is currently developing the LITTLE-JOHN nuclear arming and fuzing system shown undergoing vibration test . . . part of MSVD reliability test program.

MISSILE AND SPACE VEHICLE DEPARTMENT

...center for missile and space technology research and development at General Electric

Progress in arming and fuzing

With this nation's growing arsenal of strategic and tactical missiles, increasing emphasis is being placed upon the development of more sophisticated safing, arming and fuzing systems.

General Electric's Missile and Space Vehicle Department was the first industrial contractor selected by U.S. Army Ordnance to furnish safing, arming and fuzing subsystems for nuclear warheads. MSVD has participated in feasibility studies, development, testing, evaluation and production of safing, arming and fuzing systems for ten major U.S. Army and U.S. Air Force surface-launched missiles, including the Army's LITTLE-JOHN, HONEST JOHN, LACROSSE, NIKE-HERCULES, and the Air Force's ATLAS and THOR.

Engineers at MSVD's Missile and Ordnance Engineering Operation who contributed to many of these projects are today working with new safing, arming and fuzing concepts and techniques. These include the development of new fuze designs intended to overcome possible enemy countermeasures, the study of re-entry-stage arming for long-range strategic missiles, and development of direction sensing devices to aid in gaining even more reliable safing measures.

For more information on MSVD's safing, arming and fuzing achievements for the Army and Air Force and other contributions to U.S. space technology progress, write to Section 160-72A, General Electric Missile and Space Vehicle Department.

GENERAL ELECTRIC

MISSILE AND SPACE VEHICLE DEPARTMENT

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Scientists and Engineers interested in career opportunities in Space Technology contact Mr. T. H. Sebring, MSVD.

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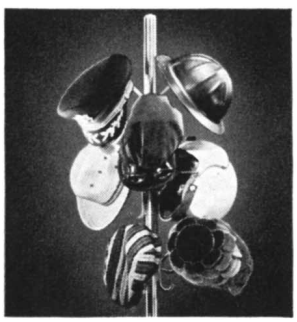
that provide accurate
guidance control at
supersonic speeds . . .

At many times the speed of sound, tremendous forces and pressures must be dealt with to properly guide jets and missiles. Power control actuator by B-W's Weston Hydraulics, however, puts 15 tons of push-pull muscle into the job—in a small fraction of a second.

. . . are helping
guarantee, too,
fast Springtime planting
of our nation's crops!

Turning over semi-frozen earth demands ruggedness in a moldboard plow. One of Ingersoll Steel Division's many specialty steels is a 3-ply steel, for plow bottoms, whose center of soft steel absorbs shock as outer layers of high carbon electric steel resist abrasion.

back of both . . . **BORG-WARNER®**



The 7 Hats of Borg-Warner . . . *(top)* national defense; oil, steel and chemicals; *(middle)* agriculture; industrial machinery; aviation; *(bottom)* automotive industry; home equipment.

Borg-Warner's world-wide divisions and subsidiaries employ over 4,000 engineers, all told. Some are specialists in materials, some in chemicals, some in electronics. All are creative. Working together in the York Division, design and mechanical engineers have perfected a new, economical compressor for air conditioning all popular makes of cars. Petroleum engineers of BJ Service, Inc., are known in the fields as the most efficient experts in the science of oil well stimulation. Hydraulic pumps, found in vehicles ranging from farm implements to industrial lift trucks, are engineered by the Wooster Division. And, through a program of creative engineering, Borg-Warner is assured a future as bright as its past. Soon, promising graduates from the college class of '60 will be joining Borg-Warner to contribute their skills to this engineering tradition.

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If you are interested in new catalysts, request our new *patent and literature survey*. M&T will then be glad to supply samples and further information based on your specific development interest.

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LETTERS

Sirs:

I feel that D. J. K. O'Connell's statement in your January issue that the green flash cannot be photographed by an ordinary camera of short focal length should be amended to cannot be *resolved*. Since the human eye has a resolution comparable to that of a good 35-millimeter camera using fine-grain color film, any statement concerning the resolution of the camera applies to the resolution of the eye. Hence if the resolution of the camera and film is too poor to allow the green flash to be photographed, the resolution of the eye would be too poor to allow it to be seen.

Actually, what occurs for the eye is that finite resolution and defects in the lens, plus light scattering in the retina, stimulate many more sense receptors than computation of the image size would indicate. The same effect should occur in the camera, giving rise to a finite, if unresolved, patch of green color.

IGOR ALEXEFF

University of Zurich
Zurich, Switzerland

Sirs:

The width of the green flash, and green rim, and the resolving power of the human eye are discussed in my book *The Green Flash and other Low Sun Phenomena*. It was not possible to treat these questions in a short nontechnical article. I cannot agree that the resolving power of a 35-millimeter camera using fine-grain color film is comparable in practice to the resolving power of the eye. The eye can profit by instants of good seeing that are too brief for a photographic exposure, which must be sufficiently long to permit the integration of the light falling on the film. Other factors also help to prevent the photographic process from attaining the theoretical resolving limit. Experienced observers can distinguish visually details of planetary surfaces that cannot yet be photographed. The fact is that, whereas the green flash has very often been seen with the naked eye, the many attempts to photograph it with short-focus cameras have invariably failed. Of course improved techniques may some day alter the picture, but up to the present it seems that a longer focal length is needed if one wishes to photograph the green flash in color.

D. J. K. O'CONNELL, S. J.

Castel Gandolfo, Italy

Sirs:

I do not make a practice of writing letters to editors, but when you print a nit-picking letter purporting to correct a trivial error, and then the correction is not only as far from the truth as the original but is also of such a nature as to tend toward perpetuating the essence of the mistaken notion which it was printed to correct, it becomes exceedingly annoying. It is as though one of your authors had stated that the moon is made of green cheese and then later you receive a rebuttal from some reader who replies: "It is not. The moon is made of green oyster shells."

I am referring to Carl B. Boyer's letter printed in your February issue, in which he states that the word ellipse does not mean, as Isaac Asimov is reported to have stated, "a defective circle," but rather "a defective parabola."

To clarify the matter for Boyer and the readers he has led up the garden path, Apollonius applied the term "ellipse" not to indicate that the curve in question was a "defective" circle or a "defective" parabola or a "defective" anything in the usual sense of the word. Incidentally, neither does "parabola" mean "equality" as Boyer asserts, but simply "parallel."

The Greek word *elleipsis* should be

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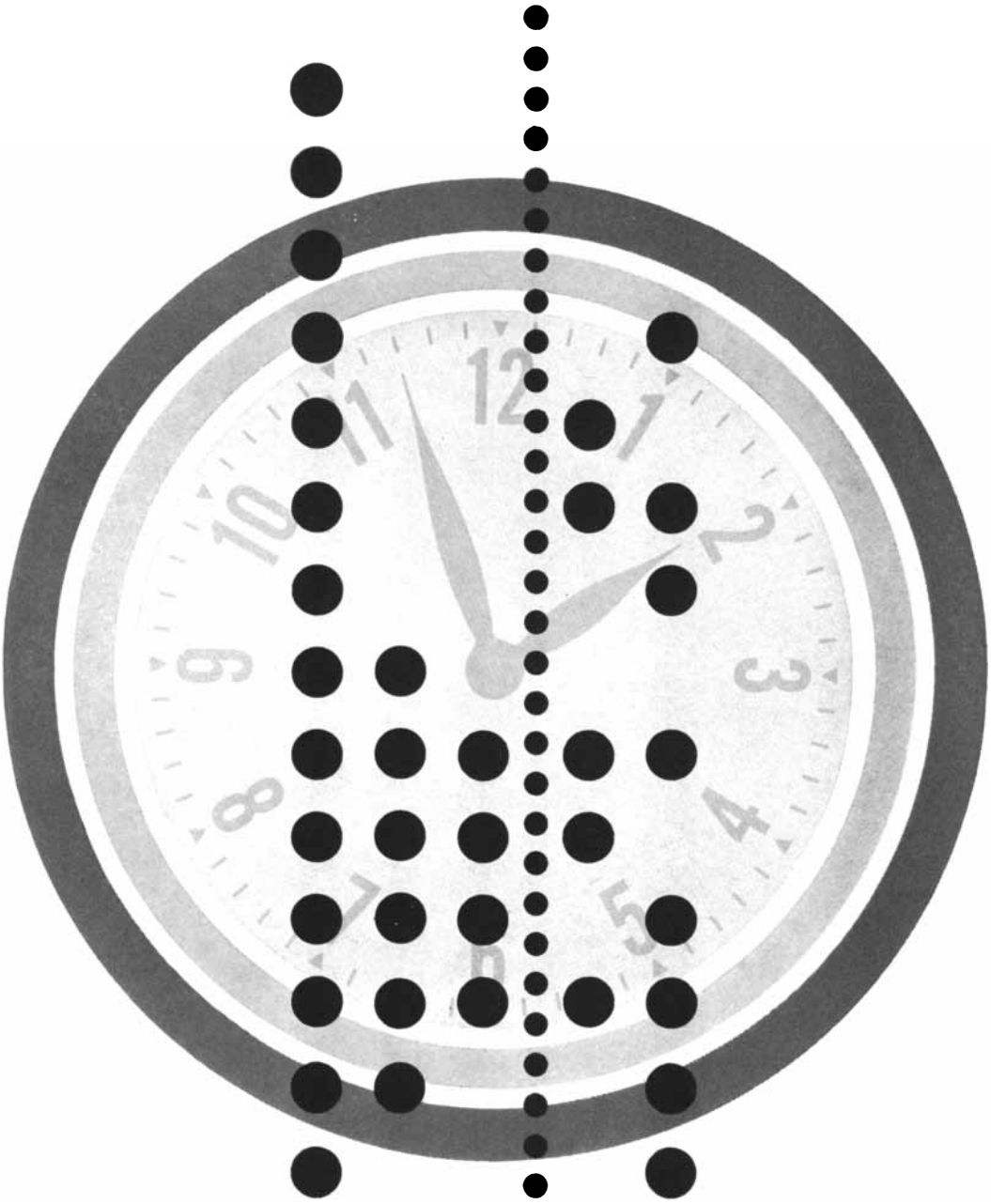


TAPE AND MICROSECONDS

are essential to missile development. Instruments must record every function against time . . . in fractions often finer than 10^{-4} seconds. Reams of electronic and optical data must be collected, reduced and evaluated before any missile can become operational. Vitro designed, built and helped instrument the Air Force missile test center at Eglin Air Force Base, Florida. Today it operates the center's test ranges and tracking stations throughout the Southeast. At Eglin, Vitro and the Air Force, working as a team since 1952, are responsible for checkout of missiles, rockets, weapon systems, countermeasures, space probe vehicles and bombing techniques, each vital to security. Another example of why Vitro means more than atomic energy... **missile testing.**

Vitro CORPORATION OF AMERICA
261 MADISON AVENUE, NEW YORK 16, N.Y.

translated "defective" only in the sense that we might term a partially filled glass of water defective. And even this only in the sense that it *could* hold more water than it *does* and without implying that a full glass of water is perfect.

"Ellipse," therefore, does not mean an imperfect circle or an imperfect parabola, but simply that the cutting plane *falls short* of being parallel with the side of the cone.

"Parabola" means that the cutting plane is *parallel* with the side of the cone; "hyperbola," that the cutting plane has been rotated *in excess* of the amount necessary to bring it parallel to the side of the cone.

This, I hope, will settle for Boyer the matter of why these curves were called by the names that they possess.

It remains therefore simply to explain why, in view of the above, Asimov is correct if he states that the Greeks viewed the ellipse as a sort of defective circle, and why Boyer is incorrect.

From many other sources we know that the Greek philosophers, seeking harmony in the universe, and being closer in time than we to the days when anthropomorphic feelings and attributes were attached to inanimate objects, considered the circle as the "perfect" geometrical form. To the Greek mind, then, the ellipse, the hyperbola and Boyer's perfect parabola, were all considered inferior to the circle. One sees, therefore, that Boyer does not know what he is talking about, and that Asimov is incorrect only if he implies that the imperfectness of the ellipse as compared to the circle is indicated by its name, rather than ascribing it to a peculiarity of classical Greek thought.

We pass a plane through a cone parallel to the base producing, to the Greek mind of Apollonius's day, the "perfect" geometrical figure: a circle. As we rotate the plane, its intersection with the cone produces first an ellipse (to Apollonius *et al.*, an imperfect circle); then, in turn, more and more imperfect curves, to wit, the parabola and the hyperbola.

"Circle" incidentally, is derived from the Latin rather than the Greek, but for Boyer's edification *kirkos,* its Greek counterpart meaning "ring," implies "perfection" in its allegorical usages.

We see, then, that although the ellipse "falls short" of being a parabola in the same sense that the hyperbola "exceeds" the parabola, the ellipse was still a defective circle to the Greeks.

JOHN D. WISE

Lexington Park, Md.

COUNTDOWN...at full fathom five

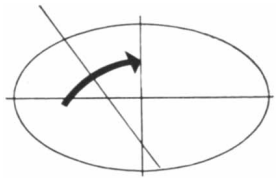
One day, a new fleet weapon system will be *on-station* beneath the ocean surface—ready to hurl retaliatory missiles toward strategic inland targets with pinpoint accuracy. This new weapon system will be part of the Navy's Polaris Fleet Ballistic Missile Program.

Though new in concept, the Polaris program makes full use of the precision Shipboard Inertial Navigation Systems (SINS) developed and produced by Autonetics for the United States Navy.

System design and components of earlier autonavigators have proved reliable in an Air Force supersonic missile, aboard the Navy's surface ship *USS Compass Island*, and on the *USS Nautilus* and *Skate*.

Advanced Autonetics' Shipboard Inertial Navigation Systems—like those to be used by the *USS George Washington*, the first Polaris-carrying submarine—will provide the critical missile alignment data to insure effective missile launching. SINS emits no tell-tale signals ... requires no receipt of external transmission at any time.

DID YOU KNOW?



The flattening of the earth at the poles can result in a navigational error of almost eleven nautical miles if not taken into account.

Inertial navigation by Autonetics

DOWNEY, CALIFORNIA

A DIVISION OF NORTH AMERICAN AVIATION, INC. • REGIONAL OFFICES: WASHINGTON, D. C. AND DAYTON, OHIO
INERTIAL NAVIGATION / ARMAMENT AND FLIGHT CONTROL / COMPUTERS AND DATA SYSTEMS

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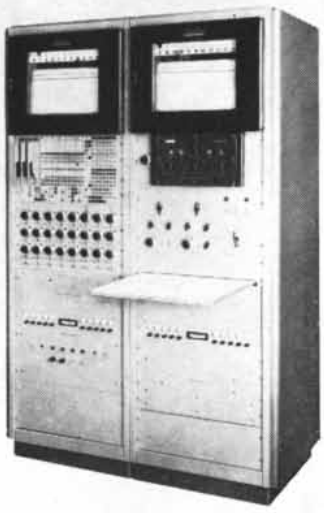

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This highly flexible Simulator is the safe, simple, and economical way to teach reactor characteristics, operating procedures, instrumentation, and interpretation of chart records. Use it with the Honeywell Thermal Plant Simulator for valuable training in nuclear power plant engineering.

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First in Control

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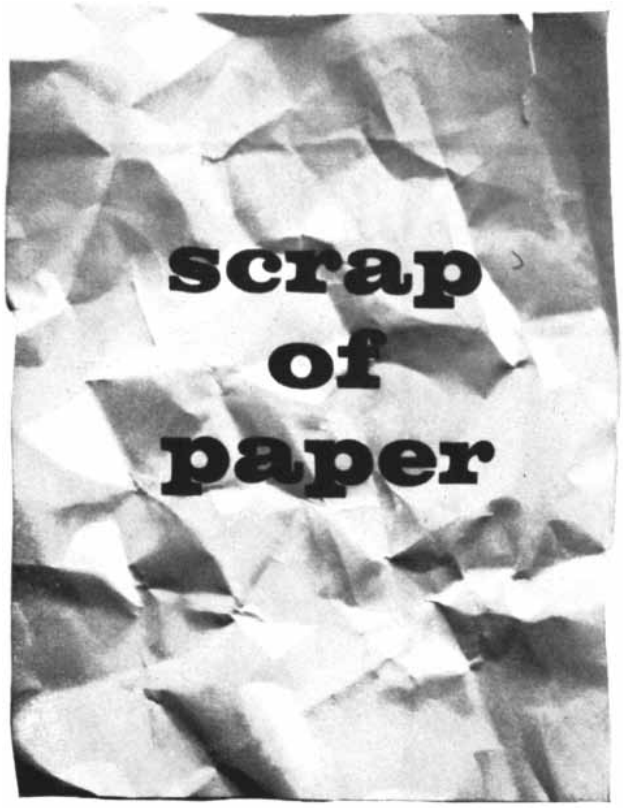


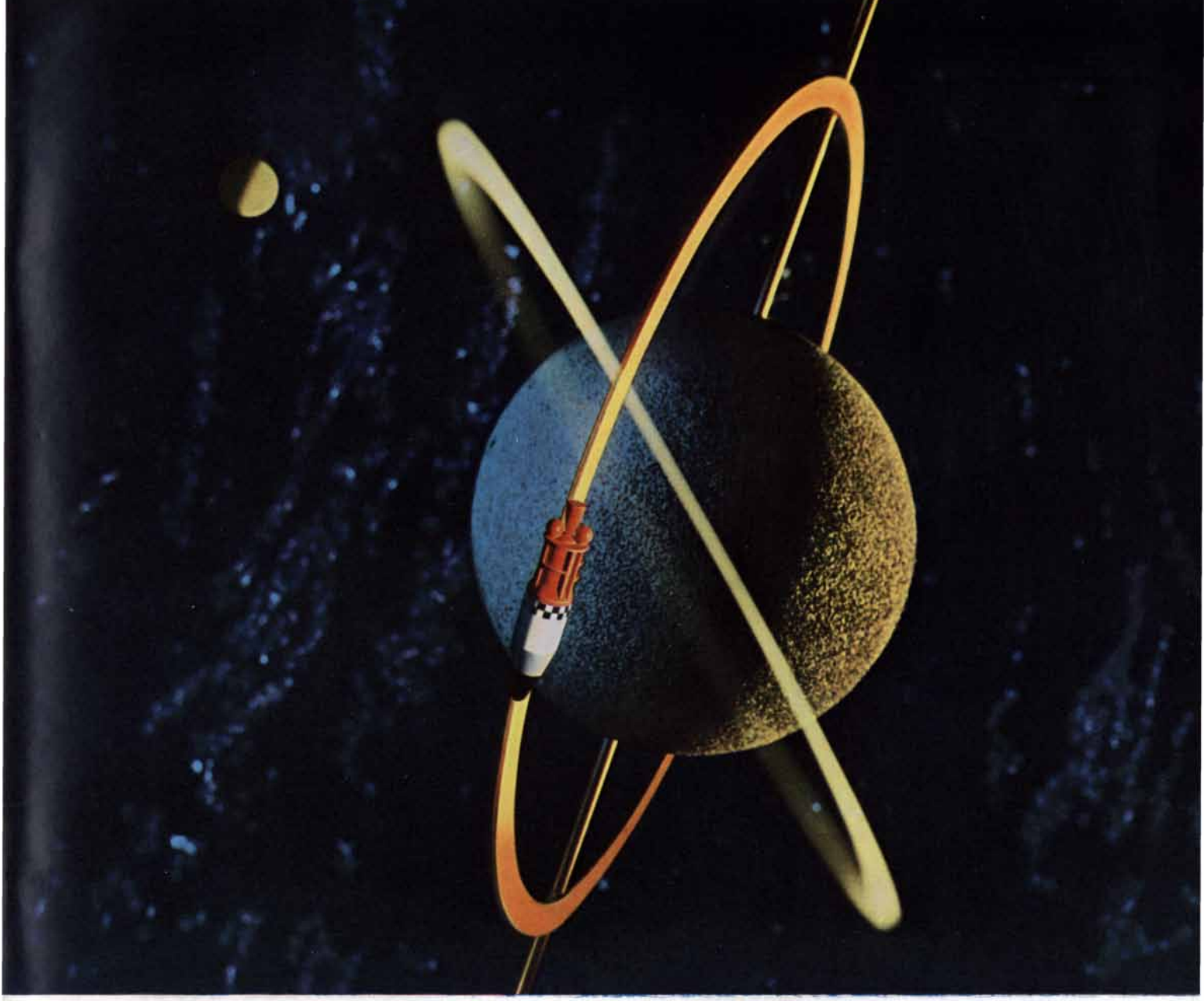
or permanent record?

the difference is a film. Greasy, creased blueprints, tattered, indecipherable office memos, faded and easy-to-tamper-with records. These are the things from which mistakes are made, everyday, everywhere, in factory, office and store. A polyethylene and Mylar* film combination, product of Dobeckmun research, offers an end to all this. Use it in conjunction with a desk-top laminator and papers become permanent records. And when appearance is important—presentation pieces, advertising layouts, mailing shots, to name a few—this speedy post-lamination process will transform run-of-the-mill pieces into stand-out successes whose polish can never rub off. Any office worker can laminate a document in seconds (both sides are treated at once), but the protection that results will defy time, scuffings, oil, water . . . you name it. Post-lamination, one of the most promising developments of Dobeckmun film research was achieved in close cooperation with a manufacturer of laminators. For complete information, write

THE **DOBECKMUN** COMPANY

*T.M. DUPONT

A Division of The Dow Chemical Company, Cleveland 1, Ohio • Berkeley 10, California • Offices in most principal cities



Bell-powered Agena satellites in orbit — symbolized.

THE ENGINE WITH THE FUTURE

Reliability . . . Efficiency . . . Flexibility.
In space, these words have a million-dollar meaning.

Vast sums of money and vital scientific data ride on these built-in attributes of Bell Aircraft's rocket engine for Lockheed's Agena satellite, second stage of the Air Force Discoverer series.

The Agena engine, designed with space in mind long before space became a household word, has fulfilled its every mission and has placed more tons of useful payload into orbit than any other power plant. Its operational reliability is backed by six years of development and 5,000 test firings.

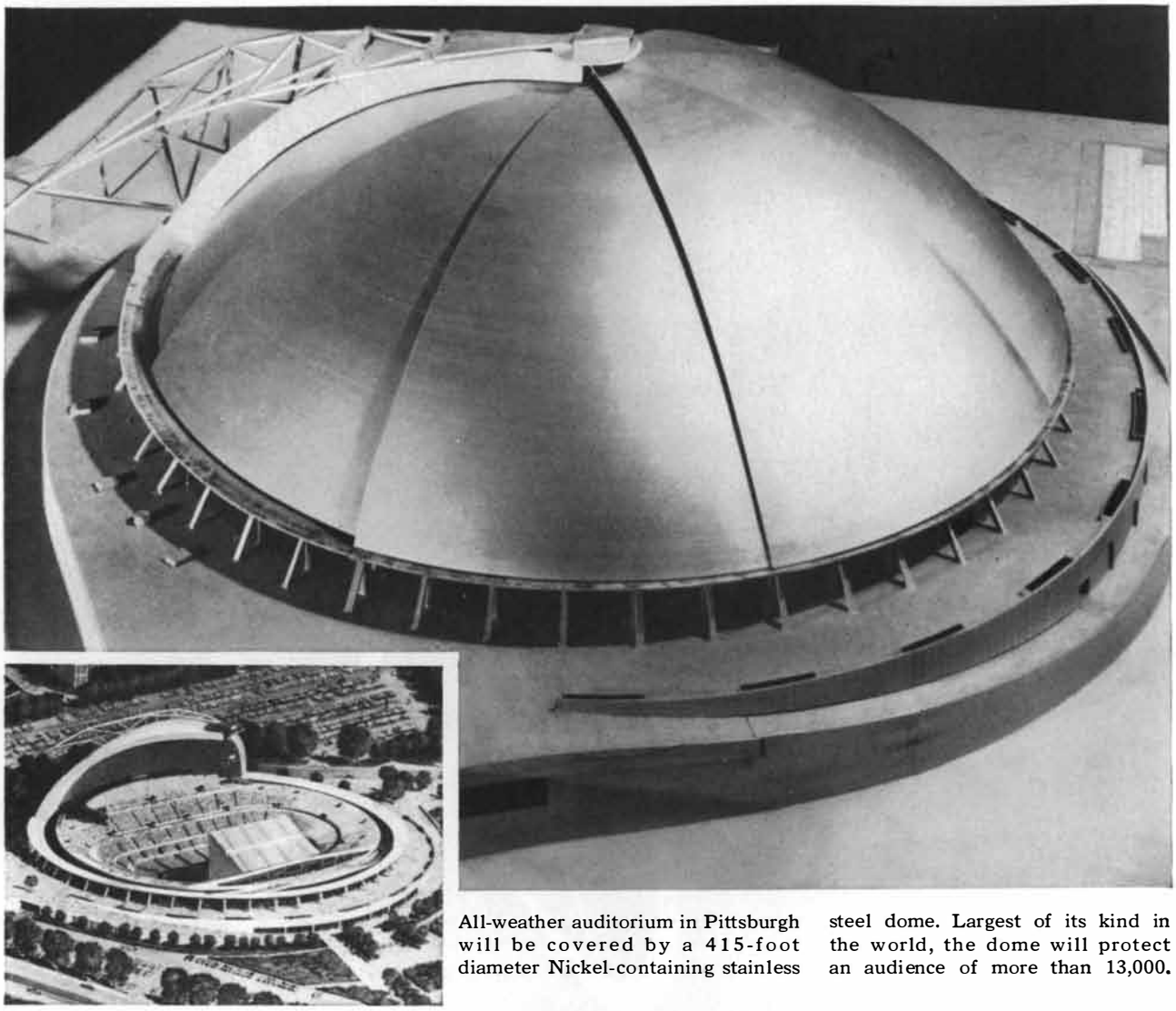
This Bell engine now has re-start capability — the first in the nation. This means that its satellite can change orbit **in space** without the penalty of extra engines. Presently in production, this engine also is adaptable to new fuels and new assignments and, consequently, is programmed for important military and peaceful space ventures of the future.

Agena's engine is typical of the exciting projects in Bell's rocket propulsion center. It is part of the dynamic new approach of a company that's forging ahead in rocketry, avionics and space techniques. These skills serve all government agencies. Engineers and scientists anxious for a new kind of personal challenge can find it at Bell.

Niagara Frontier Division

BELL AIRCRAFT CORPORATION

BUFFALO 5, NEW YORK



All-weather auditorium in Pittsburgh will be covered by a 415-foot diameter Nickel-containing stainless steel dome. Largest of its kind in the world, the dome will protect an audience of more than 13,000.

"Push-button umbrella roof" of stainless steel gives Pittsburgh a new all-weather auditorium

Watching a play or listening to music under the stars heightens the enjoyment. That is, until a passing shower comes along to wash out the fun. But now comes a new idea in auditoriums. In this one, an umbrella roof of Nickel-containing stainless steel will close at the first drops of rain—and on with the show.

It's a simple concept, but a daring one. Eight huge sections nest together when the dome is open. Push a button, and six of these sections glide quietly together around an outside track.

They looked into all sorts of sheathing materials in designing the dome before choosing Type 302 Nickel-containing stainless steel.

For stainless with Nickel in it is one of the most weatherproof metals there is. It is corrosion-resisting all the way through — in salt air as well as industrial atmospheres. What's more, it's virtually self-cleaning — rainfall alone keeps this metal clean.

No wonder you see Nickel-containing stainless wherever strength, long life and handsome appearance are called for! Not only in buildings — inside and out — but everywhere you look.

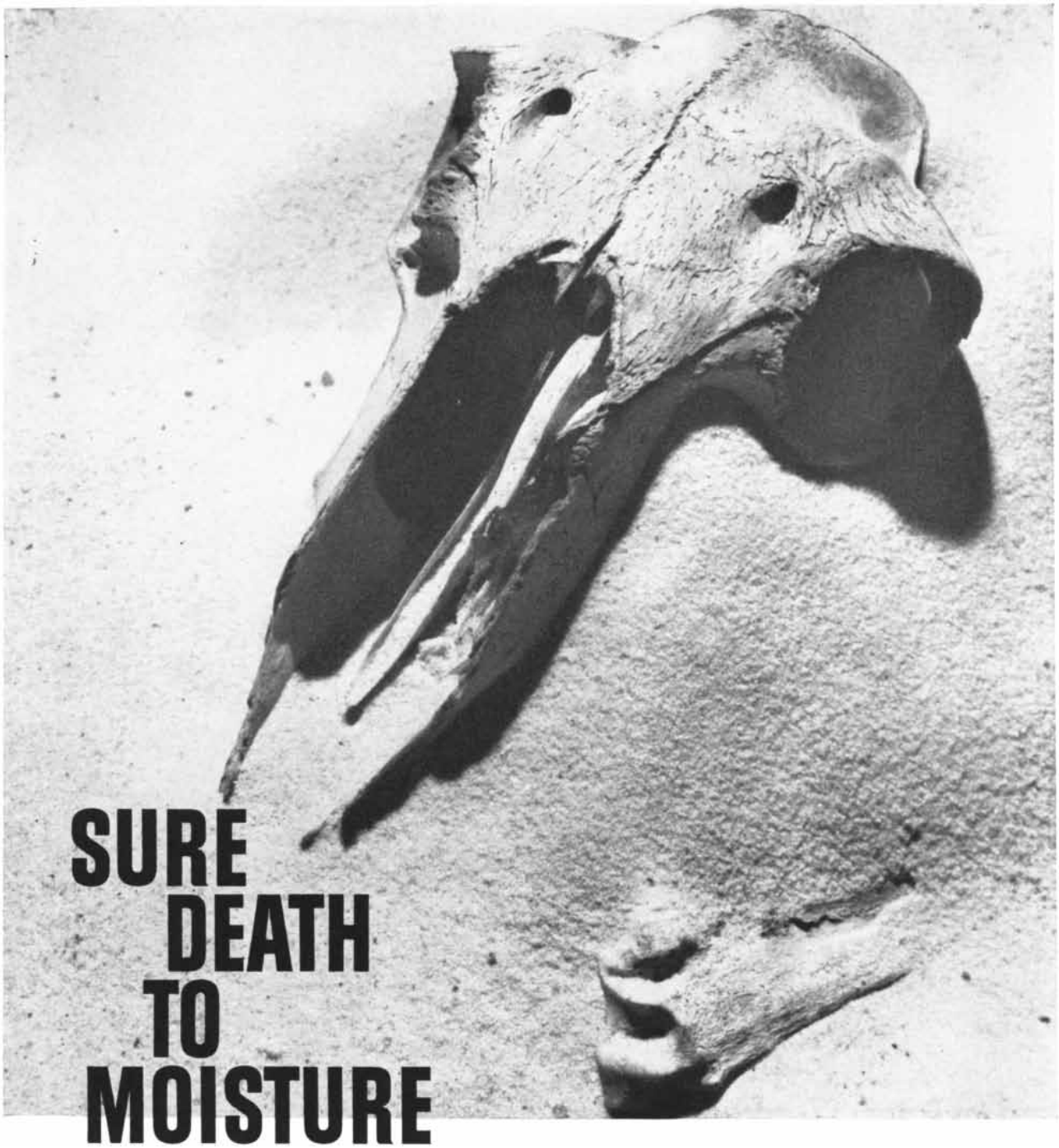
Suggest something to you? Can stainless help you solve a problem involving corrosion, stress, appearance, temperature extremes? The way to find out is to write us. We'll see if Nickel-containing stainless steel — or some other nickel alloy — may be just what you're looking for.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER



Whether it's a hermetically sealed package, a system containing gas or liquid, or many still undetermined applications, Davison Silica Gel possesses physical properties that assure better moisture removal than ordinary desiccants.

Its unique porous internal structure offers the equivalent of 90,000 square feet to a cubic inch of silica gel . . . adsorbing up to 40% of its weight of water in saturated air. This characteristic is the basis for many of its industrial applications. Because surface area, pore size and density can be carefully controlled during production, silica gel has found profitable use in such widely divergent fields as paint, oil and gas, chemical, paper, and pharmaceutical. If you have a problem in gas or liquid drying, flatting, anti-blocking, thickening, moisture removal, dehydrated packaging, or catalyst supports, write Dept. 5105 for technical assistance and information.

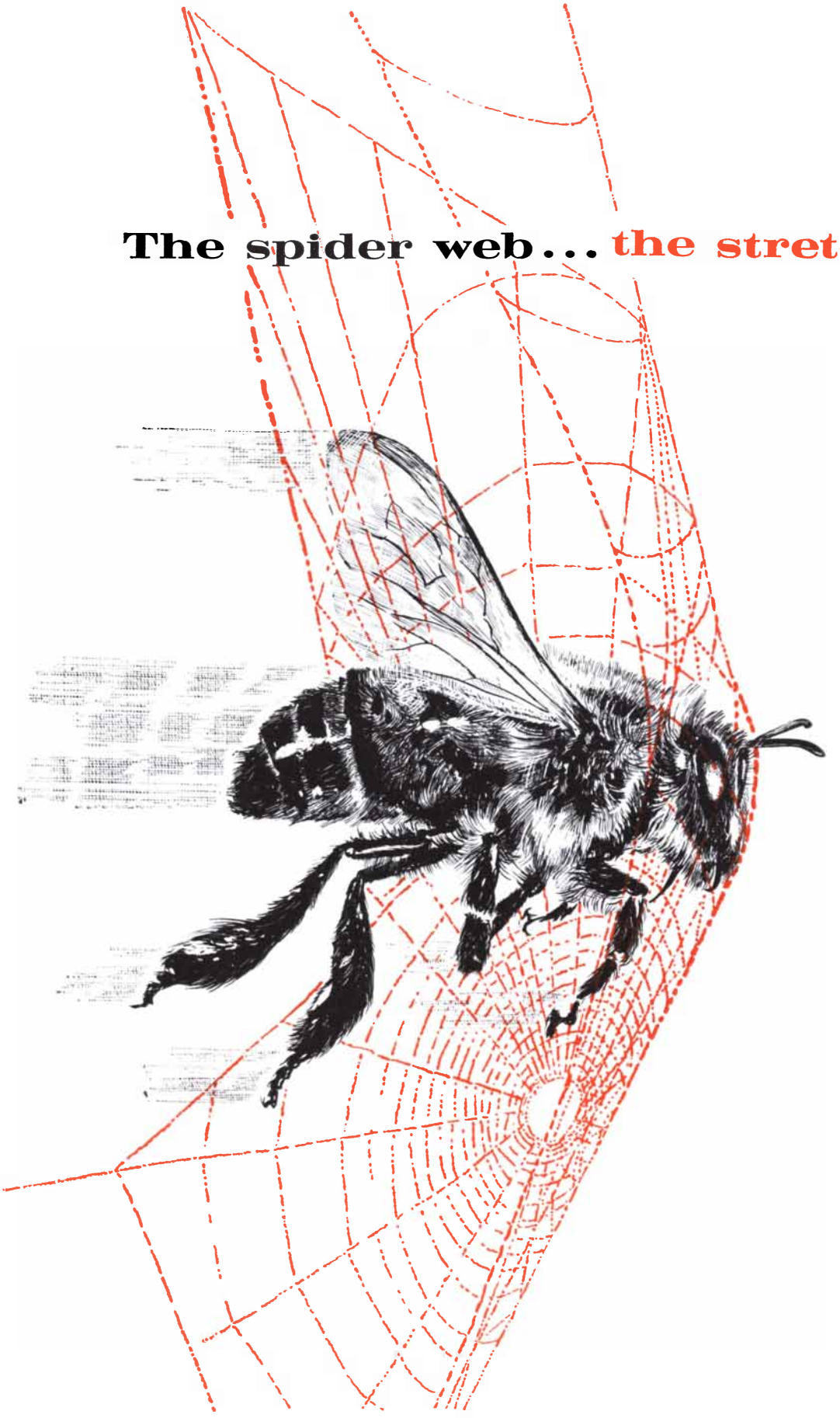
DEPARTMENT 5105

W.R. GRACE & CO.

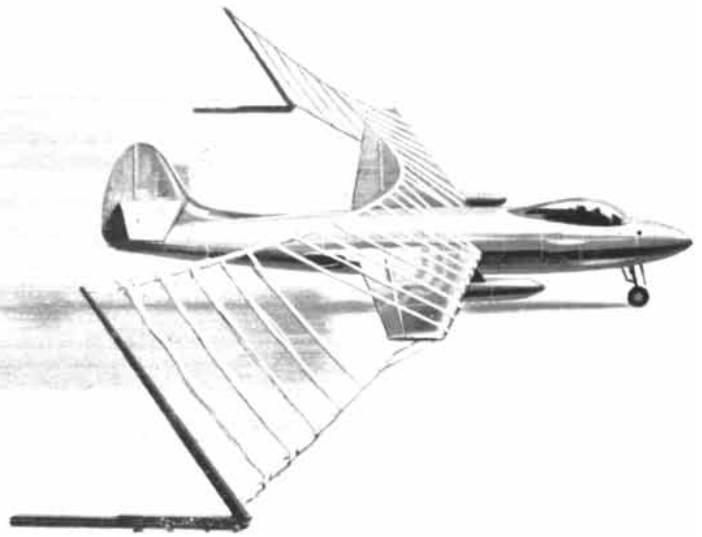
DAVISON CHEMICAL DIVISION

BALTIMORE 3, MARYLAND

The spider web... the stretch...



and a case of arrested flight



In the timeless world of nature, many an insect has been fatally snared by the surprising stretch and strength of an apparently fragile spider web.

Man, however, saves lives with a web that can safely stop a runaway jet aircraft, thanks to the remarkable properties of a synthetic fiber—nylon.

Nylon is a highly elastic fiber. Extremely light in weight, its density is only 1.14, yet it's stronger than steel wire of the same weight—has over 4 times the impact strength. In everything from sewing thread to tire cord to mooring line, nylon's usefulness is being rediscovered every day.

Perhaps nylon can serve you.

Du Pont's family of man-made fibers offers you exceptional versatility. Even now—tailored to specific needs or combined with other materials —fibers can outperform such materials as steel, wood or even lubricants.

Please tell us *your* requirements. We'll be happy to provide any information or technical assistance regarding your use of Du Pont fibers for industry.

E. I. du Pont de Nemours & Co. (Inc.), 31K1, Centre Road Building, Wilmington, Delaware.

NYLON
"DACRON"* *polyester fiber*
"ORLON"* *acrylic fiber*
"TEFLON"* *TFE-fluorocarbon fiber*
"SUPER CORDURA"* *high tenacity rayon yarn*

Du Pont Fibers for Industry

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BETTER THINGS FOR BETTER LIVING...*THROUGH CHEMISTRY*

*DU PONT'S REGISTERED TRADEMARKS

THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

THE UNEARTHLY USE OF GLASS

Some day the stellar equivalent of an archeologist will ferret his way through space, collecting debris from the sundry objects we are thrusting out past the pale of gravitation.

That man is going to find a lot of glass.

Next to the metals, glass is *the* basic material for space work. Big claim? Big fact.

You can blast glass out at the stars, shine the sun at it full open, slide it into the cold void of the earth's shadow, plummet it back into the searing atmosphere, recover it from the bobbing waves. And, all the time, glass will hold to its integrity, its properties, its dimensions.

You can design glass *into* a piece of space hardware; you can only know the beauty of this if you have had to design *around* some other material that has interesting properties but is hard to work.

Glass has hardly any design limitations. We can mold it, blow it, fuse it, press and roll it, etch it, temper it, or try any of a dozen other controlled techniques to meet exactly the shape you want, exactly the size you want, exactly the exactness you want.

We have some 60,000 glass formulae to select from, so matching your specs on properties is a snap.

We have combinations of glasses that transmit or attenuate all of the visible light spectrum and most of the infrared and ultraviolet as well.

We can take a mass of glass yards thick and make it as transparent as the objective lens on a microscope, as surface perfect as the facet on a ten-carat diamond.

Big claims? Big facts. Radomes, windows for space capsules, giant mirrors for balloon-floated telescopes, electronic components, macro and micro in size . . . these are just a few of the things you can do with glass . . . and, with all that, you haven't begun to tap the possibilities of glass in space.

We have two brochures that tell about these properties and design potentials: *This Is Glass* treats of the material itself. IZ-1 discusses the applications. Check the coupon for copies.

WE'LL GROW RED ROSES IN JUNE, JUST YOU AND I UP ON THE MOON

It goes without saying that you cannot grow terrestrial plants in a 10^{-12} mm Hg atmosphere . . . but just how high does the pressure have to be to bring a plant to maturation? What about the effects of a lower gravity? What sort and how much light will you need to make a seedling stir? How about temperature?

Republic Aviation is engaged in some research of this sort, which will form a sort of almanac for the lunar farmer.

We come into the picture with a vacuum-tight greenhouse, often referred to as a PYREX brand bell jar. Besides serving as the perfect lunar greenhouse, it recommends itself on a weight basis.

You might remember this "Moon Garden" if the time comes when you want an environment you can play with and observe. Many are the people using our bell jars for high vacuum and high pressure work, for the creation of an inert gas atmosphere; in short, for any work where you want to free yourself from the deficiencies of the terrestrial atmosphere.

HOW TO SEEK OUT AND HIT A MELTING ICE CREAM CONE IN THE MIDDLE OF ALASKA

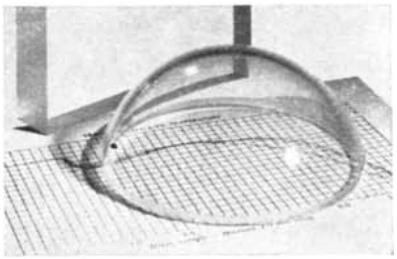
We make the glass that goes into the domes that transmit the infrared waves that activate the cunning minds of the heat-seeking missiles that go pow.

Today we make a better IR transmitting glass than ever before. We call it Code 9752.

A 2mm thickness of this glass will transmit 77% at the 4.0 micron wave length and 38% at 5.5 microns. Not bad.

At 600°C there is no transmission loss whatsoever at 4.0 microns, only 13% at the 5.5 micron wave length.

Our research people say the glass has



"good" electrical properties, "excellent" weathering characteristics. Our research people are known as conservatives.

In a durability test, we found that there was no appreciable transmittance loss in 21 days at 95% RH with temperature cycling from 25°C to 65°C twice a day.

Using standard techniques, we can mass produce this glass in a variety of hollow shapes and give it an optical finish. We can press 7″ domes automatically and make larger sizes to order. Flat pieces, 12″ square and ½″ thick, are being used in the instrumentation field for such devices as Schmidt corrector plates.

The coupon offers a bulletin on this and two other Corning IR transmitting glasses.

CORNING MEANS RESEARCH IN GLASS

CORNING GLASS WORKS, 49 Crystal St., Corning, N. Y.

- ☐ This Is Glass
- ☐ IZ-1
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Name..... Title.....

Company.....

Street.....

City..... Zone..... State.....

Advanced hot gas systems delivered by AiResearch

FOR OUTER SPACE, ATMOSPHERIC AND UNDERWATER STEERING

AiResearch is now in production on two greatly simplified hot gas steering control systems: a reaction control system for outer space flight stabilization and a hot gas actuator control system for terrestrial steering (in the atmosphere and under water).

Both systems eliminate any need for pumps, heat exchangers, accumulators and other apparatus required in earlier control systems. And both systems utilize hot gas, operating off either the main engine or a separate fuel source.

The gas in the outer space reaction control system is fed into a set of nozzles which imparts spin to the missile to stabilize its flight through space.

In the terrestrial hot gas actuator control system the gas is fed into an on-off controlled linear actuator which moves the fins controlling the missile's attitude in the atmosphere or under water. This system also utilizes a concept developed from the AiResearch hydraulic "printed circuit." This approach eliminates complicated plumbing, thereby decreasing the weight and increasing the reliability of the system.

AiResearch is a pioneer, *leading developer and manufacturer of hot gas systems and other nonpropulsive power systems for atmospheric, underwater and outer space missions. Your inquiries are invited.*

THE GARRETT CORPORATION

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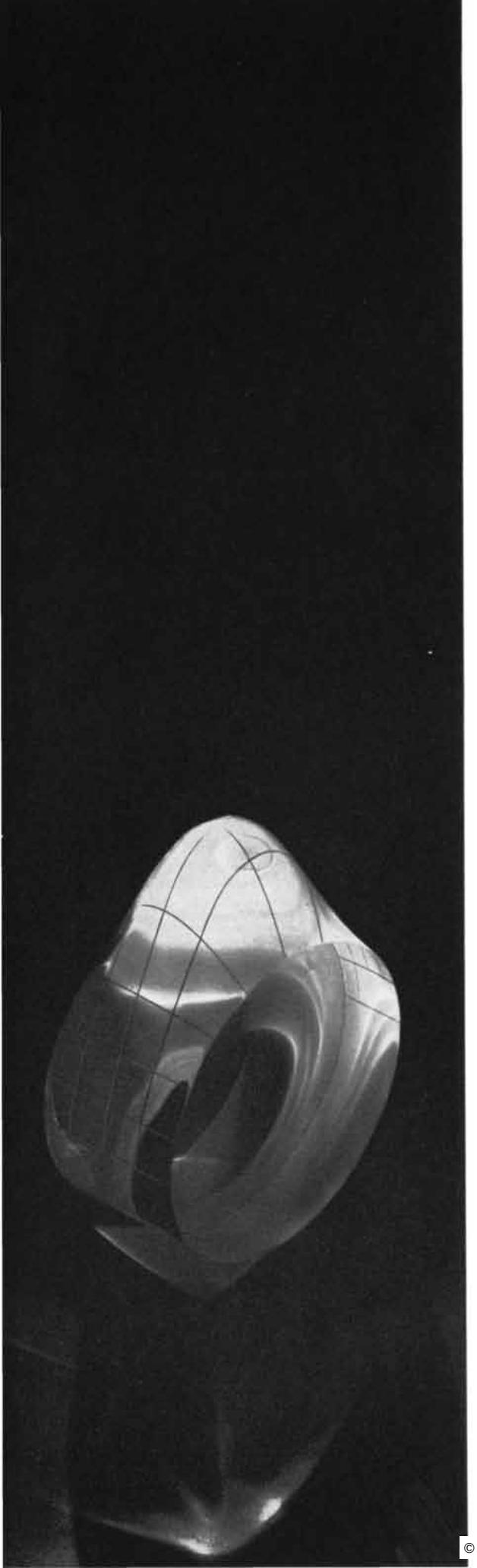
Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS



Catching Up with a Slippery Equation

What goes on when two moving surfaces are separated by a film of oil?

Simple question? Maybe, but engineers and mathematicians have been trying to answer this classic question of lubrication ever since Osborne Reynolds neatly stated the problem in equation form back in 1886.

Unfortunately, analytical methods for solving Professor Reynolds' partial differential equation worked only for unrealistic oil bearings, bearings with widths approaching zero or infinity. And approximate methods were crude, requiring a complete recalculation for each slight change in the bearing.

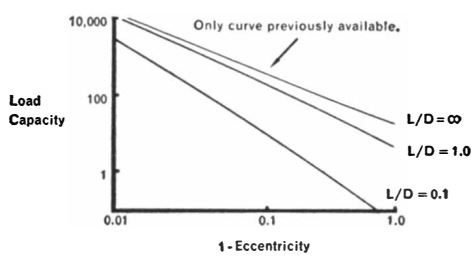
Recently, mathematicians at the General Motors Research Laboratories came up with the most versatile and efficient method of solution yet made. Their analytical method for solving the two-dimensional Reynolds' equation applies to all finite journal bearings — as well as other hydrodynamic bearings — with *no* assumptions or approximations about boundary locations. The new method uses a long-neglected energy theorem recorded by Sir Horace Lamb instead of the force relationship tried by Reynolds and others.

Besides being a valuable contribution to the theory of lubrication, this work has its practical side: namely, accurate, serviceable design curves for engineers. At GM Research, we believe delving into both the theoretical and applied sides of a problem is important to progress. It is a way of research that helps General Motors fulfill its pledge of "more and better things for more people."

General Motors Research Laboratories

Warren, Michigan

Hydrodynamic analyses have led to specific answers about bearing operation. Shown here are the oil pressure distribution (main illustration) and load-carrying capacity for a non-rotating journal with a reciprocating load.



One element for control of all three axes

Free from gyroscopic cross-coupling

Bearingless support using electric fields

FREE WHEELING

. . . für kontrolle des satellitenverhaltens

A single reaction sphere—electrically suspended—is the Bendix *free wheel* concept for space vehicle attitude control. Conceived to use the space environment to advantage, the *free wheel* concept eliminates the reliability problems of conventional reaction wheel bearings. Three stator windings placed in orthogonal planes are energized to generate control torques around any axis of the rotor (and any axis of the space vehicle by reaction).

Free from bearing vibration and gyroscopic cross-coupling, the *free wheel* provides a unique capability for precision attitude control of orbiting scientific and military observatories.

This project is part of the over-all Bendix space-systems development program which includes satellite communication, satellite navigation, radiation-resistant electronics, magnetohydrodynamics, plasma shock tubes, and infrared reconnaissance.

Opportunities are open to better engineers and scientists interested in participating in advanced space programs in an ideal scientific climate. Write today for complete information.

Bendix Systems Division
ANN ARBOR, MICHIGAN

Bendix
AVIATION CORPORATION

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MAY, 1910: "The transit of Halley's comet and the expected immersion of the earth in its tail have proven once more what may happen to the best-laid plans of mathematicians. The transit undoubtedly occurred, but whether or not the earth really encountered the tail seems to be a matter of considerable doubt. When the night of May 18th came, and the scientific world was all agog, the tail was so curved that the passage of the earth through it seemed only remotely possible. All the scientific expeditions which have been sent to various parts of the earth will probably come back with nothing to report. The more important meteorological stations of the world sent up sounding balloons at frequent intervals on the 18th and 19th of May, for the express purpose of bringing down from the upper strata of the atmosphere some record of unusual happenings which might safely be attributed to the influence of the comet. All this labor is now in vain."

"The 14-year-old president of the Junior Wireless Club of America appeared before the Senate Committee on Commerce last week to protest against the bill introduced by Senator Depew for regulating wireless telegraphy. The young president gave a very forcible argument in favor of amateur wireless telegraph operators, pointing out the fact that if the bill were passed, it would check the inventive genius of some 40,000 experimenters. He also called attention to the fact that it would be impossible to enforce the bill without a veritable army of expert wireless telegraph engineers."

"Now that aircraft have been entered as war vessels, inventors are beginning to cast about for some effective means of destroying them. Recently an aerial torpedo has been invented, which, by means of a hertzian-wave controlling system, may be directed from a distance without carrying any operator. This torpedo was exhibited at the London Hippodrome, where the inventor caused it to travel out over the audience, steering it wherever he chose by pressing buttons on a switchboard on the stage. The device may be equipped with explosives, to be dropped on an enemy. This was demonstrated by releasing flowers on the audience."

"An interesting discussion by Charles P. Steinmetz on the magnetic properties of materials was published recently. It was stated some years ago that magnetic alloys could be made by combining non-magnetic materials. Dr. Steinmetz points to the fact that in all these alloys manganese is used, and that this is slightly ferromagnetic. Dr. Steinmetz states that no magnetic alloy has been found which does not contain some of the ferromagnetic group."

"In a recent lecture before the Engineers' Club in New York, Mr. Elmer A. Sperry, the electrical engineer, demonstrated with a working model the value of his 'active' gyroscope. If the ordinary, or 'passive,' gyroscope be applied to ships, the vessel must roll some 2½ degrees before the counteracting influence is exerted. In the new type the least tendency toward a roll sets in operation a governing device, consisting of a smaller gyroscope, which starts the larger gyroscope, and thus secures an instant and absolute stability. Mr. Sperry believes this new type will provide the naval gunner with a perfectly stable platform."

Scientific American.

MAY, 1860: "The announcement of the discovery of flint weapons, spear-heads, axes, &c., associated with the remains of extinct animals—elephant, rhinoceros, bear, tiger, hyena, &c.,—in undisturbed beds of gravel in the north of France was first made by Mr. Evans, an English geologist, to the London Society of Antiquaries in June, 1859, and subsequent researches have fully confirmed it. At the meeting of the British Association in September, 1859, Sir Charles Lyell, who has hitherto favored the received chronology respecting man's existence as a race, said that he fully believed that the antiquity of these flint weapons was immensely great as compared with the times of either history or tradition; and it is conceded by all geologists that the continued existence of tropical animals is not possible in Central Europe, under the present conditions of climate. The conclusion, there-

HAROLD S. BLACK, LAMME MEDALIST

A MAN WINS A MEDAL...AND STRENGTHENS A PHILOSOPHY

The search for the "hitherto unattainable" sometimes ends in strange places.

For years Bell Laboratories engineer Harold S. Black pondered a problem: how to rid amplifiers of the distortion which unhappily accumulated as signal-transmission paths were made longer and amplifiers were added. There had been many approaches but all had failed to provide a practical answer.

Then one day in 1927 the answer came—not in a research laboratory, but as he traveled to work on the Lackawanna Ferry. On a newspaper, Mr. Black jotted down those first exciting calculations.

Years later, his *negative feedback principle* had revolutionized the art of signal amplification. It is a principal reason why telephone and TV networks can now blanket the country, the transoceanic cable is a reality, and military radar and missile-control systems are models of precision.

For this pioneer achievement, and for numerous other contributions to communications since then (some 60 U. S. patents are already credited to him), Mr. Black received the 1957 Lamme Medal from the American Institute of Electrical Engineers. He demonstrated that the seemingly "unattainable" often *can* be achieved, and thus strengthened a philosophy that is shared by all true researchers.

He is one of many Bell Telephone Laboratories scientists and engineers who have felt the challenge of telephony and have risen to it, ranging deeply into science and technology. Numerous medals and awards have thus been won. Two of these have been Nobel Prizes, a distinction without equal in any other industrial concern.

Much remains to be done. To create the communication systems of the future, we must probe deeper still for new knowledge of Nature's laws. We must continue to develop new techniques in switching, transmission and instrumentation for every kind of information-bearing signal. As never before, communications offer an inspiring challenge to creative men.

BELL TELEPHONE LABORATORIES

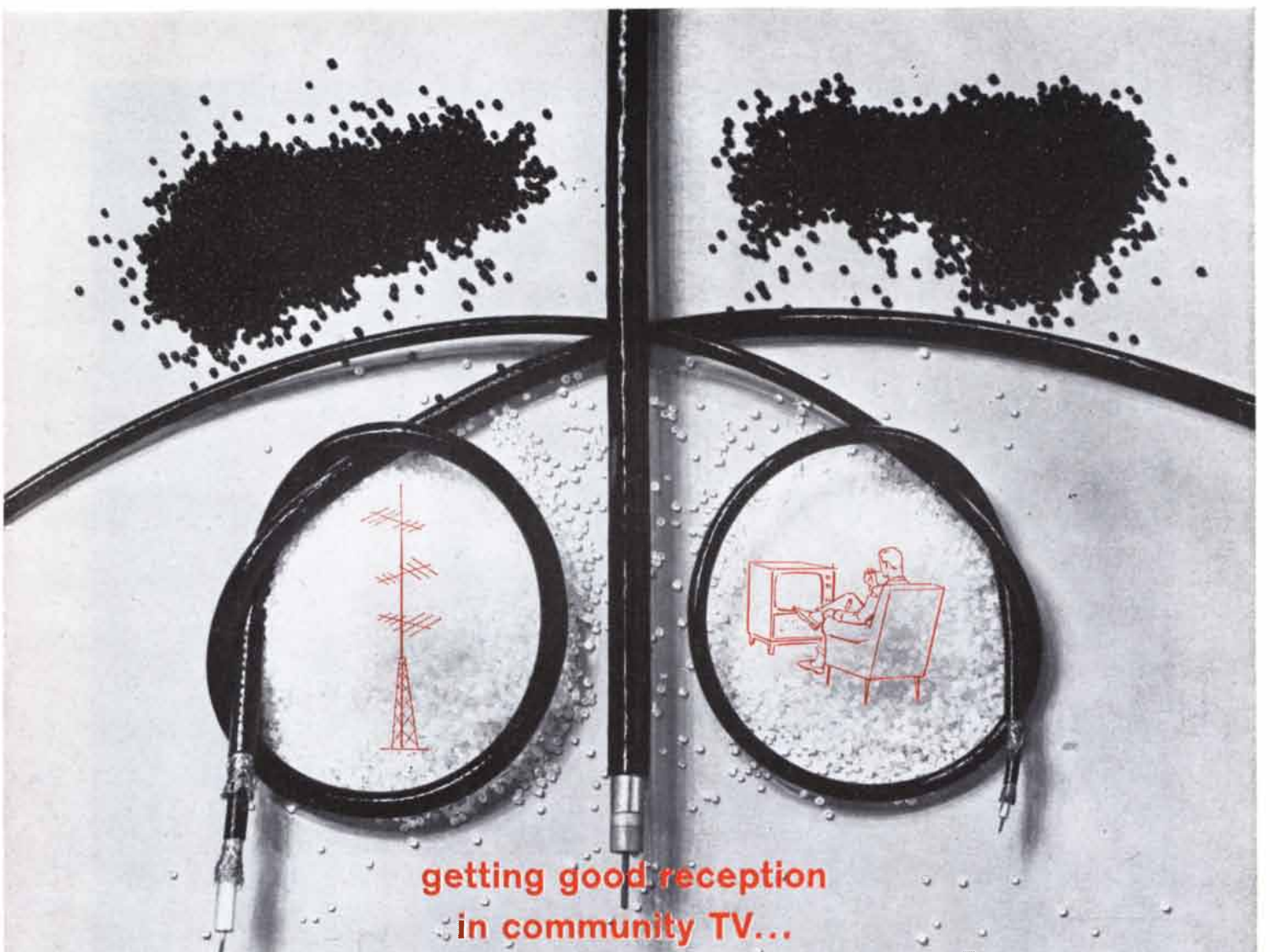
WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

fore, seems unavoidable that there were races of men inhabiting Europe at a period when its temperature was altogether different from what it now is."

"Mr. J. N. Gamewell has exhibited his police and fire alarm telegraph in Tammany Hall, New York. Its object is to convey intelligence from any of a great number of stations in a city to a central police station, and from this latter to any and all stations in an instant; also to convey information of a fire to the engineer's office, and at the same time set all the alarm bells ringing. Supposing a city to be laid out with a signal box at the corner of each street, and that a fire takes place, the policeman on that 'beat' turns a small crank in the signal box and specific intelligence of the fire is thus conveyed to the place where the chief operator is located. The latter now moves certain keys to close and break the galvanic circuit as many times as make all the alarm bells strike the number of the district where the fire is. There is no waiting, as is now the case in cities, for the sleepy bell-ringers to take up the alarm, one after another."

"In a recent number of the London *Mechanics' Magazine* there is an abstract of a paper by Professor Faraday, F.R.S., in which a detailed description is given of the application of the Electric Light to the South Foreland Lighthouse. He stated as follows: 'The current of electricity is obtained from a magneto-electric machine; neither frictional nor voltaic electricity is used. A number of powerful magnets are arranged on a shaft, and made to revolve near to the poles of helices wrapt around a core of soft iron. Currents of electricity are thus generated, and the wires of the helices are connected with a commutator, which gathers the various currents produced in the helices, and sends them up through two insulated wires in the common tide of electricity, thence into the lighthouse lantern.' "

"The steamship *Great Eastern* is being rapidly prepared for her trial trip across the Atlantic, and it is expected she will be completed in the beginning of next month, so as to accompany the Prince of Wales in his visit to our continent in July. Her proprietors having sent word to this city that she would come here if it were possible to get her into the harbor, the Board of Pilots has returned the answer that they will navigate her right straight up to 'Gotham' if she does not draw more than 26 feet of water."



getting good reception in community TV...

Mohawk's H-F coaxials, jacketed and insulated with TENITE POLYETHYLENE

For community television distributing systems in any area, Mohawk H-F coaxials do a complete transmission job, from tower or relay station right into the living room.

Tenite Polyethylene is used as jacketing and insulating material on these cables. It offers all-round high performance which gives them long life, keeps line loss low, and permits ease in installation.

As a jacketing material, tough Tenite Polyethylene provides excellent resistance to abrasion, weathering, moisture, and heat. Users can look forward to years of maximum protection.

As an insulating material, Tenite Polyethylene has a low power factor, which holds energy losses to a minimum. In these Mohawk cables, both solid and foamed Tenite Polyethylene are used for primary insulation... the foamed material having an even lower dielectric constant than the solid, thus making possible a thinner insulation with a resulting decrease in cable weight.

Linemen find that cable jacketed with lightweight Tenite Polyethylene is easy to handle and strip and is flexible even at sub-zero temperatures.

There is a formulation of Tenite Polyethylene to meet the demands of most insulating and jacketing applications. For further information on this useful plastic, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

● *Both natural and black electrical grade Tenite Polyethylene are available to cable manufacturers as unique spherical pellets which flow freely in the extrusion process and in "air-veying" bulk shipments from truck to bin.*

● *Cable manufactured by Mohawk Wire & Cable Corporation, 320 River Street, Fitchburg, Massachusetts. Jacketing and insulation extruded of* ***Tenite*** *Polyethylene.*

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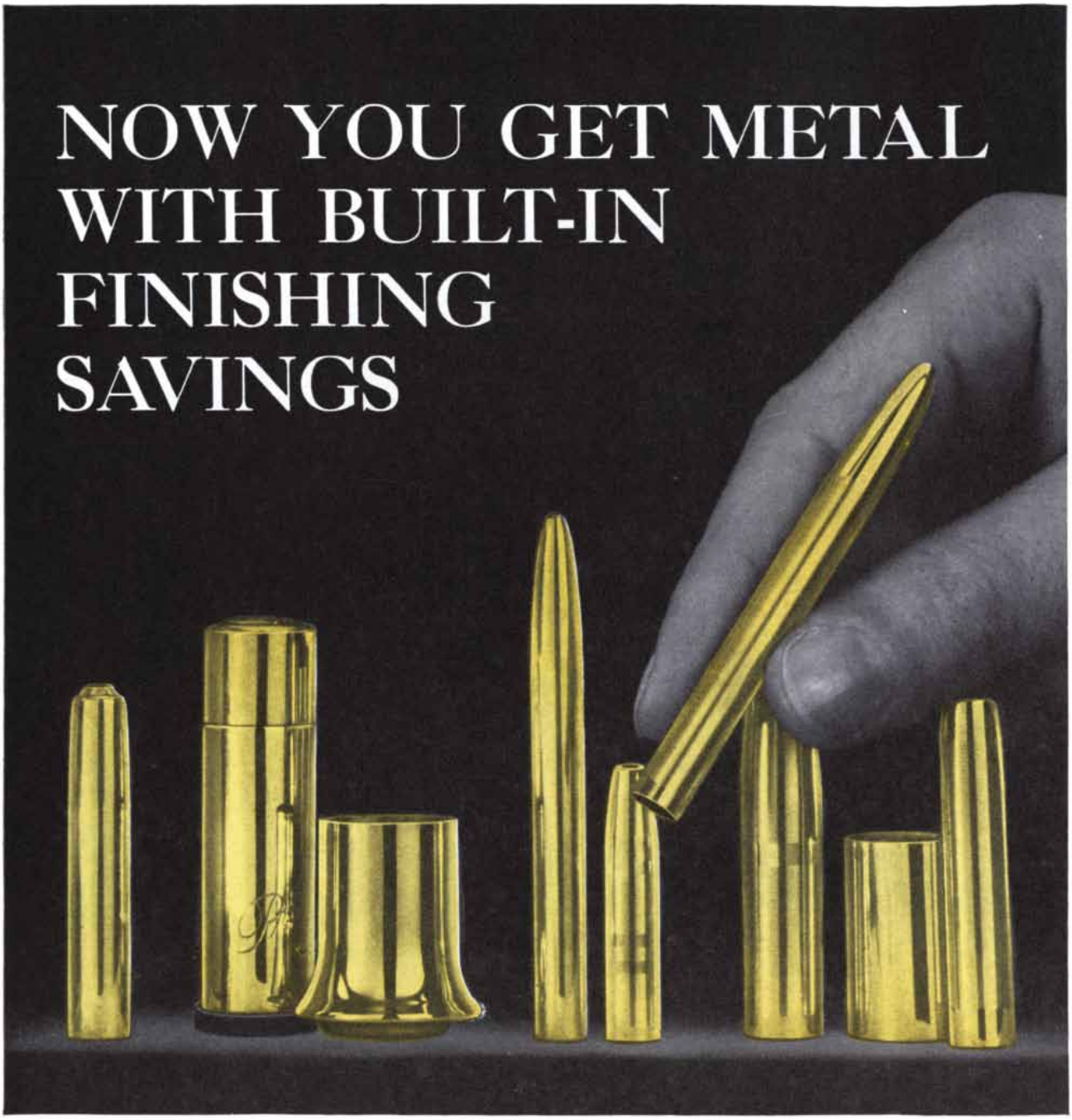
POLYETHYLENE
an Eastman plastic



Faster production and up to 40% cut in polishing costs are made possible by superfine-grain structure of Formbrite® Drawing Brass

The jeweler's finish which Accurate Forming Corp., Franklin, N. J., gives pen caps and barrels previously meant the use of five polishing heads and a time bottleneck in production—resulting in a high polishing "cost factor." After switching to Red Brass-Formbrite, they use two polishing heads for a light cut and another for a simple color buff and run the machines faster. Savings run up to 40%. The secret of Formbrite is its superfine grain, produced by special rolling and annealing techniques. Formbrite is springier, harder, more scratch-resistant than the usual drawing brasses in the same standard tempers, yet retains remarkable ductility for forming and drawing. Despite its superiority, *Formbrite costs no more than ordinary drawing brass.* Get full details from your Anaconda representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5950

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can be
expensive

in instrumentation tape recorders,
as anywhere else,

space costs money

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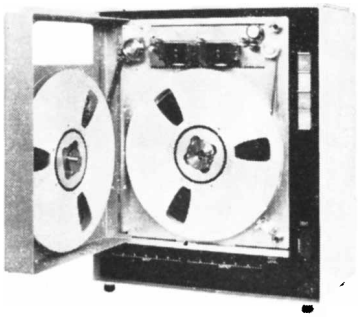

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. . . at your service on a contract basis. Here, at ELGIN MICRONICS, you'll find the specialized skills and talent you need to help keep critical projects moving . . . we're especially familiar with work involving high precision or difficult size and weight limitations. All of our people are thoroughly experienced in meeting military requirements and reliability is our long suit.

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DEVELOPMENT

From miniature synchronous motor to high-ratio precision gear train, this new and unique elapsed time indicator typifies ELGIN MICRONICS development capability. Now in wide use for reliability evaluation, it weighs less than one ounce.

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Involving both electrical and mechanical actions, this modular component of an advanced air data computer system meets extremely rigid precision requirements. It exemplifies unusual volume production capabilities at ELGIN MICRONICS.

DESIGN

Here is an unusual timing device used in a missile actuating system. ELGIN MICRONICS engineers had it ready for production only thirty days after the requirement was defined—a striking example of design capability.

for instruments that read out reliability

ELGIN MICRONICS

DIVISION OF ELGIN NATIONAL WATCH COMPANY, ELGIN, ILLINOIS

WHERE THE WORLD OF TOMORROW IS NOW

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Reflecting the tremendous growth of Philco's computer business, this huge new ultra-modern plant is devoted exclusively to research, engineering, manufacturing and marketing of Philco Electronic Data Processing Systems. Comprising nearly a quarter-million square feet of floor space, it is headquarters for a staff of more than 1200 electronic scientists, engineers and skilled technicians. Fully-equipped with the most advanced research, testing and production facilities; manned by the leading scientific skills in the industry; it is the nation's outstanding computer plant. This new Computer Center will enable Philco to keep pace with the rapidly expanding demands of industry, government and science for the Philco 2000 Large-scale Data Processing System. You are cordially invited to visit the new Philco Computer Center and see the Philco 2000 in operation.

Computer engineers and scientists are invited to investigate the advancement opportunities at Philco.

PHILCO 2000 DATA PROCESSING SYSTEM. World's First in All-transistor Logic and Circuitry.

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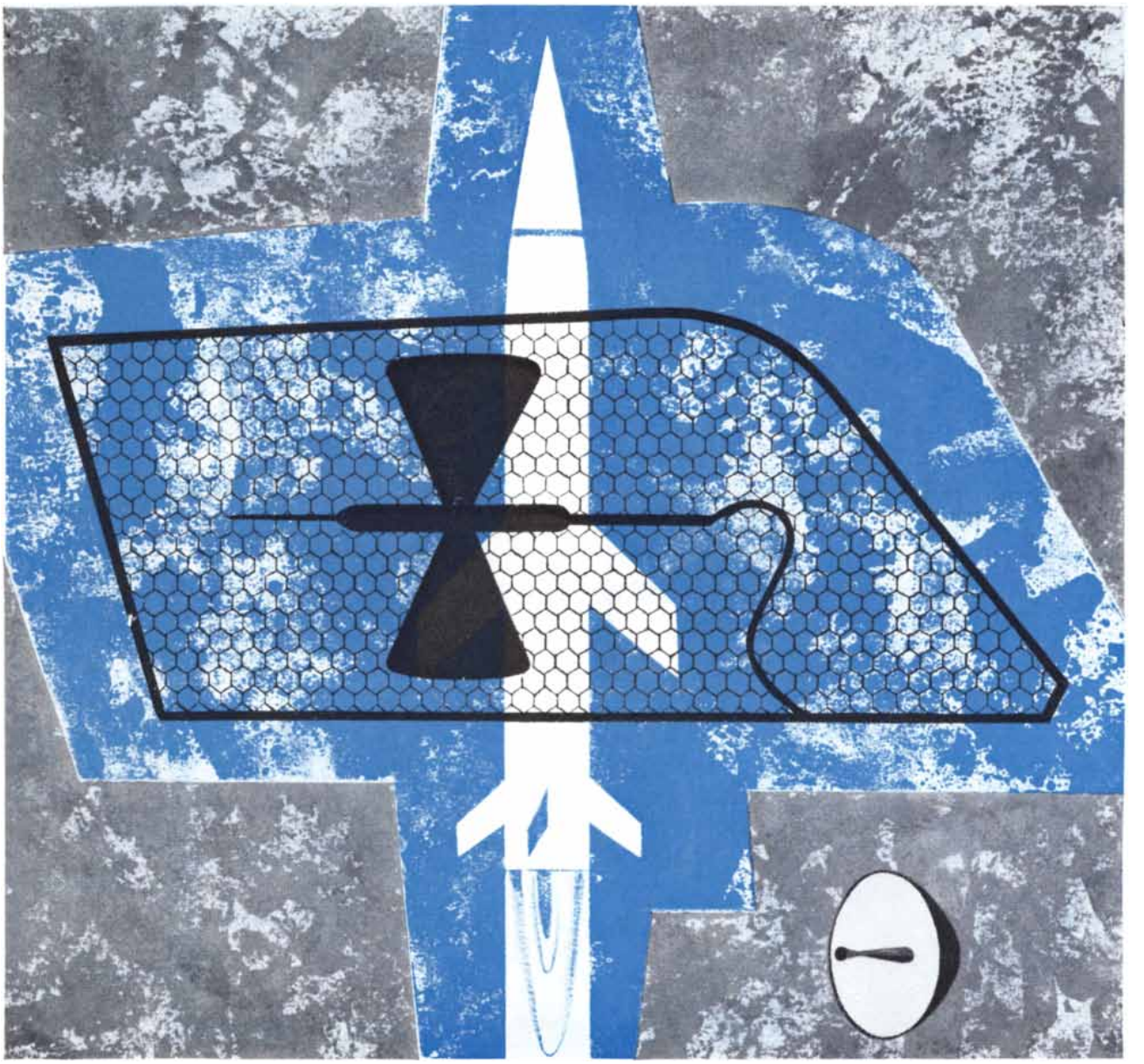

ANTENNAS INTEGRATED WITHIN PLASTIC PRIMARY STRUCTURES

Our design engineers are now totally integrating all communications, telemetry and navigational antennas and reflectors within primary structures. Already fully tested and in actual use, these plastic (honeycomb and foam sandwich; solid laminated) primary structures with plastic skins do not interfere with reception or transmission units hidden inside. All-plastic fins, wing tips and other assemblies for aircraft and missiles give a highly efficient weight-strength ratio, while providing aerodynamically clean lines that are unbroken by stubs or ports. The marriage of plastics and antennas is a capability developed and advanced by Brunswick as a result of many years experience with aircraft and missile problems. For every new primary structure problem, Brunswick draws on its vast reservoir of knowledge gained through this experience. Brunswick can not only construct entire, integrated units, but can provide complete in-house design and testing for unique components that will meet the most rigid specifications. Can Brunswick help you? Investigate! Take time right now to call or write: The Brunswick-Balke-Collender Company, Defense Division Sales Manager, 1700 Messler Street, Muskegon, Michigan.

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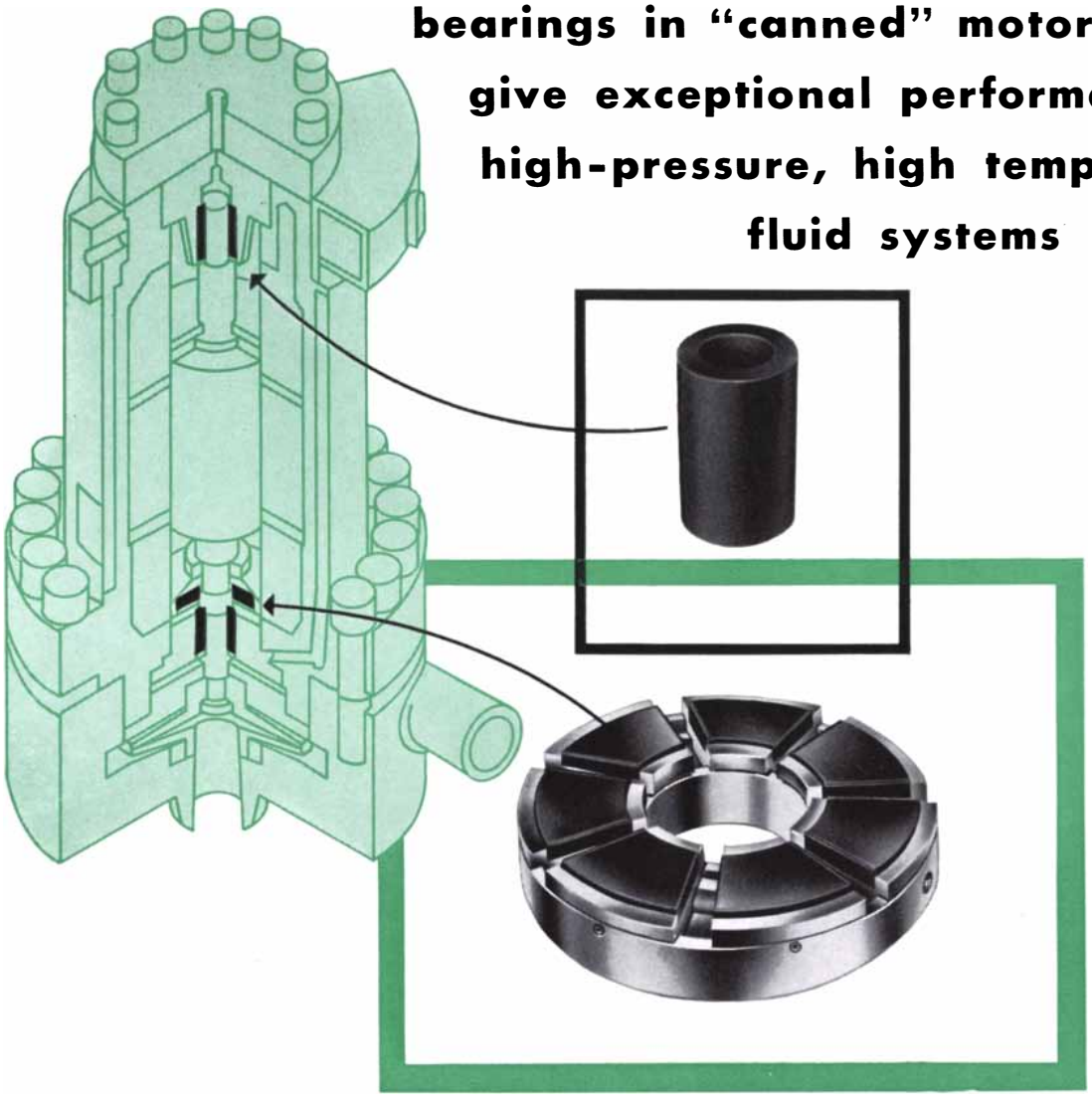
(CARBON-GRAPHITE)

bearings in "canned" motor pumps give exceptional performance in high-pressure, high temperature fluid systems



Special hermetically sealed motor-pumps, known also as "canned" motor pumps, were developed by Westinghouse Electric Corporation to handle radioactive water with zero leakage. These same pumps have proven a convenient means of pumping high temperature fluids for a number of nuclear reactors and other high pressure, high temperature fluid applications.

The thrust bearing utilized in the "canned" motor pump is a self-equalizing, water-lubricated, pivoted-pad bearing with inserted GRAPHITAR bearing surfaces. The radial sleeve bearings are also made of GRAPHITAR and are designed to be lubricated by the pumped fluid only . . . in the case of pumps used in nuclear reactors, only radioactive hot water is employed as lubrication.

GRAPHITAR is utilized extensively in tough applications because of its many unusual properties. It is non-metallic, resists chemical attack, has self-lubricating properties, a low coefficient of friction, is mechanically strong, hard as steel and lighter than magnesium. GRAPHITAR will not warp and shows no expansion or contraction in extreme temperature changes.

This versatile engineering material, GRAPHITAR, may well solve one of your difficult design problems. For further information on GRAPHITAR and its many applications, send for our engineering manual No. 20.

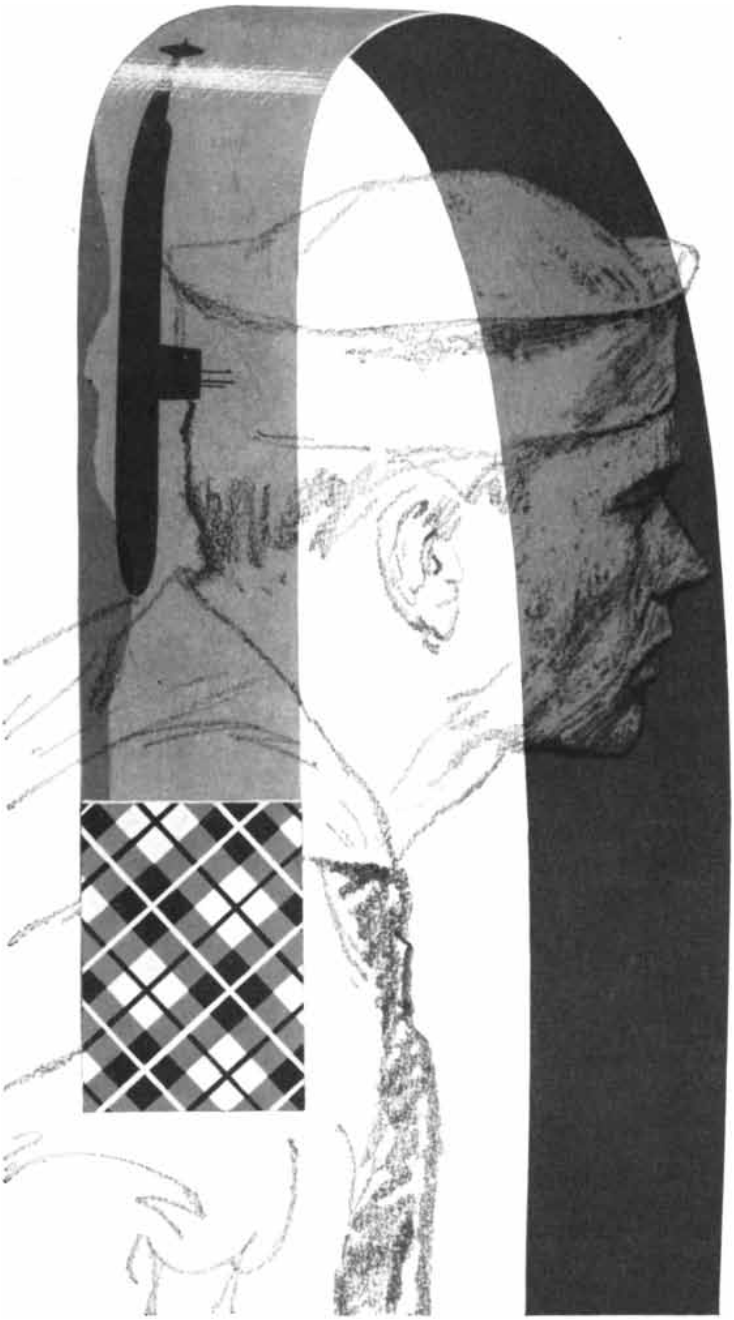
R-266-1

THE UNITED STATES GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW 6, MICHIGAN

GRAPHITAR® CARBON-GRAPHITE • GRAMIX® POWDER METALLURGY • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES

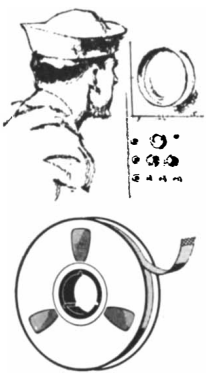
Sonar student takes his training on a simulated sea— with magnetic tape **SEAPRINTS**



TODAY'S STUDENT SONARMAN is certain of his skills long before he gets his sea legs. He meets his tests in an electronic classroom based on dry land—and his tutor is a sonar console and a reel of magnetic tape.

Seaprints—magnetic tape recordings of problem situations encountered at sea – are pre-taped as problems occur. These are combined in turn on a magnetic tape master. The one-inch master tape carries as many as 70 multiplexed electronic signals—13 tracks of data, plus one audio track of the sonar instructor's voice.

When the master is played into the sonar console at the training center, the signals on it reconstruct the problems just as they occurred at sea. The sonar student thus gains experience in solving actual problems he will encounter at sea—and perfects his skills in the classroom. The advantages of the electronic classroom are many and manifest. Without calling ships into service, more sonarmen can get better training in less time—and at less cost.



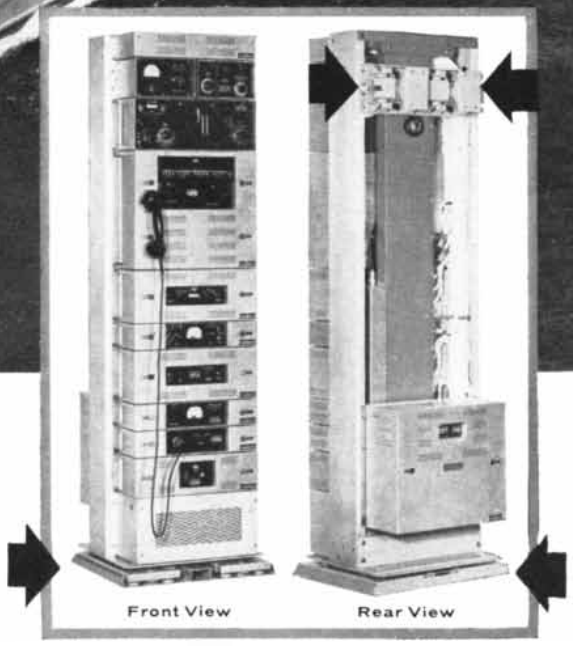
Versatile "SCOTCH" BRAND Magnetic Tape for instrumentation is one of the few media that could perform this vital service—and this training program is but one of the ways "SCOTCH" BRAND Tapes now serve the future. The first practical magnetic tape devised, "SCOTCH" BRAND Magnetic Tape controls industrial automation, helps the scientist explore earth, sea and space —and remains the leader as newer, more sensitive tapes are developed for science, business and industry. For details on tape constructions that can serve your needs, write Magnetic Products Division, Dept. MBO-50, 3M Co., 900 Bush Avenue, St. Paul 6, Minnesota.

how ROBINSON *Vibration and Shock Control*

PROTECTS PERFORMANCE and assures RELIABILITY in Shipboard Installations . . .

Robinson has pioneered in the development and production of all-metal, low frequency vibration ***and*** shock mounting systems for the Navy's latest communications, radar, sonar and electronic computing equipment.

These are the **first all-metal environmental control systems** to be accepted by the Navy, and many are already in service aboard the latest missile cruisers, destroyers, aircraft carriers and nuclear submarines throughout the fleet.



This is Robinson Model W664-3 with the Collins AN/URC-32 single sideband shipboard transceiver installed. This all-metal mounting system includes a heavy duty, dual stage base and a stabilizer unit which is mounted on the rear of the equipment.

Exclusive dual stage concept and highly damped MET-L-FLEX® resilient cushions assure the full range of vibration isolation and shock attenuation—double protection for extra reliability! *Send for FREE brochures.*

VIBRATION CONTROL IS RELIABILITY CONTROL

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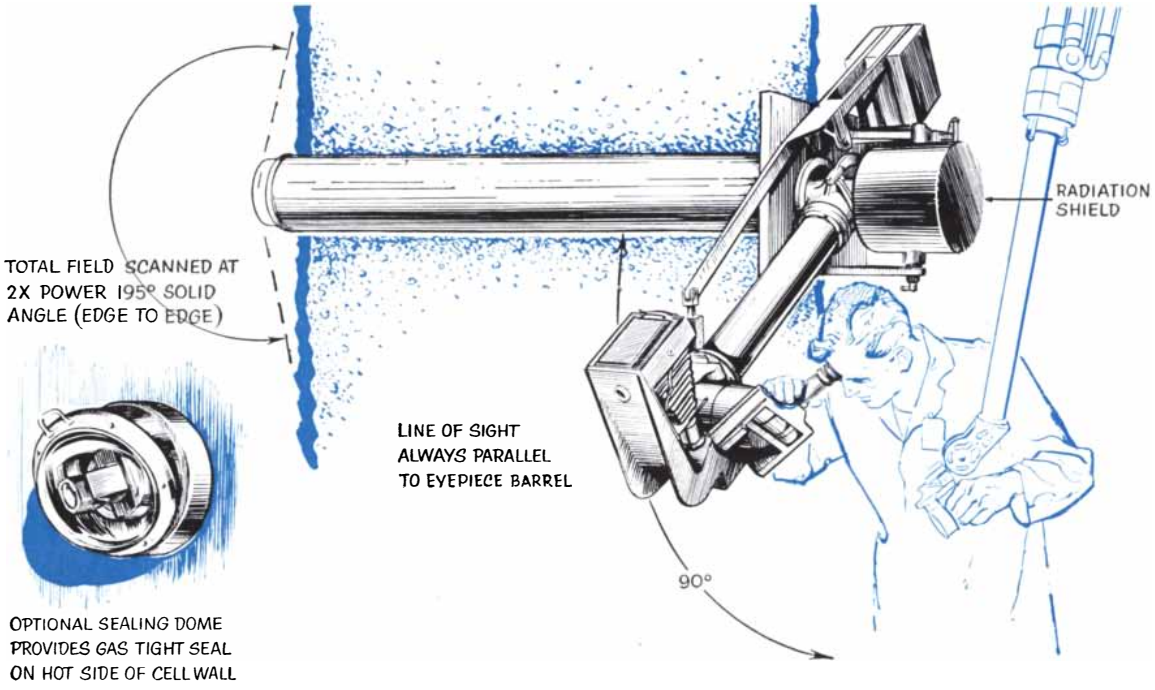


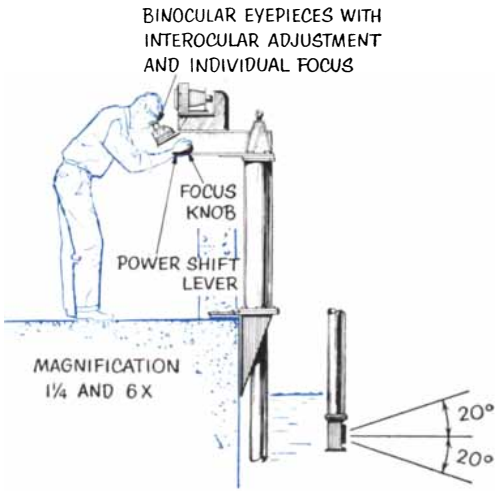
Kollmorgen instruments are bridges between the eye and the invisible

Danger of radioactive contamination prevents a contiguous close look at many vital operations and processes. Kollmorgen remote viewing equipment lets you see with complete safety and maximum freedom of observation.

Kollmorgen designs and manufactures more remote viewing and inspection equipment for use in "hot" labs and reactors than any other company. Wall periscopes, underwater periscopes, microphoto periscopes, continuous strip fuel-inspection cameras and similar equipment by Kollmorgen have been installed in almost every major nuclear installation on the North American continent.

Kollmorgen is foremost in the design, development and manufacture of mechanically and electronically controlled optical instruments and systems for industrial and defense applications.

Write on your company letterhead for a copy of our new twenty-four page facilities brochure. Your copy will reach you by return mail.



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TUNES IN EVERY FABRIC'S FAVORITE WASHDAY PROGRAM

After nine years' steady growth, the simplicity of the automatic washer was being threatened by new fabrics that required special handling. Warning tags said, "Wash with Care," "Do not Agitate," "Hand Wash Only." Delicate fabrics needed gentle agitation. Wash 'n wear items required cold rinsing and slow spinning.

Controls Company of America (long creators of timers, solenoids, etc., for the appliance industry) introduced the complete answer to simplify control of the multi-fabric washer. It was the Cycle-Set Power Timer, which makes it possible for the housewife to pick the right wash cycle for any fabric simply by pushing a single button.

CREATING CONTROLS FOR TIME, TEMPERATURE, FLOW, MOTION

CONTROLS COMPANY OF AMERICA

THE AUTHORS

ROBERT JASTROW ("The Exploration of the Moon") is chief of the Theoretical Division of the National Aeronautics and Space Administration and chairman of the N.A.S.A. Lunar Explorations Working Group. He graduated from Columbia College in 1945 at the age of 19, and three years later acquired his Ph.D. in physics at Columbia University. After a postdoctoral fellowship at the University of Leiden in the Netherlands, he spent a year at the Institute for Advanced Study in Princeton, N.J., and then became a research associate in nuclear physics at the University of California. In 1953 and 1954 he was assistant professor of physics at Yale University, and from 1954 to 1958 he was a consultant to the Naval Research Laboratory in Washington. He also worked on the Navy's Vanguard satellite project, and some three years ago he switched from nuclear physics to space studies. Jastrow comments that in January, 1959, Harold C. Urey of the University of California at La Jolla delivered two lectures to the N.A.S.A. Theoretical Division and "opened our eyes for the first time to the scientific importance of the moon, leading us to make lunar studies an important part of our theoretical research-program."

RHODES W. FAIRBRIDGE ("The Changing Level of the Sea") is professor of geology at Columbia University. A native of Australia, he attended the Bedales School in England from 1926 to 1932, and then went to Queen's University in Kingston, Canada, where he acquired his B.A. in 1936. He received a Rhodes bursary, and in 1940 took his B.S. degree at the University of Oxford. From 1942 to 1946 he served in the Royal Australian Air Force, and in 1944 he took his Doctor of Science degree at the University of Western Australia, where he specialized in tectonics and sedimentation. After teaching for several years at the University of Western Australia, Fairbridge joined the Scripps Institution of Oceanography's Capricorn expedition of 1952 and 1953 to study the oceanography of the South Pacific. He was on the faculty of the University of Illinois in 1953, and spent the next year at the Scripps Institution. In 1955 he went to Columbia.

SEYMOUR LEVINE ("Stimulation in Infancy") holds a fellowship from the Foundations Fund for Research in Psychiatry, and is presently working with Geoffrey W. Harris, neuroendocrinologist at the Institute of Psychiatry of the University of London. A native of Brooklyn, N.Y., Levine took his B.A. at the University of Denver in 1948 and his Ph.D. at New York University in 1952.

ALBERT L. LEHNINGER ("Energy Transformation in the Cell") is DeLamar Professor of Physiological Chemistry and director of the Department of Physiological Chemistry at the Johns Hopkins School of Medicine. He was born in Bridgeport, Conn., in 1917. In 1939 he acquired his B.A. at Wesleyan University, and in 1940 and 1942 he received his M.S. and Ph.D. degrees from the University of Wisconsin, where he served as an instructor until 1945. From 1945 to 1952 he was on the biochemistry faculty at the University of Chicago. In 1951 he was exchange professor at the University of Frankfurt, and in 1951 and 1952 he held a Guggenheim fellowship and served as a Fulbright research professor at the University of Cambridge. He went to Johns Hopkins in 1952. Lehninger was elected to the National Academy of Sciences in 1956. He discovered in 1948 that the mitochondria are the site of oxidative phosphorylation, which is the main mechanism by which the energy of respiration is stored.

ALOHA HANNAH-ALAVA ("Genetic Mosaics") is a research associate in the newly created Genetics Institute of the University of Turku in Finland, her husband's native country. Born Aloha Hannah in Big Timber, Mont., she took her B.A. at Montana State University, her M.A. at the University of Oklahoma and her Ph.D. at the University of California. Before going to Finland she had been associated in research with the noted geneticists Richard B. Goldschmidt, H. J. Muller and Curt Stern. At the Genetics Institute of the University of Turku she is studying mutation on a grant from the International Atomic Energy Agency.

LEONARD I. GROSSWEINER ("Flash Photolysis") has since 1957 been associate professor of physics at the Illinois Institute of Technology. He was born in Atlantic City, N.J., in 1924 and studied chemical engineering at the College of the City of New York. After serving two years in the Army, he acquired his bachelor's degree in 1947. In the same year he joined the staff of the Argonne National Laboratory, where he remained until 1957. He received his

M.S. in 1950 and his Ph.D. in 1954, both at the Illinois Institute of Technology.

MILTON HILDEBRAND ("How Animals Run"), associate professor of zoology at the University of California campus in Davis, Calif., is at present spending some months in England visiting British anatomists and writing. He was born in Philadelphia in 1918, and decided at the age of six that he wanted to be a zoologist. "As a boy," he reports, "I collected skeletons. My private teaching collection now includes about 1,000 specimens from all over the world." He took his B.A., M.A. and Ph.D. degrees at the University of California; "this scholastic inbreeding," he says, "is largely responsible for my present study in England." During World War II he was an officer in the ski troops, and taught skiing, winter warfare, rock-climbing and mountain combat. During the Italian campaign he served as a battalion pack officer in charge of mule transport in the Apennines.

MEIR YOELI ("Animal Infections and Human Disease") is associate professor of preventive medicine at the New York University School of Medicine. He was born in 1912 in Lithuania, and from 1928 to 1934 studied biology and medicine at the University of Kaunas there. In 1934 he emigrated to Palestine, and served until 1938 at the Malaria Research Station of the Hebrew University in the Galilee. He then spent two years studying medicine and tropical medicine at the University of Basel, where he received his M.D. degree, and at the University of Padua. During World War II he served with the British forces as a lieutenant colonel in charge of a malaria and tropical-disease field laboratory. He returned to Palestine to lecture at the Hebrew University, and in the 1948-49 war in Israel he was commanding officer of the department of preventive medicine of the Israeli forces. From 1951 to 1953 he was a visiting investigator at the London School of Hygiene and Tropical Medicine and at the Rockefeller Institute in New York. He lectured in South Africa in 1954, and since 1956 he has held his present position at the New York University Medical Center.

LORD ADRIAN, who in this issue reviews *Speech and Brain-Mechanisms,* by Wilder Penfield and Lamar Roberts, is Master of Trinity College at the University of Cambridge. A noted physiologist, he was awarded a Nobel prize in physiology and medicine in 1932.

LIFEGUARD STATION

for a man in space

The vital Cape Canaveral nerve center for Project Mercury, the U.S. program to put a man in space, is being designed and built by Stromberg-Carlson-San Diego. Display information about the flight will be fed to the operations room from computers and from a world-wide network of tracking and telemetry stations. One wall of the 40 by 60 ft. operations room will be a large map display, visually summarizing all pertinent information about the flight. It will show the capsule moving along its orbital flight path around the earth and will also show the location, range and status of all ground based equipment and communications links. The operations room will contain display consoles presenting information to the Flight Director, Chief Flight Surgeon, Capsule Communicator, Flight Dynamics Officer and other decision-making personnel. For information on how Stromberg-Carlson-San Diego can help solve your data/display problems, write to Department A-42, 1895 Hancock Street, San Diego 12, Calif. Telephone CYpress 8-8331.

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A DIVISION OF **GENERAL DYNAMICS CORPORATION**

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Bendix G-20

the new data processing system with the ORGANIZATION CHART *concept*

"Organization Chart" design in the Bendix G-20 means far faster, more efficient processing of scientific and business problems. The reason is clear:

The electronic manager of every data processing system is a computer. But most are poor "bosses" because they cannot delegate authority, or even supervise more than one operation at a time. Many computers run operations as complex as your own business, but with an inefficiency that you would never tolerate. Bendix engineers saw this shortcoming, and turned for a solution to the organization chart common to any well-managed business.

The G-20 Central Processor, or computer, has a staff of well-taught subordinates that can take instructions from the "boss" and go to work on their own, directing the workers that perform such tasks as reading punched paper tape and cards, looking up data on magnetic tape, and printing results. The "boss" can direct numerous subordinates, and without human intervention, schedule the work for each, making sure the most important work is done first. While the subordinates handle the details, the Central Processor is free to do the all-important computing.

This "organization chart" delegation of authority means several operations may be performed simultaneously, and with a minimum of equipment. The results? Call it "low cost per operation", or "just plain efficiency", but it is all the same . . . the Bendix G-20 gives you more performance per dollar than any other data processing system. The actual performance specifications listed at the right show the tremendous speed and power of the G-20. Components and design are the most modern in the industry today. System sizes can vary from a medium-scale system to a very large system with remote on-line or off-line sub-systems. Write for complete descriptive literature.

BENDIX AVIATION CORP., COMPUTER DIVISION Dept. C25, Los Angeles 45, California

SPECIFICATIONS:

MEMORY: Core, to 32,768 words in 4096 word modules.

EXECUTE +: 7 μs. avg., fixed point, one-word precision. 13 μs. avg., floating point, one-word precision.

EXECUTE ×: 49 μs. avg., fixed point, one-word precision. 49 μs. avg., floating point, one-word precision.

ARITHMETIC: Built-in floating pt., 12 dec. digit precision.

CIRCUITRY: Solid-state; parallel; 2.5 kva.

PROGRAMMING: Symbolic assembler or algebraic compiler.

INPUT/OUTPUT: 165,000 char./second max., asynchronous.

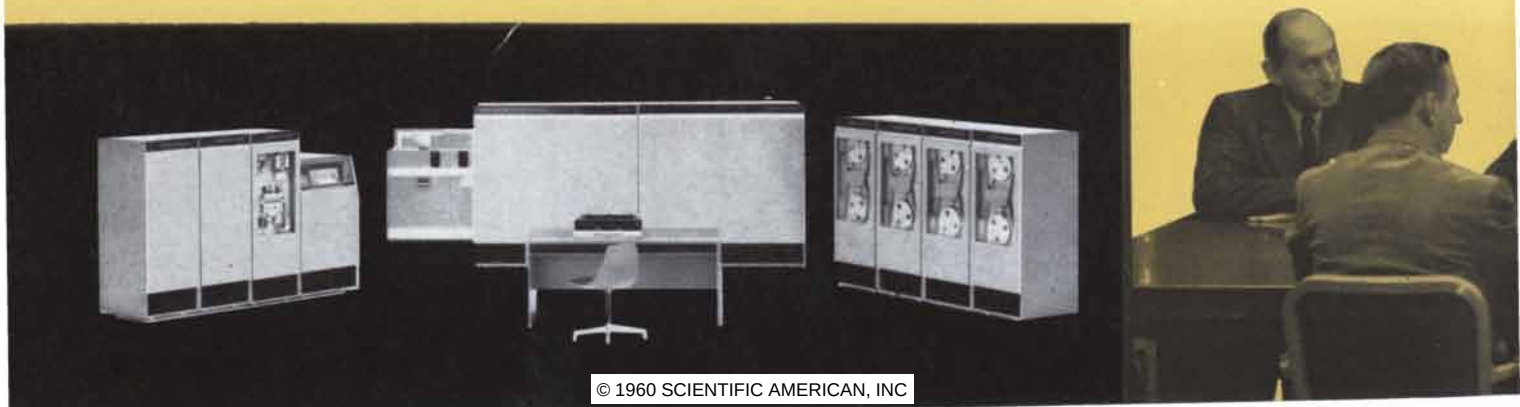
MAGNETIC TAPE: 120,000 decimal digit/second read-write.

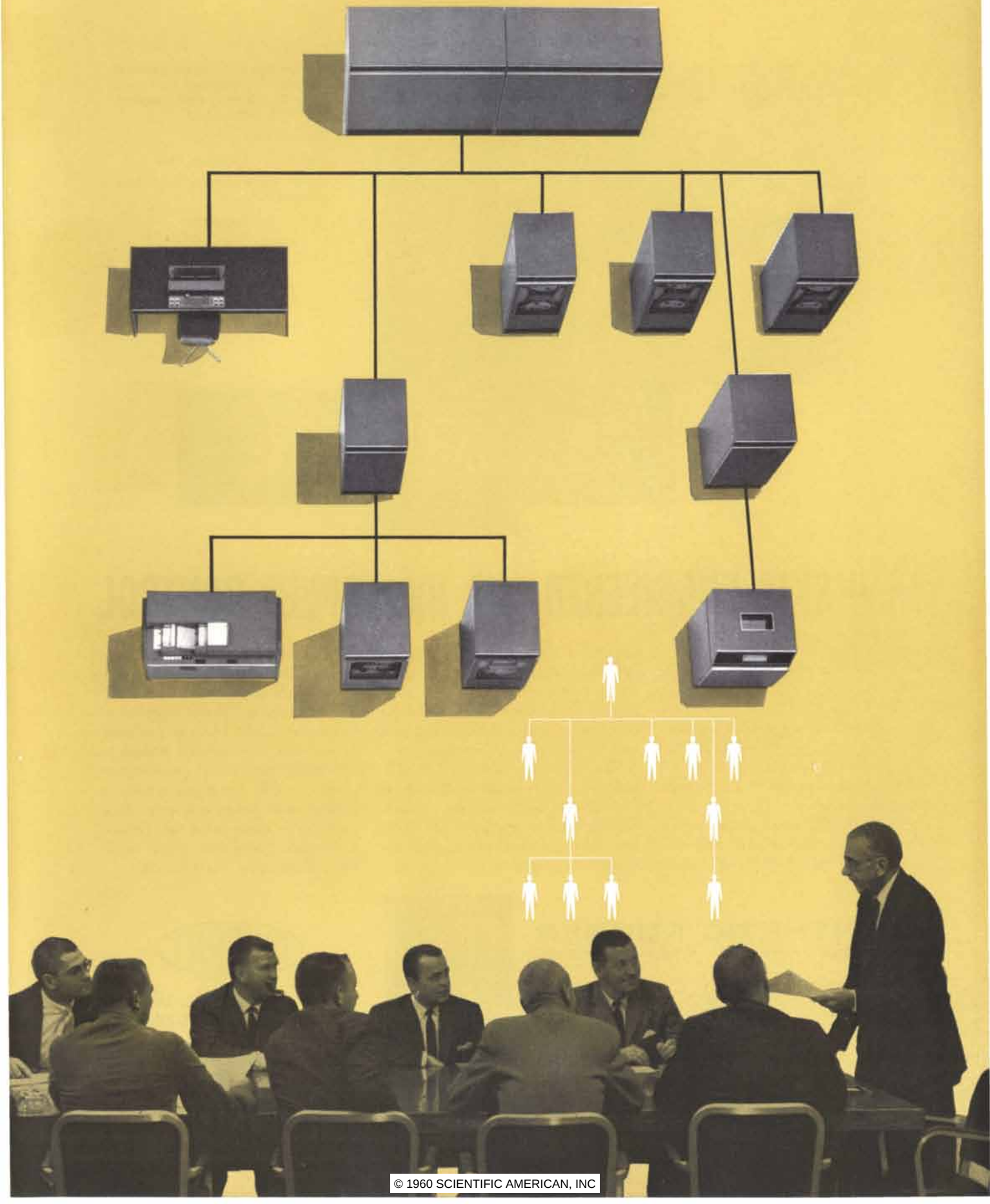
LINE PRINTERS: 600 lines per minute.

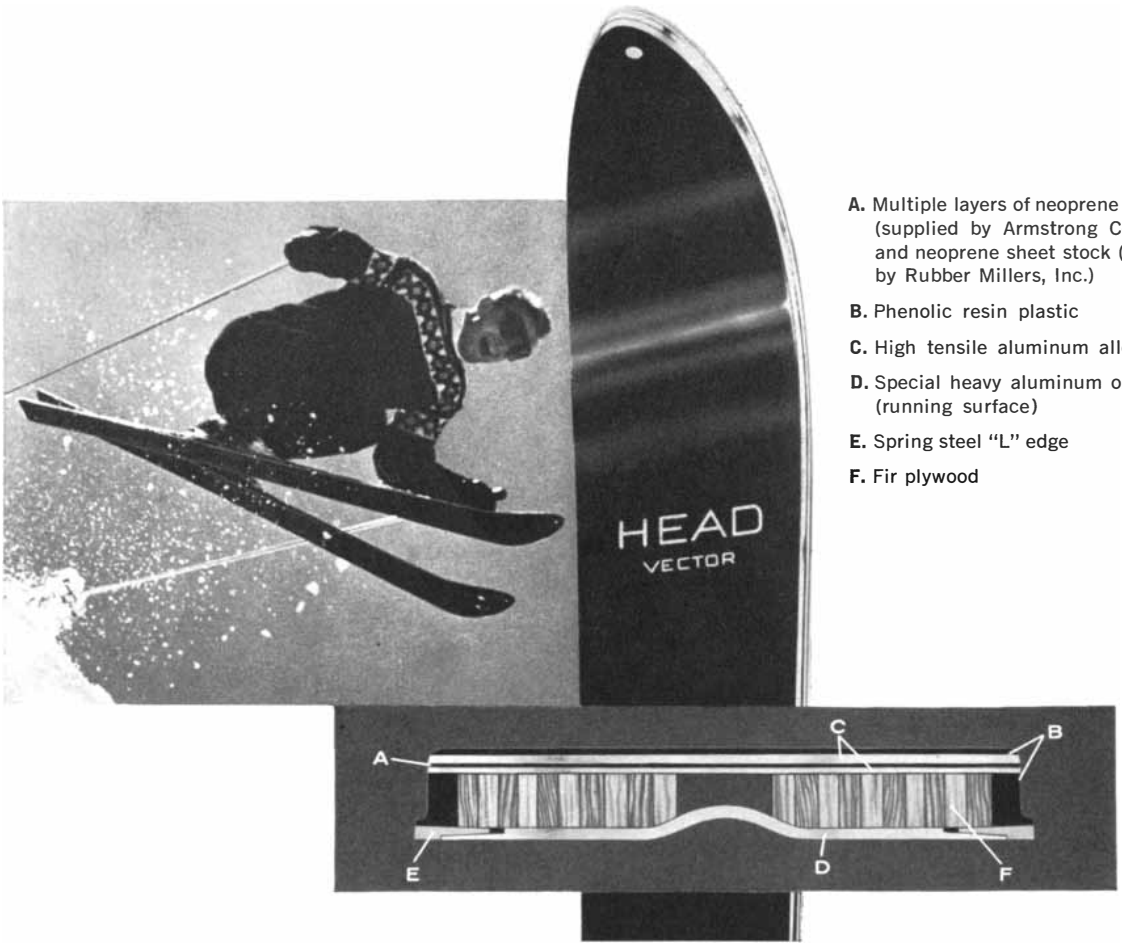
PUNCHED TAPE: 500 or more character/second readers. 100 or more character/second punches.

PUNCHED CARDS: Standard high-speed 80 column units.

CONTROL BUFFERS: 1024 character memory for data and commands. Controls transmission on-line or off-line.







A. Multiple layers of neoprene adhesive (supplied by Armstrong Cork Co.), and neoprene sheet stock (supplied by Rubber Millers, Inc.)

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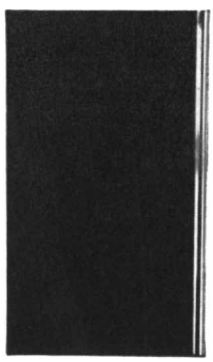

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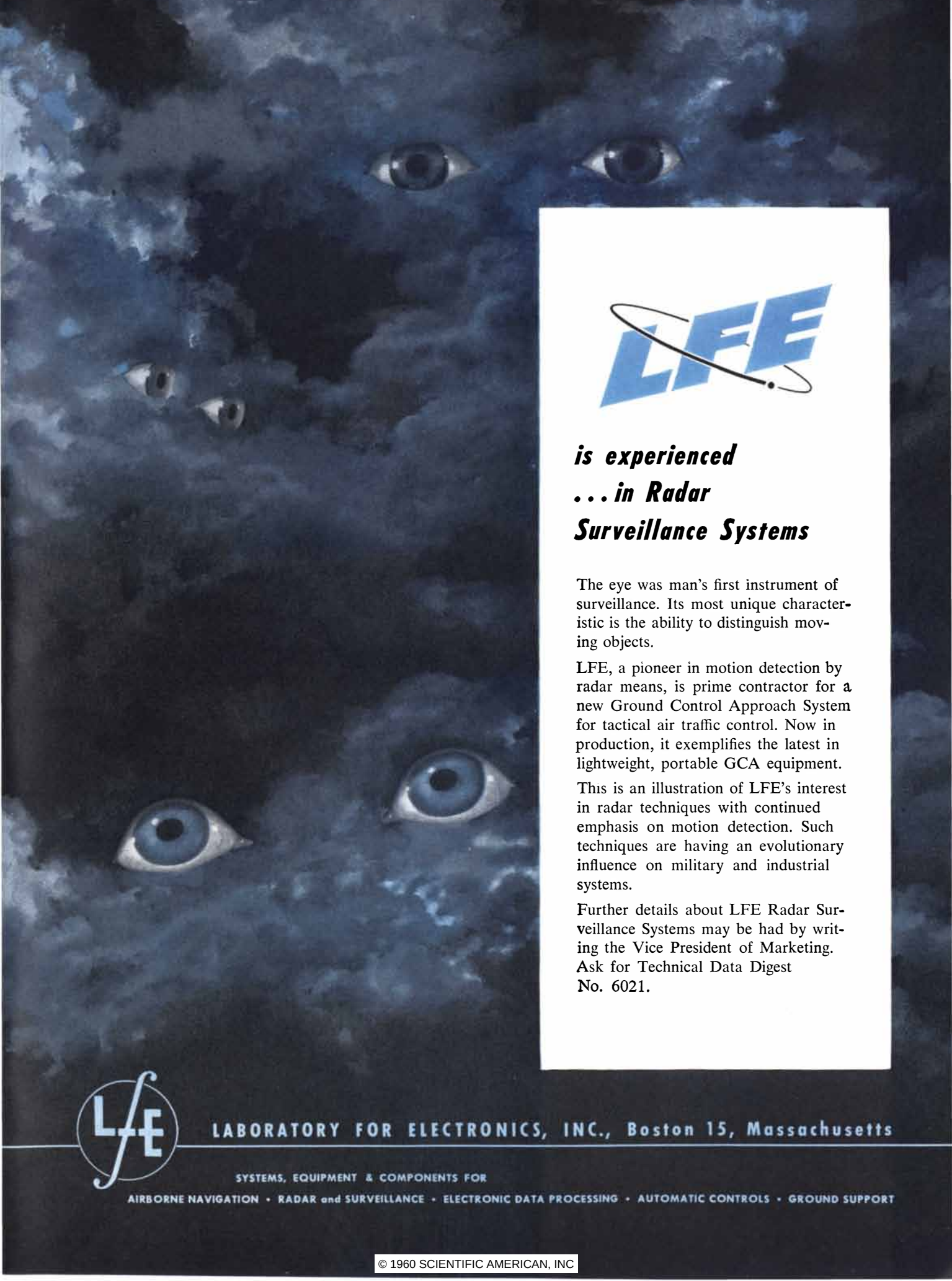

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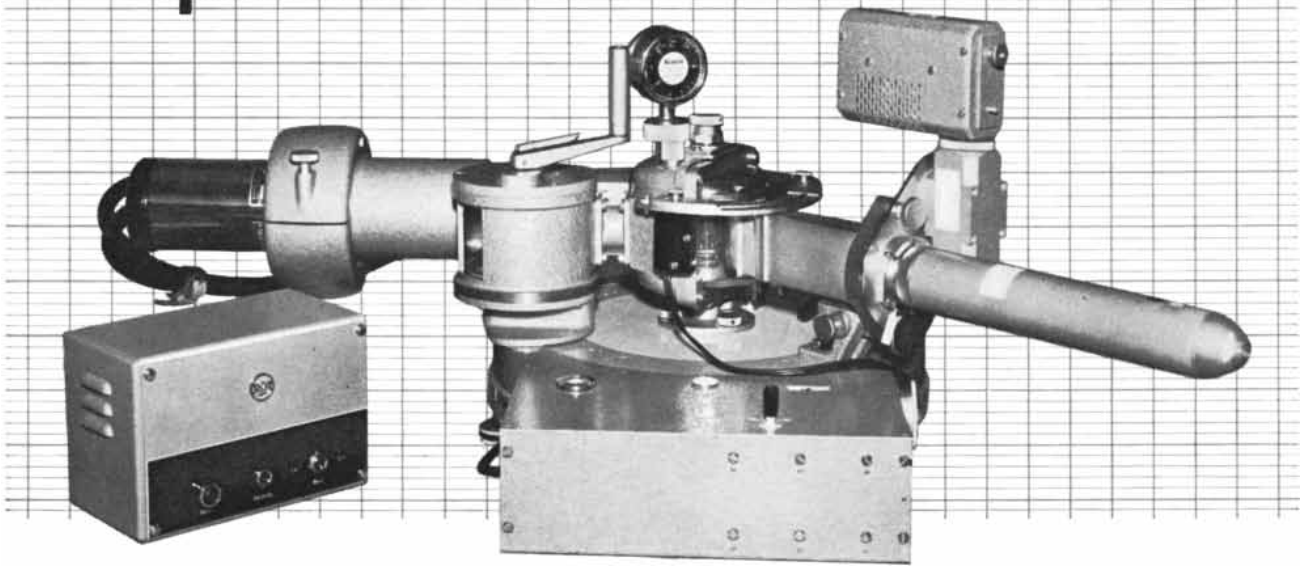

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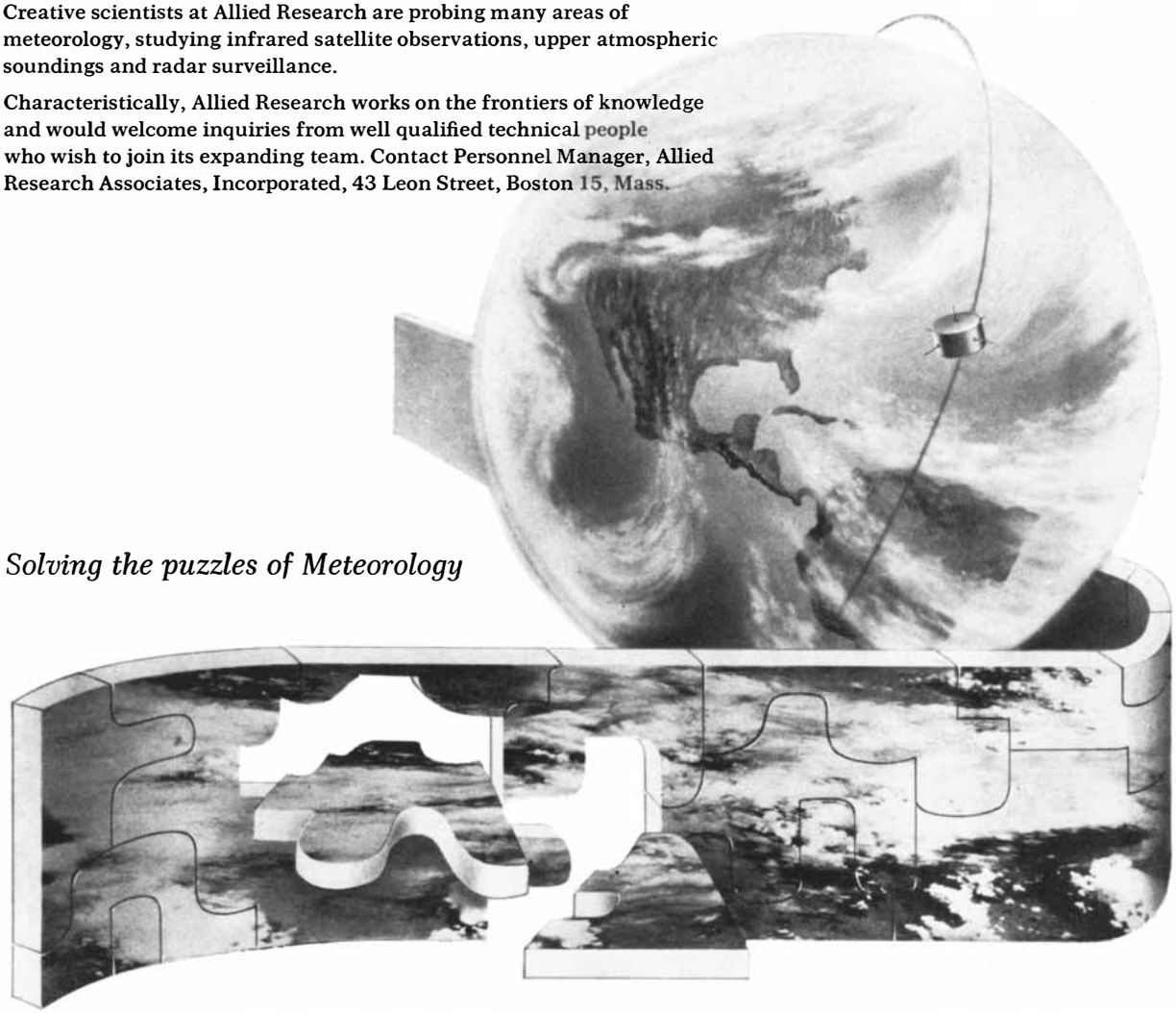

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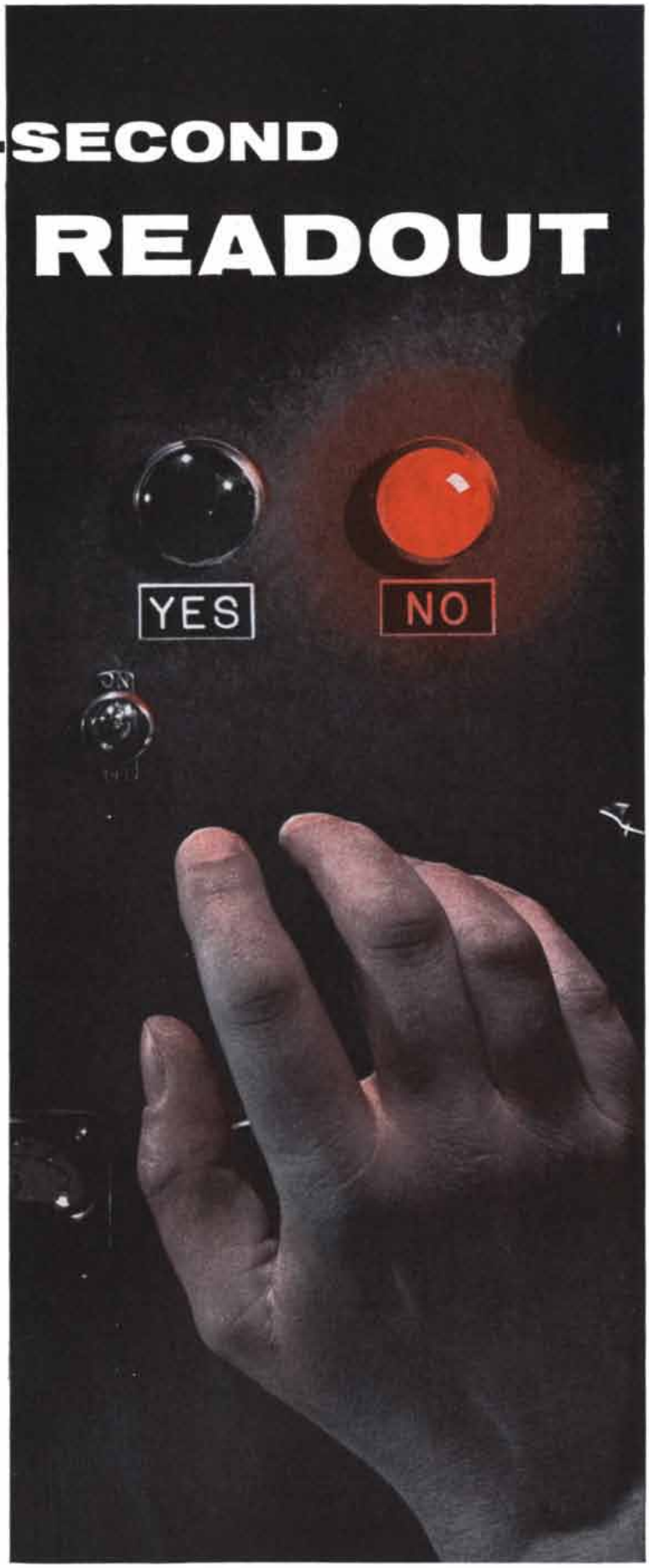

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Gilbert Lewis... on practical aims

"The scientist is a practical man and his are practical aims. He does not seek the *ultimate* but the *proximate*. He does not speak of the last analysis but rather of the next approximation. His are not those beautiful structures so delicately designed that a single flaw may cause the collapse of the whole. The scientist builds slowly and with a gross but solid kind of masonry. If dissatisfied with any of his work, even if it be near the very foundations, he can replace that part without damage to the remainder. On the whole, he is satisfied with his work, for while science may never be wholly right it certainly is never wholly wrong; and it seems to be improving from decade to decade.

"The theory that there is an ultimate truth, although very generally held by mankind, does not seem useful to science except in the sense of a horizon toward which we may proceed, rather than a point which may be reached."—*The Anatomy of Science, 1926.*

Established 1845 SCIENTIFIC AMERICAN May, 1960 Volume 202 Number 5

The Exploration of the Moon

The importance of the enterprise is increased by the fact that the surface of the moon, lacking an erosive atmosphere, has preserved a record of the history of the solar system

by Robert Jastrow

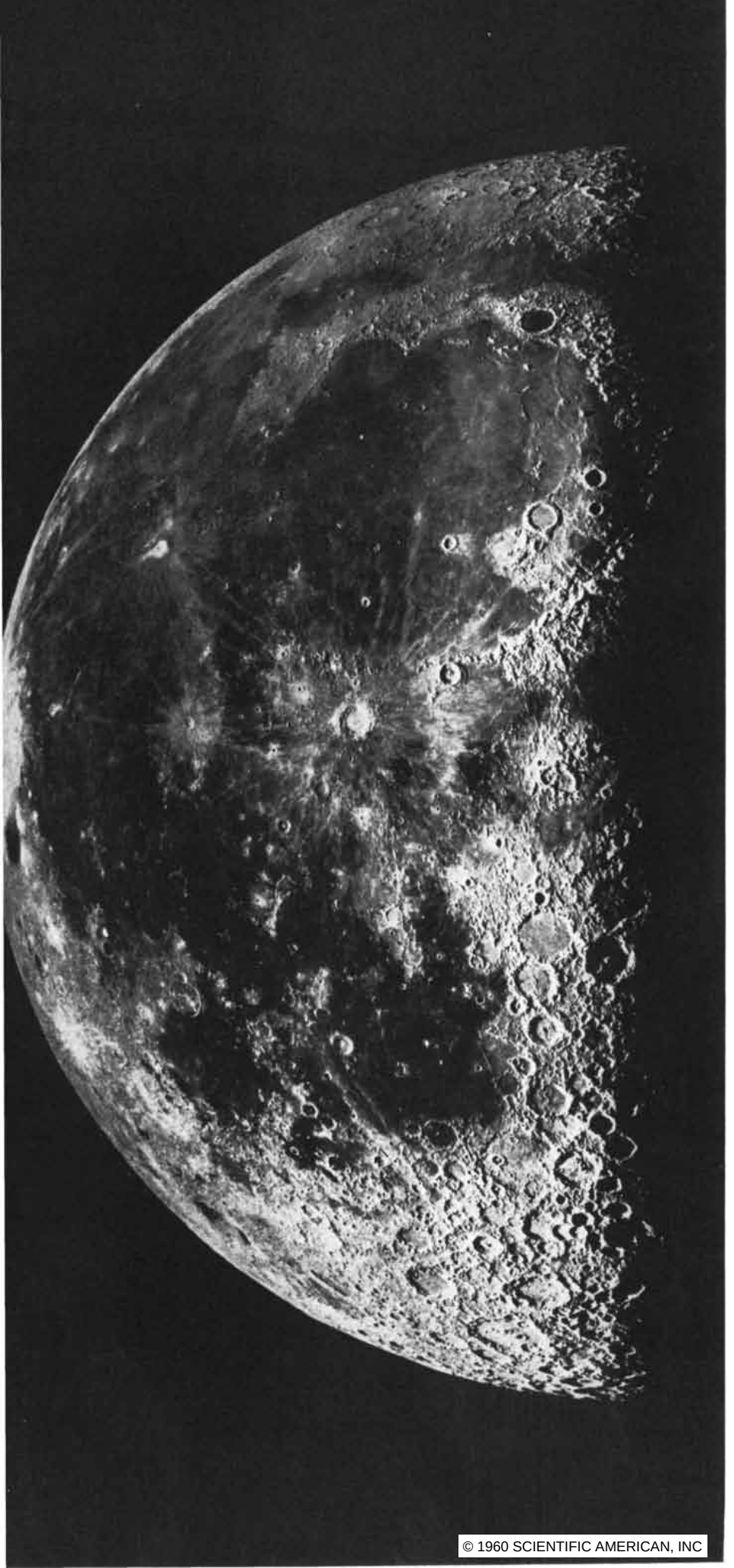
The first extraterrestrial body to be explored will undoubtedly be the moon. The moon is the earth's nearest neighbor. Mars and Venus are at least 100 times more distant, and a rocket that would take months to reach one of these planets can travel to the moon in a day or two. An instrument station on the moon could communicate with the earth with greater ease than one on Mars or Venus. The moon is a way-station en route to the planets, and a testing ground for the development of the rocket technology and scientific instrumentation of planetary exploration.

By a fortunate coincidence the moon also has a great importance for the scientist. In fact, a growing body of scientific opinion holds that the moon will in many ways more richly reward the effort to reach it than will either Mars or Venus. To investigators preoccupied with the remarkable developments in contemporary astronomy and physics, the moon has seemed a dead and changeless world. But there has been a growing realization that out of its very deadness and changelessness the moon may yield the answers to some fundamental and universal questions about the solar system and the universe at large. Harold C. Urey of the University of California at La Jolla has been the most vigorous and effective advocate of this point of view. Indeed, he has been almost single-handedly responsible for the revival of interest in the physics of this hitherto neglected body.

The moon is an astronomical Rosetta stone. Because its surface has preserved the record of ancient events, it holds a key to the history of the solar system. The air and water that support life on the earth continuously wear away the surface features of our planet. Processes in the interior of the earth heave up chains of mountains for demolition by the forces of erosion, and the cycles of building and erosion from one epoch to the next erase the record of the past. Similar processes presumably occur on Mars and Venus. The moon, on the other hand, has neither atmosphere nor oceans, and has never been eroded by wind and water. The lunar surface does disintegrate to some extent under a hail of small meteorites, and exposed rocks may flake as a result of the great difference between the temperature of the lunar night and that of the lunar day. But such erosion is slight in comparison to that on earth. Furthermore, the circular formations that dominate the moon's topography indicate that its crust has never undergone the violent changes which are involved in mountain-building processes on earth. Otherwise the circular craters of the moon would have been distorted out of all recognition in a few tens of millions of years, and the major features of the lunar surface would be the irregular linear structures so characteristic of the earth's surface. (One of the rare linear structures on the moon is the so-called Straight Wall, a cliff 60 miles long and 800 feet high. This structure is shown in the photograph on page 67.) The dead surface of the moon probably possesses features that are some four billion years old.

Upon this surface cosmic dust has rained for eons unimpeded by any atmosphere. Here is a biographical record of the solar system. Moreover, the cosmic sediment may contain complex organic molecules—precursors of living matter—and perhaps even living spores that have drifted in from other planets or from outside the solar system.

One of the primary objectives of the first-hand exploration of the moon will be to obtain evidence on its temperature history. Such evidence will help to settle uncertainties about the origin of the sun and the planets, and indicate whether the solar system is a common or a rare phenomenon in the universe. One of the older ideas of planetary creation—the "collision" hypothesis—postulates that a passing star tore great masses of material from the sun. Condensing first into hot, liquid protoplanets, this material then cooled to form the planets. But stars are so far apart that such encounters must be extremely rare. The collision hypothesis therefore implies that planets are similarly rare in our galaxy. The more widely accepted idea—the dust-cloud hypothesis—holds that stars arise from the condensation of the immense clouds of dust and gas that are observed in interstellar space. Variations in the density of such a cloud bring into action gravitational forces that form the stars, and local variations within the cloud give rise to planets. According to



this scheme, planets may grow by the accretion of dust particles, or they may come into being when small, solid planetesimals fall together. In either case a planet would be cool at birth. The dust-cloud hypothesis implies that planets and planetary satellites such as the moon may be nearly as numerous as stars, because they are a natural accompaniment of star formation.

A cool birth does not exclude the later heating and melting of planetary bodies by the radioactive elements that they contain. However, in the case of a relatively small body such as the moon, the heat of radioactivity would be lost at the surface very rapidly. In fact, Urey, and more recently Gordon J. F. MacDonald of the University of California at Los Angeles and the National Aeronautics and Space Administration, have shown that radioactivity alone could not raise the temperature of the entire moon to the melting point unless the primitive moon were already quite warm at the time of its creation. According to MacDonald's latest calculations, the heat generated by the radioactive elements would probably not be sufficient to produce extensive melting unless the moon were initially at a temperature greater than 600 degrees centigrade. This high initial temperature would be improbable in the product of a dust cloud, but it would be more than likely if the moon arose from hot gases pulled out of the sun in an encounter with another star.

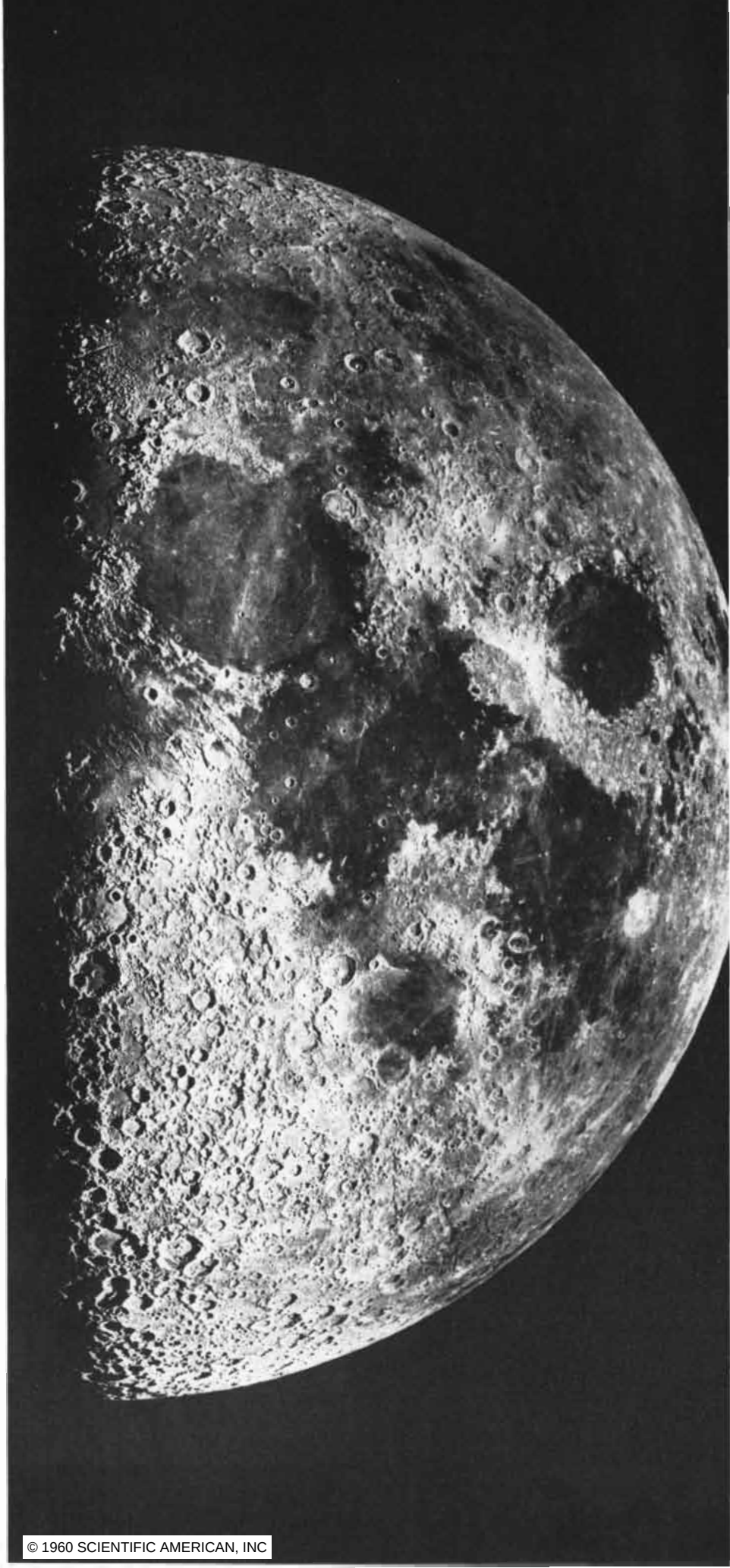
Some evidence gained by remote observation from the earth indicates that the moon has never been molten. There is, first of all, the shape of the moon. If the moon were a warm body with a relatively plastic interior, its rotation about its own axis would give rise to an equatorial bulge like that of the earth. This bulge is produced by centrifugal forces that depend on speed of rotation. The earth's 24-hour rotation-period has produced a bulge of 21 kilometers (13

THE MOON is shown on these two pages in its last quarter (*left*) and first quarter (*right*). The terminator (the line dividing the lighted hemisphere from the dark hemisphere) is at the inner side of each picture. The north pole of the moon is at the top. The crater Copernicus is in the center of the photograph at left. Among the lunar features discussed in this article is Mare Imbrium, the large dark area above Copernicus. Rainbow Bay is the "inlet" at top left in Mare Imbrium. Half an inch to the left of the terminator and about an inch below the center is a vertical row of three large craters. The middle crater

miles). Because the moon rotates more slowly on its axis—only once in 28 days—its equatorial radius should be only 50 meters greater than its polar radius. In actuality the equatorial radius is one kilometer greater. Moreover, there is a bulge in the side of the moon that always faces the earth. This "moon nose" has been pulled out by the gravitational attraction of our planet. According to calculations based on the known force of gravity, the nose should be about 40 meters high. In reality, it is about a kilometer high.

The explanation for these discrepancies probably lies in the fact that the moon was once much closer to the earth and rotated much faster on its axis. The enormous forces then prevailing molded the moon in its present shape. But these forces waned as the moon swung out on a more distant orbit and turned more slowly on its axis. This happened no later than a few tens of millions of years after the birth of the moon. In the subsequent four billion years the moon has retained the irregular shape it acquired in its infancy. If the moon had been plastic at any time, the bulges would have sunk into its interior. The preservation of these irregularities shows that for most of its history the interior of the moon has been quite cold and mechanically quite strong.

Measurements made with the help of artificial satellites have recently disclosed that the earth also departs significantly from its calculated shape. Bulges in the Northern and Southern hemispheres give it a slightly pearlike configuration. Furthermore, the equatorial bulge is somewhat greater than was expected. In fact, the present equatorial bulge must have come into existence some 100 million years ago, when the earth was rotating faster and its day was shorter. Thus the interior of the earth, unlike that of the moon, is sufficiently



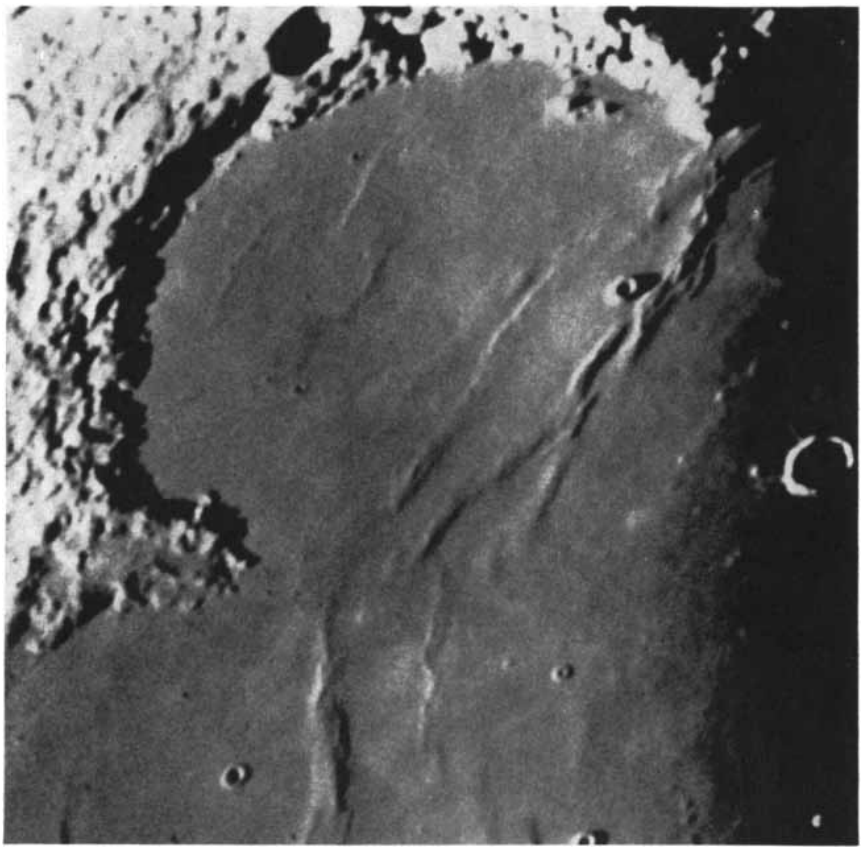
is Alphonsus. The Straight Wall is slightly below and to the left of Alphonsus. Somewhat lower and nearer the terminator is the region of the volcanic type of crater enlarged in the illustration on page 68. In the center of the photograph at right the large dark area with the irregular outline is the Sea of Tranquility. The crater Theophilus, with its prominent central peak, is the large crater immediately beneath the lowest extension of the Sea. The photographs of the moon on these two pages were made with the 36-inch refracting telescope of the University of California's Lick Observatory on Mount Hamilton.

warm and plastic to respond to changes in rotation rate, although with a lag of 100 million years.

The orbit of the first closely tracked lunar satellite will be able to measure the irregularities in the shape of the moon with great accuracy. The same observations will yield another crucial bit of evidence to decide whether the moon has ever been molten. Certain characteristics of the satellite orbit will show whether the lunar material has a relatively even density. If the moon has ever been completely molten, its iron will have collected in its core, as has the iron of the earth. On the other hand, if the moon grew by the accretion of small, cool bodies, it is likely to have a "raisin-bread" structure in which chunks of metal are spread evenly among the lighter materials.

The chemical composition and physical characteristics of the lunar surface are also important clues to the temperature and other conditions both at the time of the moon's birth and during its later development. Telescopic observations have produced a tantalizingly incomplete picture of the lunar surface, a picture that is compatible with several different conjectures as to what the surface is really like. The dominant features of the lunar landscape are craters and dry "seas," or maria. At one time it was widely believed that the craters were volcanic in origin. The U. S. geologist G. K. Gilbert dealt this idea a heavy blow in 1892, when he pointed out that lunar craters have virtually none of the characteristics of volcanoes. Among the tens of thousands of craters on the moon, only a dozen resemble terrestrial volcanoes [*see illustration on page 68*]. Most students of the moon now agree that meteorite collisions and not vulcanism created the vast majority of the craters visible on the moon.

The absence of lunar volcanic activity reinforces the picture of the moon as a relatively cold planetary body. It is true that in 1958 the Soviet astronomer Nikolai A. Kozyrev made observations that indicated such activity in the crater Alphonsus [*shown in the illustration on the opposite page*]. However, an extended discussion at the Space Exploration Symposium in Washington last year brought general agreement that what Kozyrev had observed must have been simply the release of residual gas and not a true eruption.



RAINBOW BAY is a semicircular "inlet" on the northern shore of Mare Imbrium. In 1892 G. K. Gilbert suggested that the bay was created by a large object that smashed into the moon. This photograph and those on pages 65 through 67 were made by Gerard P. Kuiper with the 82-inch reflecting telescope at the McDonald Observatory on Mount Locke in Texas.

In his 1892 lecture Gilbert asserted that meteorites had probably created some of the lunar seas as well as the craters. He reasoned that the flying fragments of a giant meteorite had carved the series of deep valleys that radiate from Mare Imbrium. The fragments would have had to be large and considerably denser than the material of the lunar surface. Gilbert suggested that they came from an object 100 miles in diameter. Striking the moon at an oblique angle, the meteorite first created the "inlet" in Mare Imbrium known as Rainbow Bay [*see illustration at left*] and then came to rest in the center of the sea.

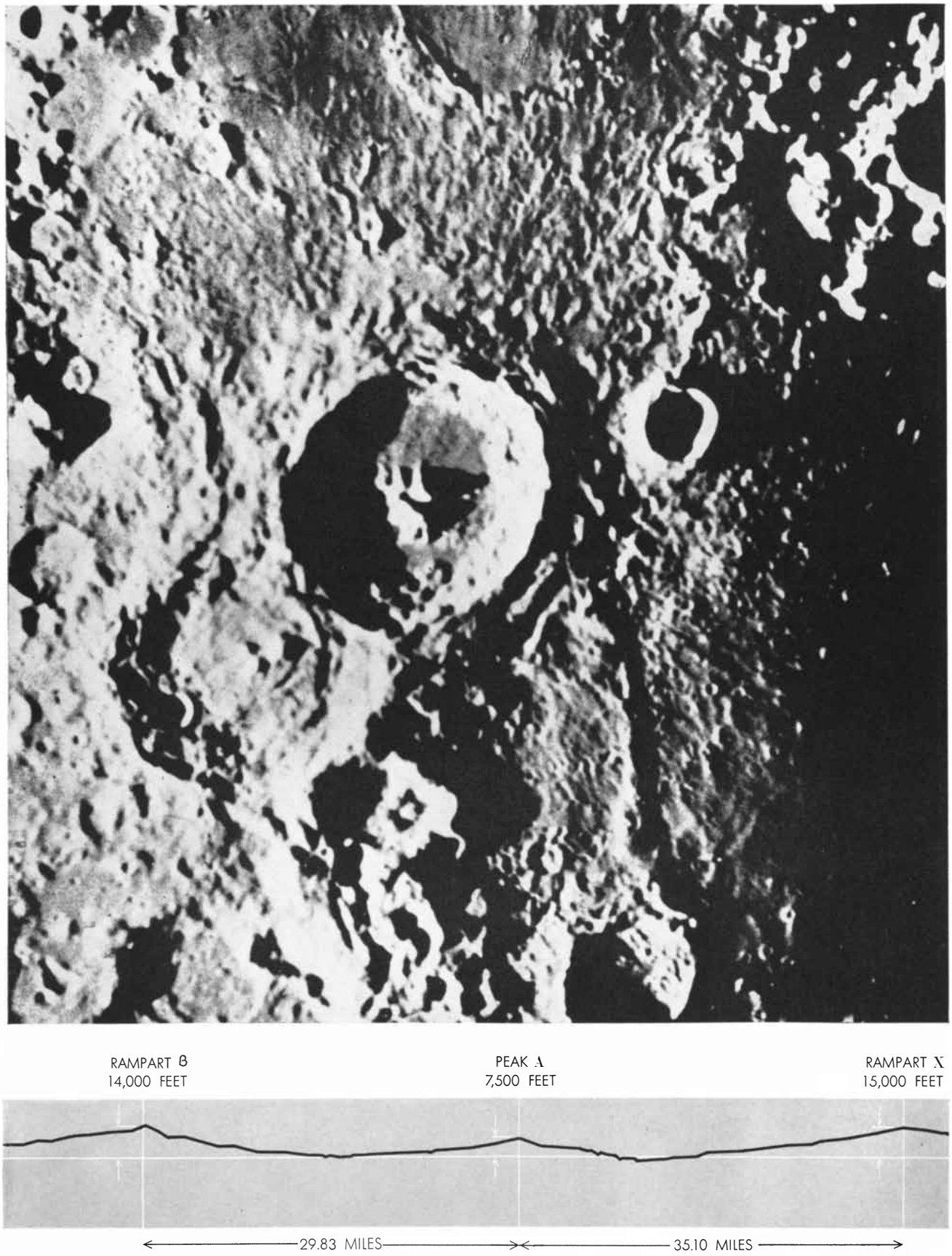
Gilbert thought that Mare Imbrium itself was a lava flow produced by the heat of impact. However, Thomas Gold of Cornell University, Robert S. Dietz of the Naval Electronics Laboratory in San Diego and MacDonald have pointed out that a meteorite collision is more likely to pulverize rock than to melt it. A small amount of lava, they say, may appear at the point of contact, but most of the energy will go into creating dust and rubble that in an airless environment will drop back in the area of the collision to form a relatively flat bed.

Although this argument weighs against the idea that the seas were created by the melting of rock in major meteorite impacts, it is still possible that the seas are flows of lava, but lava that welled up through fissures in the surface during periods of internal activity. Gerard P. Kuiper and other students of the moon subscribe to this view of the formation of the maria, and it may turn out to be the correct one. However, difficulties are associated with it also. In particular, the irregular figure of the moon indicates that it has been relatively cold during a large part of its history, and a cold interior could not have given rise to large lava flows at the surface.

At the same time it must be said that some features on the moon are hard to explain unless it is assumed that they are lava flows. The Sea of Tranquility, for example, has the irregular outline that is characteristic of the flow of a liquid over a rough terrain [*see illustration on page 63*].

The answer to the question of what really does cover the lunar seas must await detailed reconnaissance and surface exploration. In the 67 years since Gilbert gave his lecture telescopic observations have yielded practically no

ALPHONSUS, the upper of the two large craters seen here, is the site of the apparent volcanic activity observed in 1958 by the Soviet astronomer Nikolai A. Kozyrev. Activity may have been the release of trapped gas rather than an actual volcanic eruption.



THEOPHILUS, the crater in the center of photograph at top, appears to have a rugged central peak and steep encircling ramparts. This is a deceptive characteristic of photographs of objects lying near the lunar terminator (*right*), where long shadows exaggerate surface features. The measured profile of the crater and peak, shown in the diagram at the bottom, indicates that the crater has average slopes of six degrees or less. The profile was measured at the McMath-Hulbert Observatory of the University of Michigan.

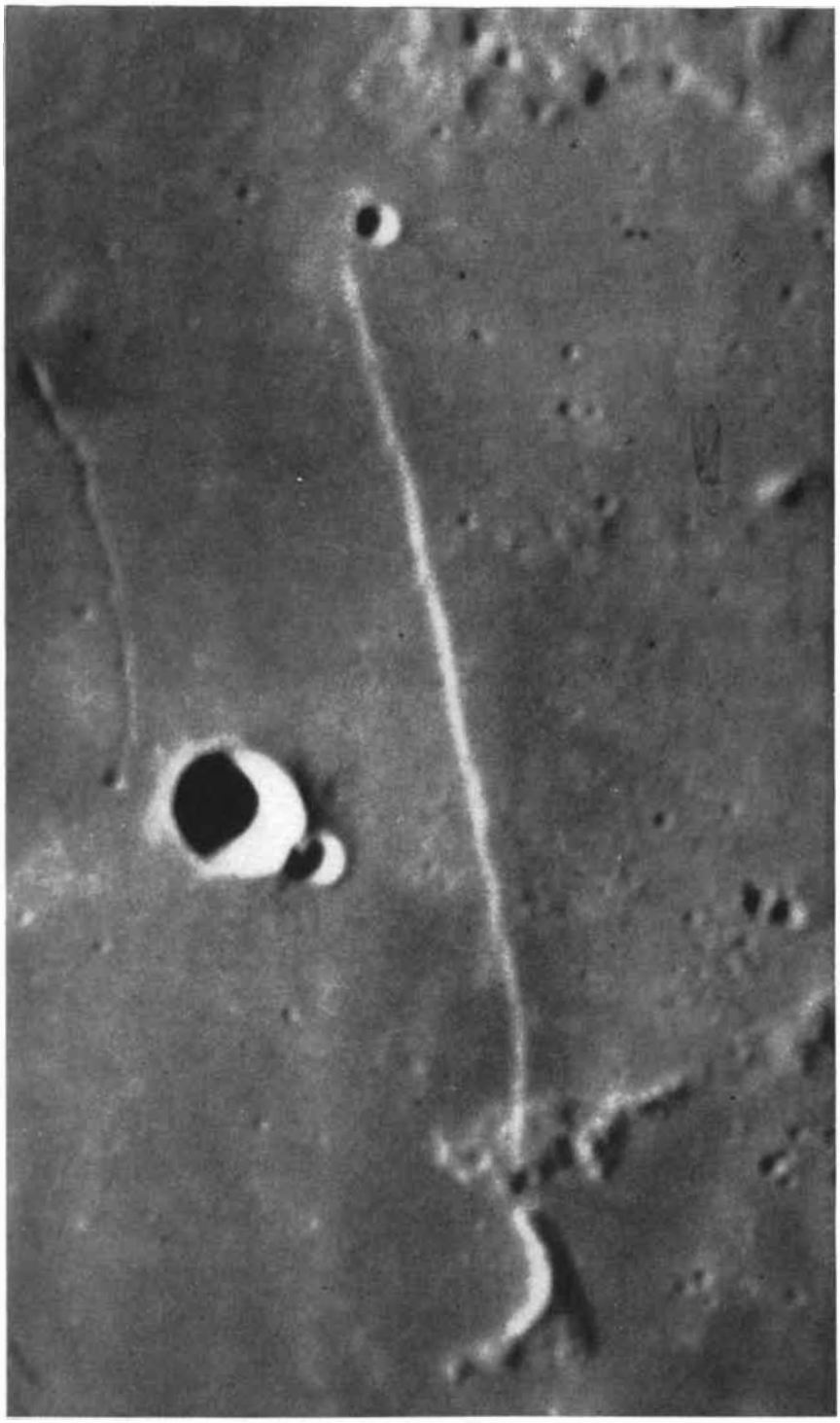
new information about the moon. The resolving power of present-day telescopes is not appreciably greater than that of the telescopes in Gilbert's time. According to Kuiper, who has made some of the finest lunar photographs, the large telescopes of today might under the best seeing conditions be used visually to resolve objects a 10th of a mile across. Photographic resolution is considerably poorer; unlike the eye, the photographic plate cannot accommodate the wobbling of images caused by the instability of the earth's atmosphere. For all practical purposes a feature of the moon can be observed visually only if it is more than 1,000 feet across, and can be observed photographically only if it is more than 2,500 feet across.

In 1957 an important detail was added to the telescopic picture of the moon by a series of remarkable radio observations conducted at Jodrell Bank in England and at the U. S. Naval Research Laboratory. The observations took advantage of the fact that when light or any other electromagnetic radiation, such as radio waves, strikes the surface of a polished sphere, it is reflected back to the source as though from a single point within the sphere. If the surface of the sphere is not polished—that is, if the average size of the irregularities is equal to or greater than the wavelength of the radiation falling upon it—the reflected radiation will be diffused, and the entire illuminated area will appear uniformly bright, like a frosted lightbulb. The lunar surface does diffuse the visible light that it reflects. Light waves are of the order of .0001 centimeter long, and on this fine scale the surface of the moon is fairly rough. The radio observations showed, however, that the moon sharply reflects radio waves that are 10 centimeters (four inches) long. On this coarser scale the surface of the moon is relatively "polished": its irregularities must be, on the average, less than 10 centimeters in diameter.

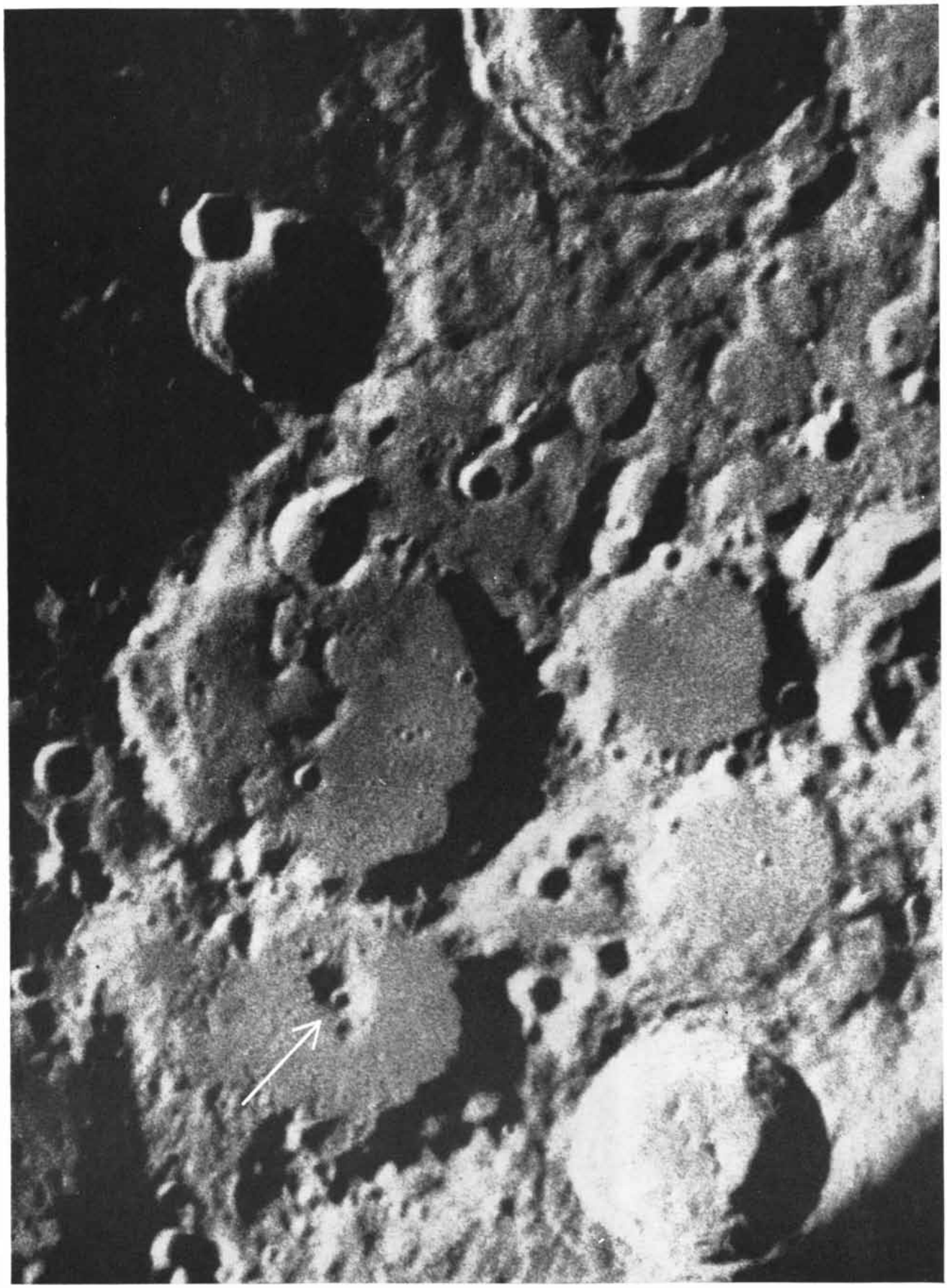
This relative smoothness of the lunar surface poses a question. The surface should be covered with pits with a diameter of more than 10 centimeters, caused by the meteorites that undoubtedly rain steadily on the moon. Yet the pits are not there; at least there is no evidence for them. Of course the hail of meteorites must have chipped away at the rocks, and the moon must be covered with a layer of rock dust; the large meteorites that created the visible craters doubtless manufactured even more dust. But since there is no wind on the moon, even the dust should be pitted.

Some unknown agent distributes the dust over the lunar surface with such uniformity that the small pits and craters are filled in. Perhaps the continued bombardment of the surface by micrometeorites moves enough dust to make the surface virtually smooth.

Gold has proposed a more interesting and more original solution to the problem. He suggests that the solar protons which bombard the moon would give some neighboring dust particles a positive electric charge. Under the mutual repulsion of their like charge, the particles would hop about. Gold and his students have bombarded dust particles with electrons in the laboratory, and the



THE STRAIGHT WALL, a cliff 60 miles long and 800 feet high, is one of the rare linear structures on the moon. It may be a large fault caused by a disturbance in the lunar crust.



POSSIBLE LUNAR VOLCANO appears at lower left (*arrow*). The small cone is one of about a dozen on the moon that resemble terrestrial volcanoes. Zdenek Kopal made the photograph with the 24-inch refracting telescope at Pic du Midi Observatory in France.

particles act like Mexican jumping beans. Their hopping makes them migrate; if they are on a slope, for example, they will march downhill under the influence of gravity. Thus the moon's highlands should be scoured clean, and its depressions should be filled with dust to a considerable depth. The weight of the overlying dust would compact the deeper materials, but for some distance down it is possible that the lunar surface is relatively porous, perhaps with the texture of a rusk. If Gold is right, it would be well not to choose the otherwise smooth and inviting surface of a lunar sea for the first landing on the moon. The porous rusk might not be able to bear the modest lunar weight of an exploration vehicle, and so might swallow it up.

One of the first objectives of the lunar-exploration program will be to obtain views of the surface that are more detailed than those available from telescopes on the earth. A first step in this direction has been taken by the U.S.S.R. with *Lunik III*, which transmitted television pictures of the "back" of the moon. More revealing views of the lunar surface will be made by cameras mounted either in lunar satellites or in spacecraft designed to land on the moon. The images may be obtained by television or by photography; perhaps both methods will be developed and tried. The pictures relayed to earth by these cameras will provide the definition needed to determine the structure of the lunar surface and will at the same time permit the selection of landing sites for vehicles. Over limited areas the resolution of detail may be about 100 times better than that of the best terrestrial telescopes. It will be a few years before such systems are perfected, although either the U. S. or the U.S.S.R. may obtain images of intermediate resolution at an earlier date.

The region of extended shadows near the terminator—the line dividing light from dark on the moon—may prove to be a good place for such reconnaissance. Here all surface details are thrown into exaggeratcd relief, and it may be possible to detect differences in elevation of a few feet or less. An important supplement to the television studies will be an instrument designed to penetrate the surface and reveal its hardness or the degree to which it is compacted.

Even in advance of these achievements it is clear that the lunar landscape does not at all resemble the earlier conception of the moon as a Gothic spectacle of steep cliffs and needle-like spires. To a man standing within a typical lunar crater its slopes would appear rather gentle; indeed, they seldom exceed a grade of 10 degrees [*see illustration on page 66*].

Beyond the initial objective of surface reconnaissance, several experiments that are in prospect will make major contributions to knowledge of the moon. Perhaps the most important experiment in the early stages of lunar exploration will be carried out by the gamma-ray spectrometer. The instrument, mounted in either a lunar satellite or a landing capsule, might consist of a crystal to detect gamma rays emitted by radioactive uranium, thorium and potassium, and a pulse-height analyzer to separate the various wavelengths of the rays. Since the different elements emit gamma rays at different wavelengths, the analyzer will indicate how much potassium, thorium and uranium the lunar crust contains. The relative abundance of these elements will in turn reveal a great deal about the rocks of the lunar crust, because different kinds of rock contain different amounts of these elements. Moreover, the concentration of these elements will indicate how much of the heating of the young moon was accountable to radioactivity.

Finally, several years further in the future, the stage of serious lunar exploration by unmanned landings involving remotely controlled instrumentation can begin. The Soviet *Lunik I* has already made contact with the moon's surface, but it carried no instruments to report what it had encountered. The first instrumented landings may be rather rough. Nonetheless a seismometer that should sustain the impact of a rather hard landing is already being developed. This instrument, by reporting on moonquakes, could supply valuable information on the internal structure of the moon. With the development of the guidance and control needed for truly soft landings, an X-ray fluorescence spectrograph might be sent to determine the chemical composition of the lunar surface. This instrument, working wide-open in the high vacuum of the lunar environment, would bombard the rock with an electron beam. The atoms in the rock would respond by emitting X-rays at characteristic energies, thus identifying the metals in the rock.

Another important instrument would be a gravimeter for measuring small changes in the force of gravity at the surface of the moon. Such changes are produced by land tides that occur when the sun and the earth pull on the moon. Land tides are similar to the earth's ocean tides, but their amplitude is much smaller, since solid land responds far less than water does to an attracting force. In a land tide the surface of the moon moves outward a few inches or a foot, and a gravimeter on it would move away from the center of the moon by that amount. Since the force of gravity grows weaker with increasing distance from the center of the attracting body, the gravimeter will record a decrease in the gravitational force as a result of this outward movement. A variation of six inches is only a ten millionth the radius of the moon, yet gravimeters are so sensitive that they can detect far smaller effects. The height and timing of lunar land tides will furnish precise measurements of the viscosity and elasticity of the moon's interior.

The soft-landing packages may also contain ionosphere and plasma probes, density gauges, magnetometers and television cameras. The latter could be fitted with telescopic lenses for inspecting the surrounding area to some distance and with lenses for close examination of materials near the vehicle. The ultimate in unmanned exploration may be a roving vehicle that will land on the moon's surface and then be piloted about by remote control. The machine would have to travel over the unfamiliar surface in a vacuum and under extreme temperature conditions, carrying delicate physical and chemical instruments that do their work as it proceeds, all under the control of an operator a quarter of a million miles away on the earth. But the vehicle would get away from the disturbed conditions at the landing site and would be able to correct the possibly misleading impressions gained from the limited number of sites at which earlier instruments will have landed. This self-propelled laboratory might be powered by solar batteries and would have to hibernate during the two-week lunar night, coming to life again during each lunar day.

The remote-control instrument station in its most complex form will reveal a great deal of information about the moon. But no matter how complex this instrumentation may become, it will never be able to grapple with unforeseen circumstances and to capitalize on unexpected opportunities. With the advent of manned flights a decade or more hence, lunar exploration will enter upon its most rewarding phase.

The Changing Level of the Sea

Glacial cycles and the slow sinking of the ocean floor have caused sea level to fluctuate from epoch to epoch. The last great upsurge apparently culminated in the deluge described in the Old Testament

by Rhodes W. Fairbridge

A deluge such as that described in the Book of Genesis occurs in the legends and folklore of almost every ancient people. The Greeks told how Deucalion, son of Prometheus, was forewarned by his father and thus survived the flood wrought by Zeus to destroy mankind. Babylonian scripture related how the city was founded on the site where the god Ea conquered the floodwaters gushing from the mouth of the nether world, which he sealed with a giant stone. The magnificent bas-reliefs of the Cambodian temple of Angkor Vat illustrate the Hindu legend that relates how Manu, one of the 14 progenitors of mankind, was saved from the deluge by a fish whose life he had spared.

Such agreement among the legends of so many peoples living in distant parts of the world has caused scholars in modern times to wonder whether mankind did in truth experience the world-wide catastrophe of a deluge. The evidence of legends cannot be accepted as proof of geological events. But it can be argued in reverse that geology might produce evidence of events that could have inspired the legends. The seacoast was the home of many primitive peoples and the site of many early centers of civilization. A major and relatively quick rise in the sea level—say a few feet in a decade—could have had profound effects upon the way of life and the imagination of those who experienced it. If the sea level had continued to rise generation after generation, even with intervals of retreat, floods would surely have become incorporated in legends the world over. A major swing in climate, bringing increased rainfall and the thawing of mountain snows, could have caused calamitous river floods throughout an entire climatic zone of the earth and could have made a similar imprint upon human memory. If the two kinds of flood had occurred together, they could easily have been recorded as a deluge.

A century ago it would have been difficult to persuade geologists to entertain such a possibility. In their effort to establish natural causes for the grand-scale workings of nature they spurned the Scriptural concept of catastrophe. Under the leadership of the Scottish pioneers James Hutton and Charles Lyell they advanced the principle of uniformity, which held that the events of the past could be explained in the light of

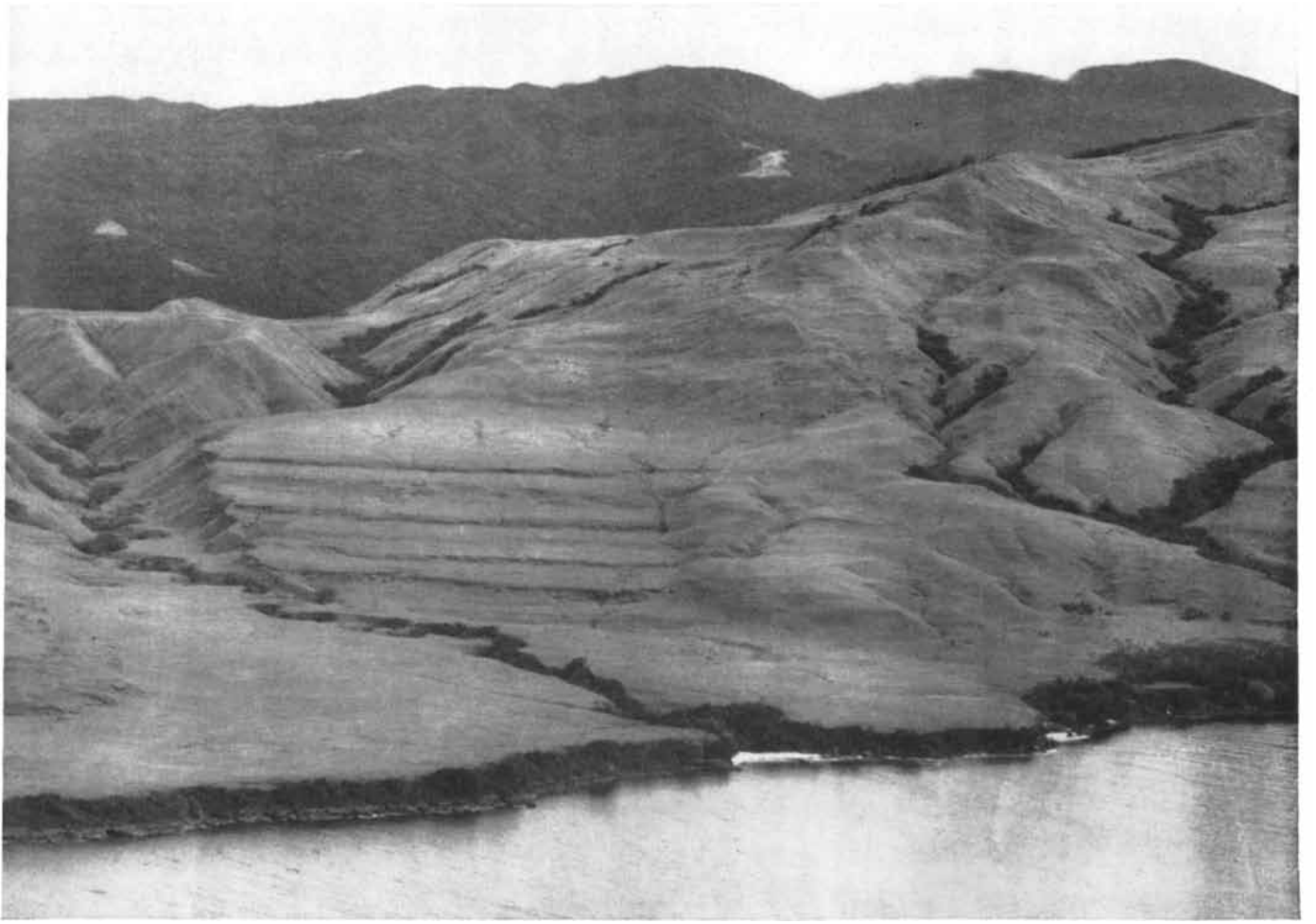
COASTAL TERRACES reflect the sea levels of the past. This terrace, on the coast of New Guinea near Finschhafen, was formed partly by the higher sea-levels of warm interglacial

processes at work in the present. This point of view especially cherished the constancy of the sea level. After all, the sea covers from 70 to 75 per cent of the earth's surface. The level of the sea represents the simplest basic shape of the earth. That shape is close to a spheroid, but exhibits slight departures, and is known to the geodesists as the geoid.

Yet the founders of modern geology were also the observant fieldworkers who first recognized the traces of the ice age. Soon geologists found evidence for several ice ages in the lengthening span of geologic time. By the turn of the century they were finding ice ages at every stage of the geologic history, in keeping with the philosophy of uniformity. Careful reexamination of the evidence in recent years, however, has rejected many of these ice ages; formations once identified as glacial moraines have been reinterpreted as beds laid down by mudflows, submarine landslides and turbidity currents: avalanches of turbid water that carry silt, sand and gravel out over the deep-ocean floor. But from all the data four great ice ages remain: the Late Pre-Cambrian (600 to 700 million years ago); the Siluro-Devonian of South America (350 to 450 million years ago); the Late Paleozoic of the Southern Hemisphere (200 to 300 million years ago); and the Quaternary (from 500,000 years ago to the present).

During these periods an immense portion of the earth's total supply of water was locked up in ice sheets on the continents. That they held enough of the total to substantially affect the sea level may be judged by the volume of the world's present glaciers. The icecaps of Greenland and Antarctica, the remnants of the waning Quaternary ice age, would raise the sea level by some 300 feet if they were to undergo a sudden thaw.

It remains to be shown, however, that the melting of glaciers could alone cause major changes in the sea level. From other information about the earth and its structure it is clear that the transfer of such an immense burden from the continents to the sea must set further changes in motion. Over the span of geologic time the earth's outer crust may be regarded as a tough skin enclosing a more plastic interior mantle and core. The melting of a continental ice sheet 9,000 to 10,000 feet thick—the thickness of the antarctic icecap—would cause the continent to rise, as Scandinavia and certain parts of North America are rising even today. This rise is compensated by the sinking of parts of the ocean floor. Certain regions of the sea bottom are sinking now. Although the details of this isostatic mechanism are not fully understood, the continents may be pictured as blocks of lighter material floating in a viscous substratum. The shift of the burden of ice from the continents to the sea would be compensated by a slow lateral movement of the rock under the roots of the continents, buoying the continental blocks upward. Thus the sea level does not depend solely upon the amount of water in the sea; it also depends upon



periods and partly by the interrupted uplift of the land, which lies in one of the earth's most unstable volcanic belts. The oldest terraces are the highest; each contains fossil plants and shells that indicate the date and temperature of the ancient shore.

the height of the land and the depth of the ocean basin.

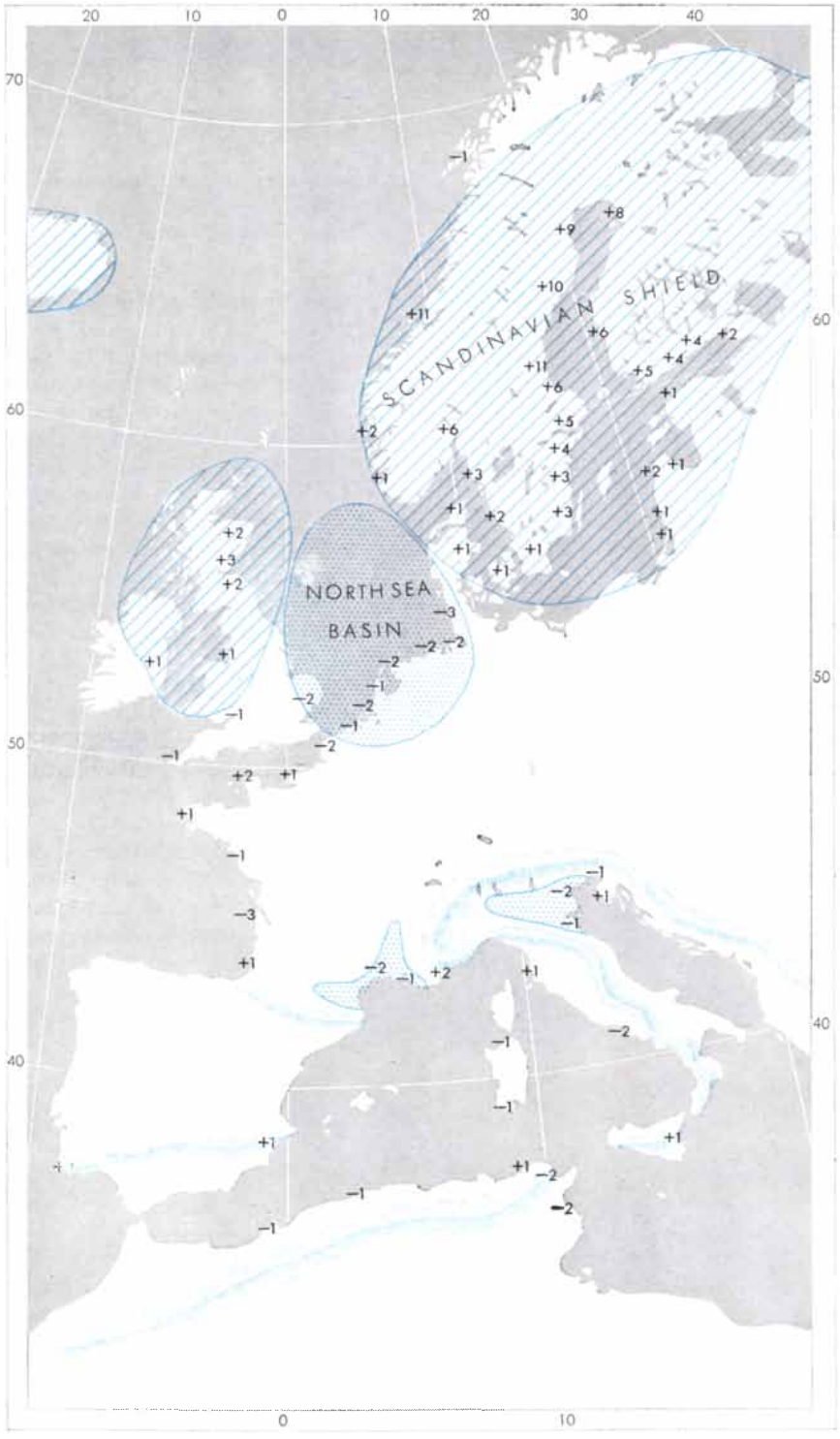
Of course rock does not flow so quickly as water. The melting of glaciers is likely to occur faster than the tectonic readjustments that follow in the crust. It is clear, therefore, that the flow of such immense volumes of water into the sea has had its effect upon the sea level in the course of geologic time. The record indicates, in fact, that the sea level must go through cyclic changes. How rapidly and substantially these changes occur depends upon the interaction of several variables.

At what point in the cycle does the sea level now stand? The question requires, first of all, a consideration of the record of the past. Such consideration should settle, incidentally, the question of the flood of ancient times. It will also provide a basis for judging whether the flood might recur.

Tide gauges at every important harbor

POSTGLACIAL UPLIFT of parts of North America and Europe can be detected from tide-gauge measurements. Regions formerly covered by glaciers (*hatched areas*) and those lying in the axes of old mountain belts are slowly rising. Stippled areas indicate the

of the world keep the sea level under constant surveillance. The world-wide sea level does not itself emerge as the first quantity measured by these observations. The tide gauges show a number of other interesting things: the local rise and fall of the tide due to the attraction of the moon, the sun and the nearer planets, the annual cycle of regional patterns in atmospheric pressure, periodic and seasonal changes in the wind and even longer-term effects such as the cycles of atmospheric pressure and wind set up by the cycle of sunspots. These data are gathered at the International Tidal Institute in Liverpool, England, and the International Association of Physical Oceanography is currently collecting evidence of the long-term effects recorded by the tide gauges.



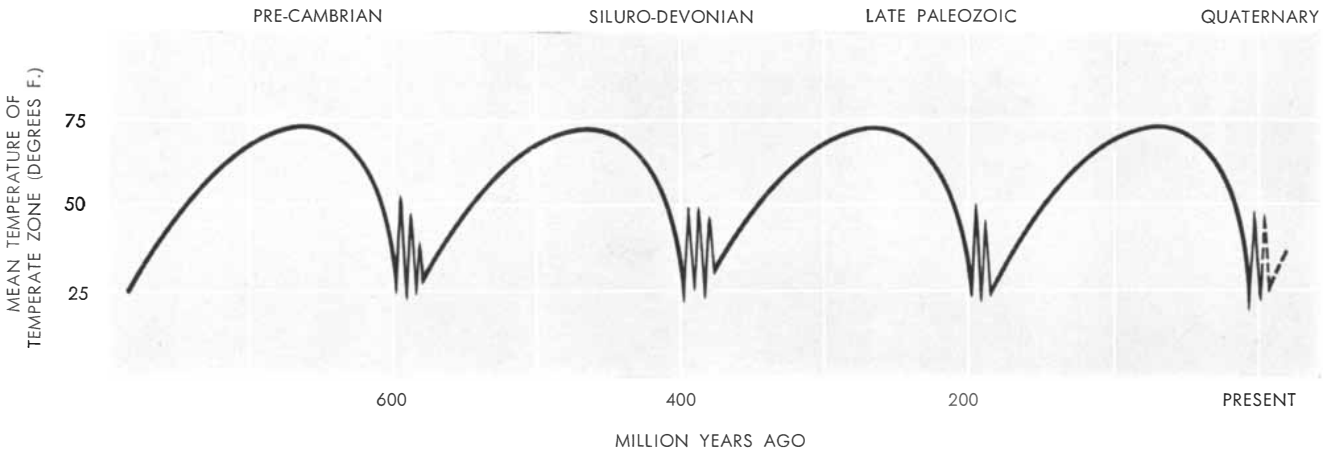
parts of the sea basin and coastal plains that are now sinking. Numbers show the rising or sinking of harbors in millimeters per year. The maps are not drawn to the same scale.

Studies of tide-gauge charts that have been kept for a sufficient length of time reveal two other components in the local records. One of these arises from the motion of the continental blocks. Some regions are so unstable that their rate of movement can be measured within as short a time as half a century. Generally speaking, the harbors that lie in the axes of ancient mountain ranges are rising slowly, as at Biarritz and Nice. Those that lie near regions that were heavily laden with ice during the last ice age are rising moderately fast [*see maps on these two pages*]. In many parts of Scandinavia this uplift is so rapid that docks used by fishing boats are literally rising out of the water. On the other hand, gauges located near deltas or regions of heavy sedimentation consistently show a subsidence. Harbors in active volcanic regions and in earthquake zones show a variety of changes, both upward and downward.

The other important component in the tide-gauge records is the sea level itself. Since water seeks its own level, any change in sea level must ultimately be measurable everywhere in the world. Such a change can be detected by correcting for all the other variations recorded by the gauges. For the past 50 years the tide-gauges have shown a steady rise, averaging about 1.2 millimeters per year, or about 4.5 inches per century.

The possible causes of this trend that must be taken into account are many and varied. In addition to the melting of ice and the movement of the earth's crust they include the thermal expansion of water, the filling of the ocean basins with sediment and the addition of "juvenile" waters from rocks brought to the surface by volcanic eruptions. However, calculation of the magnitude of each of these processes shows that only glacial and isostatic effects need be reckoned with.

Geological records show that a number of oceanic basins—notably parts of the Caribbean, the Mediterranean and the Indian Ocean—have been subsiding for millions of years at a rate averaging up to one inch per century. A rough calculation suggests that the volume of the area involved is about 35 million cubic kilometers; since the total area of the ocean is about 360 million square kilometers, this represents a world-wide fall in the sea level of about 100 meters (330



TEMPERATURE CYCLES deduced from the fossil record reveal the climatic patterns of the past. The mean temperature of the earth is normally much higher than it is today. The long warm cycles are interrupted by ice ages (*jagged peaks*) at intervals of approximately 200 million years. The temperature changes in the immediate geological future should follow the pattern of the broken line.

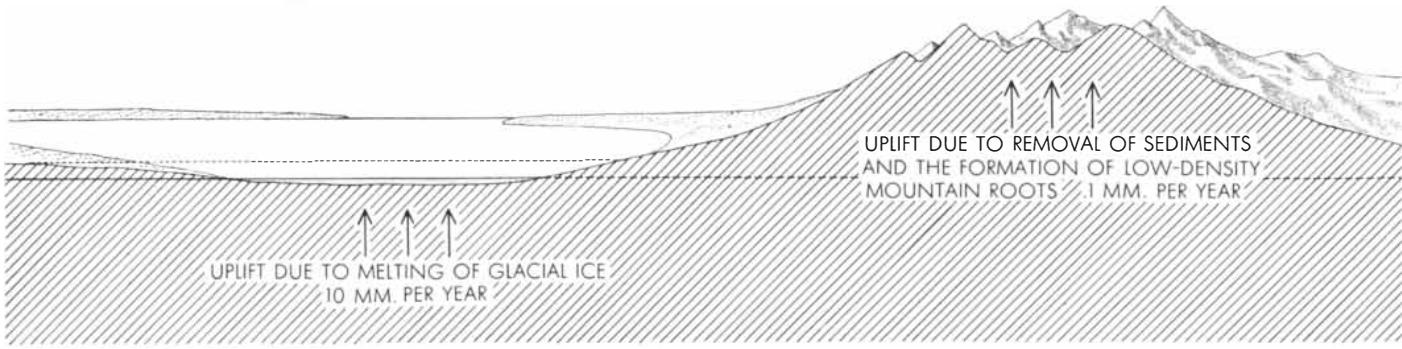
feet). Spread over five million years, this would represent an average fall in sea level of about .02 mm. per year, with a possible acceleration at times to a maximum of .2 mm. per year. Some geologists have argued that the subsidence of the sea floor in one region is compensated by the rise of others. It seems more likely, however, that the net increase in the average depth of the sea is compensated by the rise of the continental platforms; the Colorado plateau of the western U. S., for example, has been pushed upward some 2,000 feet in the present postglacial period. The tectonic depression of the sea floor is thus a real factor to be taken into account.

The present four-inch-per-century rise in the sea level, however, indicates that the melting of glaciers by far overwhelms all other factors and trends. Tide records show that the rise has been constant for about a century. This trend exactly parallels the world-wide climatic warm-up that began in about 1850. During this period the Arctic Ocean has become measurably warmer and increasingly free of ice; the interior of the Sahara has become warmer and drier, and monsoonal regions have become warmer and wetter. In the same period the glaciers of the Rockies and the Sierra Nevada have practically vanished, and those of Switzerland, Norway, Iceland and Alaska have measurably retreated.

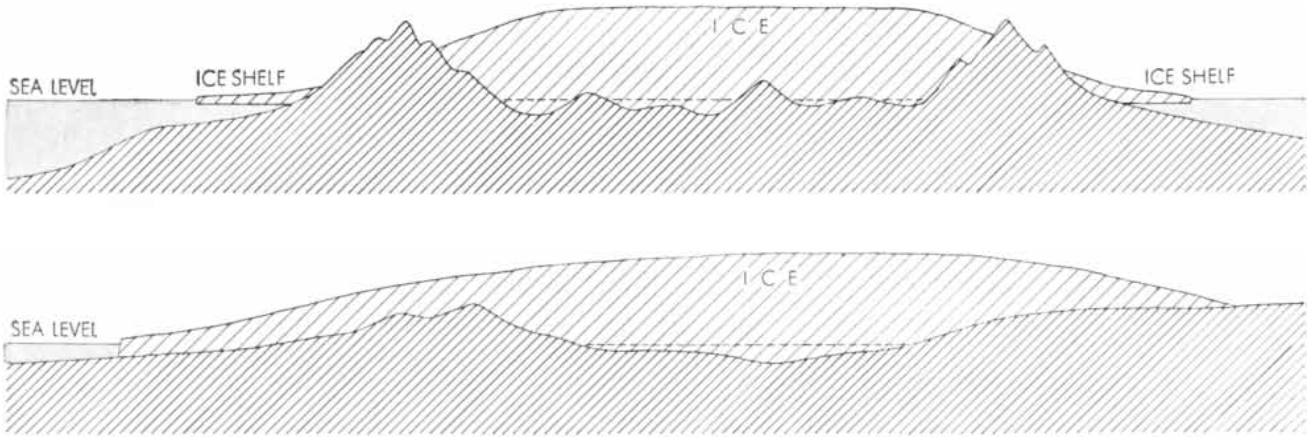
All these trends add up to two conclusions. The first is that there seems to be very little time lag between the warming of the climate and the melting of the glaciers. Exceptions do occur as the normal consequence of local weather changes; for example, an increase in the area of open water near a glacier-covered land mass may lead to an increase in snowfall, and thus certain glaciers actually advanced during the warm-up. But there has been a substantial net outflow from the glaciers to the sea. The second conclusion is even more significant: The increase in sea level caused by glacial melting is from 100 to 1,000 times greater than the offsetting factor of the sinking of the ocean floor. The tide records, by recording a measurable rise in the sea level in so short a period as a century, demonstrate that the sea level is highly sensitive to the transfer of water from the ice on the continents.

These conclusions are buttressed by the tide records kept since 1682 in Amsterdam. The coast of the Netherlands lies at the margin of the North Sea basin, which is subsiding at the rate of about four inches per century. Hence the Amsterdam records show that the sea level has risen eight inches during the past century, only four inches of which are due to the true rise. Prior to that time, however, the fluctuations of the sea level faithfully reflect climatic history. The level rose at about the present rate between 1725 and 1770, then fell during the period of exceptionally cold winters recorded in most Temperate Zone regions from 1800 until 1850. Then, with the beginning of the retreat of the Alpine glaciers, the Amsterdam gauges began the upward swing that continues into the present.

So even though the tide records reach



DEFORMATION OF THE EARTH'S CRUST causes long-term changes in sea level. When glacial ice melts in an area such as Hudson Bay or the Baltic Sea (*far left*), or when sediments are washed down from mountains (*left center*), the newly unloaded land rises. At the continental margin (*right center*) some of the weaker parts of the crust are slowly sinking. Under an increasing



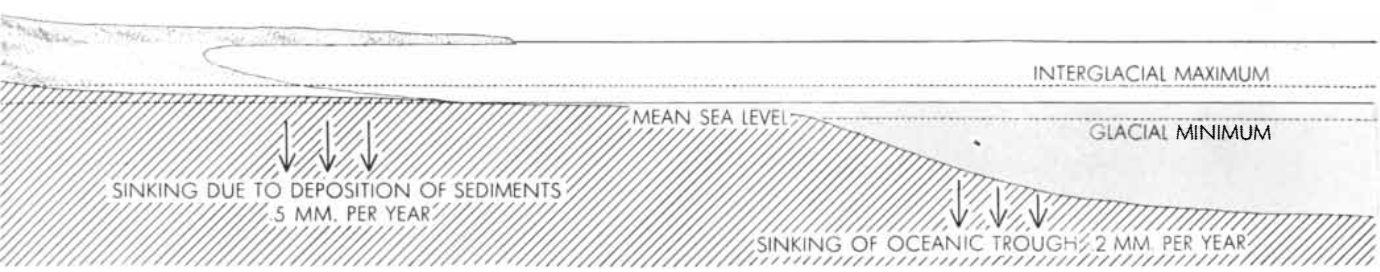
COMPARISON OF GLACIERS suggests an explanation of the continued survival of the ice sheets of Antarctica and Greenland. Both lie in pan-shaped depressions (*top*) ringed by mountains that hold back the ice and permit it to accumulate in thick sheets. The ancient glaciers of North America and Scandinavia (*bottom*) spread out thinly over the plains and melted quickly as the earth warmed.

back only a brief time, they make it possible to assert with confidence that climatic changes in the distant past must have been accompanied by concurrent changes in the sea level. Since no tide data survive from Noah's time, investigators look for evidence in the fossils buried in ancient beaches. Fossil plants are the best indicators of temperature. Traces of the fig and the magnolia, for example, are characteristic of a semitropical climate; those of the juniper and mosses of the peat type are evidence of a cool or cold environment. By studying the plants in a given stratum the paleobotanist can determine the mean temperature of the time within one degree centigrade. The nature of the sediment, its elevation and its fossils provide an approximate indication of the age of a shoreline. More exact dates can be obtained from radiocarbon measurements. The precision of this technique rests upon the steady decay rate of carbon 14; the radioactive carbon taken up by a plant or animal during its lifetime dissipates half of its radioactivity every 5,568 years. By combining radiocarbon dating and paleobotany, it is possible to determine the major changes in climate and sea level for the past 20,000 years.

Plotted on a graph, the level of the sea during this period appears to oscillate about two straight-line curves: one running from 17,000 to 6,000 years ago; the other, from 6,000 years ago to the present [*see illustration on next page*]. The earlier of the two curves reveals a striking pattern. Drowned beaches at the edge of the continental shelf show that 17,000 years ago, at the height of the last large-scale advance of the glaciers, the world-wide sea level was some 330 feet lower than it is today. As the great North American and Scandinavian glaciers melted, the sea level began to rise at a rate of about 40 inches per century. Radiocarbon dates for this period, obtained by dredging submerged shorelines on the continental shelf or from boreholes put down near the outer edge of coastal plains, indicate that the rise of the sea was not uniform but varied, with short periods of retreat. During some of these oscillations the sea surged upward at a rate of more than 30 feet per century.

The greatest and fastest rise yet discovered in the geological record reached its crest about 6,000 years ago. The cumulative incursion of the sea flooded low-lying coastal lands in every part of the world. This was the deluge that drowned the homes and troubled the legends of the ancients. The flood of the sea was joined by floodwaters brought down from the highlands by rivers. In the world-wide climatic shift that brought on and reinforced the melting of the glaciers, climatic belts shifted everywhere on earth except near the Equator. Regions of the Temperate Zone —where the recorded history of mankind was just beginning—became noticeably milder and wetter. Archaeological evidence in the valley of the Tigris and the Euphrates and geological evidence in the valley of the Mississippi testify to calamitous and spectacular inundations.

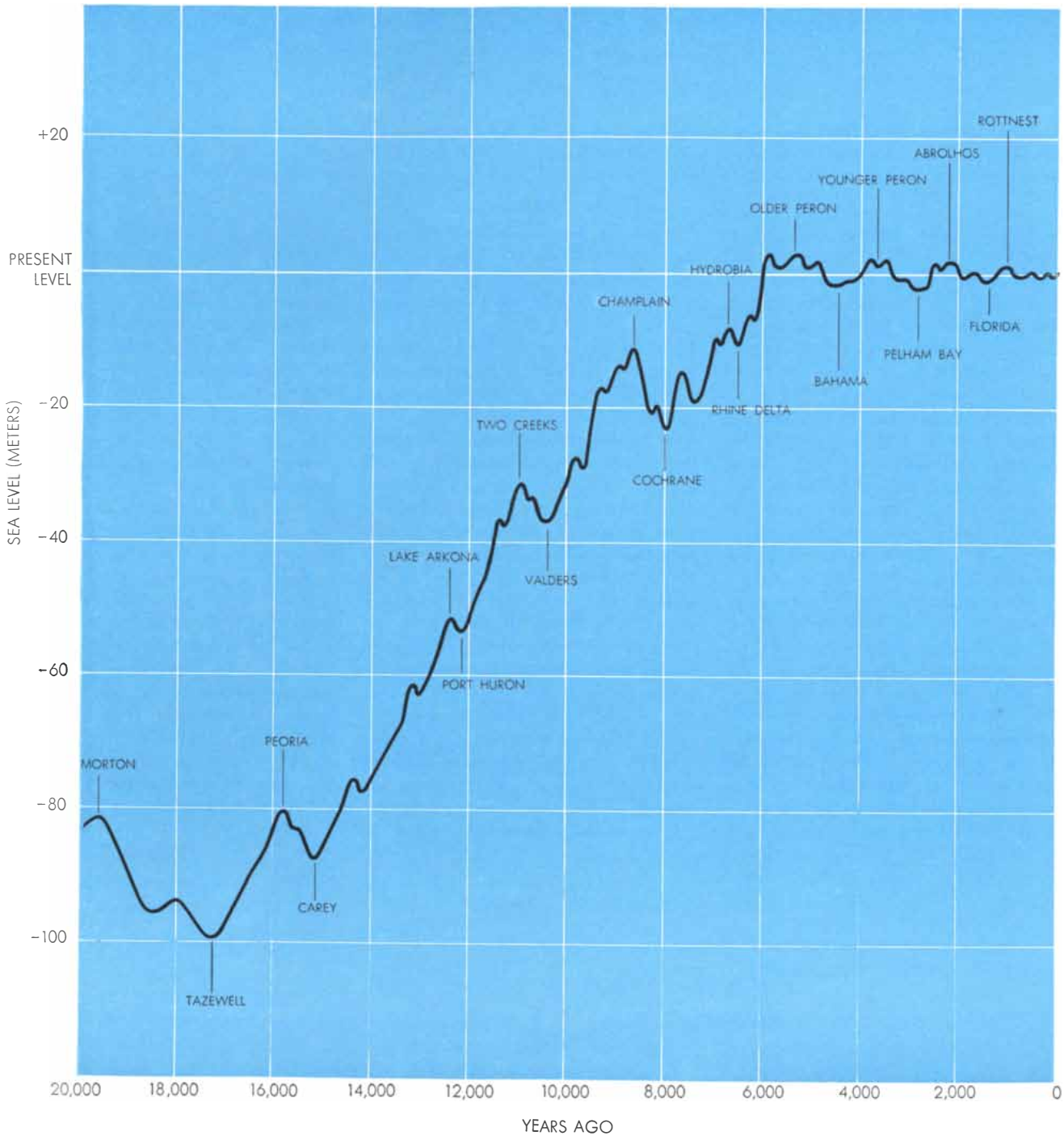
Contrary to legend, however, the del-



load of sediments they sink further. The sinking of deep-ocean trenches (*far right*) partially compensates for the postglacial uplift of the continents. The slow changes in sea level caused by these crustal movements are either reinforced or obscured by the more rapid changes caused by the melting of glaciers. Broken lines indicate sea levels characteristic of typical glacial and interglacial ages.

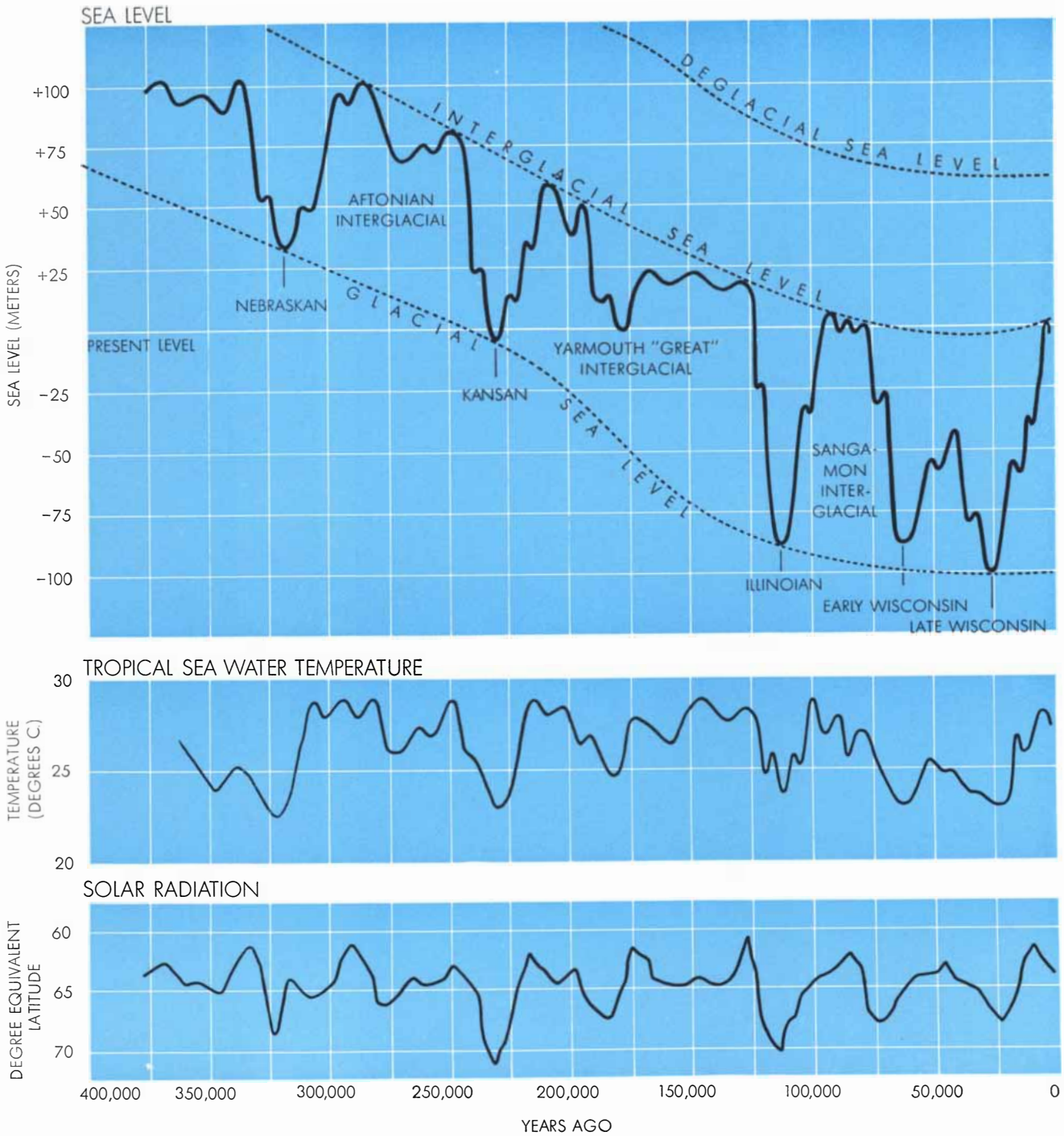
uge did not recede, at least not very far. This is indicated by the sea-level curve for the last 6,000 years. The highest and lowest sea levels during this time are not more than 10 or 12 feet above or below the present sea level. The amplitude of the oscillations in the sea level appears to be damped, falling off gradually from 20 to five feet. The period of oscillation seems to approximate a 550-year cycle with 1,100- and 1,650-year harmonics. The last upswing corresponds to the well-known floods of medieval times, when the Dutch began to build their dikes. The world now appears to be midway in the next 550-year rise. Over the entire 6,000-year period, however, the sea level evinces a very small net decline. This reflects the sinking of the sea bottom in the prolonged isostatic readjustment to the shift of the ice burden from the continents. Thus, although the sea level appears to be rising rapidly in the short run of 550 years, it also appears to be falling slightly in the longer perspective of 6,000 years.

The waters of the flood represented



RISE IN SEA LEVEL from 17,000 to 6,000 years ago is the most rapid upsurge yet identified in the geological record. The floods that accompanied this 100-meter increase are believed to be the subject of the deluge legends of ancient peoples. The names on the curve indicate the locations where the principal oscillations in sea level were discovered, or where their shorelines are most prominent. Sea level has remained relatively constant for the past 6,000 years, and the amplitude of short-term oscillations is diminishing.

the last traces of the North American and Scandinavian glaciers. Since their disappearance, the world ice budget has remained in a state of dynamic equilibrium; any melting of glaciers is replaced by an equal amount of fresh snowfall. Nowhere is this equilibrium more evident than in Antarctica, where the glacier fronts have not appreciably advanced or retreated for the past 50 years. The icecap of Greenland also seems to be essentially static, although some minor changes have been observed near its edges. Why have these glaciers survived for 17,000 years in a period of almost universal warm-up? Both Greenland and Antarctica are pan-shaped depressions with rocky rims that rise as high as 10,000 feet. The rims hold back the ice, permitting it to accumulate in sheets 9,000 to 10,000 feet thick. A small overflow can leak through gaps in the mountains, but only the ice shelf—the ledge over the sea—shows any sign of melting. The antarctic icecap alone covers five million square miles, an area one third larger than the U. S. An enormous



GLACIAL CYCLES have caused long-term changes in sea level (*top graph*). The sea falls during glacial stages such as the Nebraskan, and rises during interglacial stages such as the Aftonian. Dates were deduced from author's modified version of the Emiliani curve of ancient sea-water temperatures (*middle graph*), which fits the Milankovitch curve of solar radiation at latitude 65 degrees North (*bottom graph*). The Milankovitch curve indicates climatic changes as apparent shifts in latitude toward or away from the Equator.

GLACIAL SPILLWAYS like the one at left center permit only a small overflow of ice to leak away from the icecaps of Greenland and Antarctica. This ice sheet in Victoria Land in the Antarctic has almost reached the height of the mountains: about 8,500 feet.

amount of heat acting over an extremely long period would be required to melt it.

In contrast, the great continental ice sheets that once covered North America and Scandinavia melted because they were not bounded by rings of mountains [*see illustration at top of page 75*]. From their mountain birthplaces the glaciers spread out thinly over the plains. They extended from the Subarctic Zone to the Temperate Zone. When the present warm-up began, the thin fringes in the Temperate Zone melted quickly, and the glaciers began to retreat.

The geological record for the entire Quaternary period, going back some 600,000 years, shows that the continental ice sheets advanced and retreated in at least four crescendos. These have been named for the geographical regions in which they were first studied: the Nebraskan glaciation (about 320,000 years ago); the Kansan (about 240,000 years ago); the Illinoian (about 115,000 years ago); the Early and Late Wisconsin (about 60,000 and 25,000 years ago). During the three interglacial periods the climate appears to have warmed up to higher temperatures than it has attained so far in the present interglacial.

The Quaternary cycle of glaciation has now been matched to a remarkable record of the fluctuations in the world climate contained in the ocean floor. Buried in the oceanic ooze lie the skeletons of tiny Foraminifera that once inhabited the warm surface waters of the ocean. Harold C. Urey, now at the University of California at La Jolla, first showed how such remains could be used as a geological thermometer to determine the temperature of ancient seas. He observed that when water evaporates, molecules containing oxygen 16 (the lightest stable isotope of oxygen) vaporize at a slightly faster rate than those containing the heavier isotopes oxygen 17 and oxygen 18. Since the rate of evaporation increases with temperature, the ratio of the isotopes in oxygen-bearing carbonates incorporated in the skeletons of the Foraminifera provides a sensitive index of the sea temperature at the time they were alive. Taking advantage of this effect, Cesare Emiliani of the University of Miami has plotted the temperature of the sea for the past 350,000 years [see "Ancient Temperatures," by Cesare Emiliani; SCIENTIFIC AMERICAN, February, 1958]. His curve, as an index of world-wide climatic changes, agrees well with the geological record of the advance and retreat of the glaciers, and has helped to date them [*see page 77*].

The cyclic ups and downs of the Emiliani climatic curve also correspond to cycles in solar radiation that were plotted by the Yugoslavian astrophysicist Milutin Milankovitch. The cycles in the Milankovitch curve sum three cycles in the orientation of the earth to the sun: one of 26,000 years, one of 40,000 years and one of 92,000 years. The shortest period represents the precession of the equinoxes, caused by the slow, slight wobbling of the earth's axis as the planet moves around the sun. The 40,000-year period corresponds to the variation in the obliquity of the ecliptic, that is, the tilt of the plane of the earth's orbit. The plane tilts three degrees in this period, increasing or decreasing the temperature changes that accompany the change in seasons. The longest cycle corresponds to the period of the change in the eccentricity of the earth's orbit. Because of this eccentricity the earth is at present slightly closer to the sun in December than it is in June, causing the winters to be milder and shorter in the Northern Hemisphere and the summers to be seven days longer and somewhat cooler. In a few hundred centuries the situation will be reversed and the Southern Hemisphere summer will be longer. From time to time two of the cycles fall into phase with each other. These resonances, giving rise to more pronounced variations in the amount of sunlight reaching the various parts of the earth, may well have brought on the great climatic swings that melted the glaciers, built them up and melted them again.

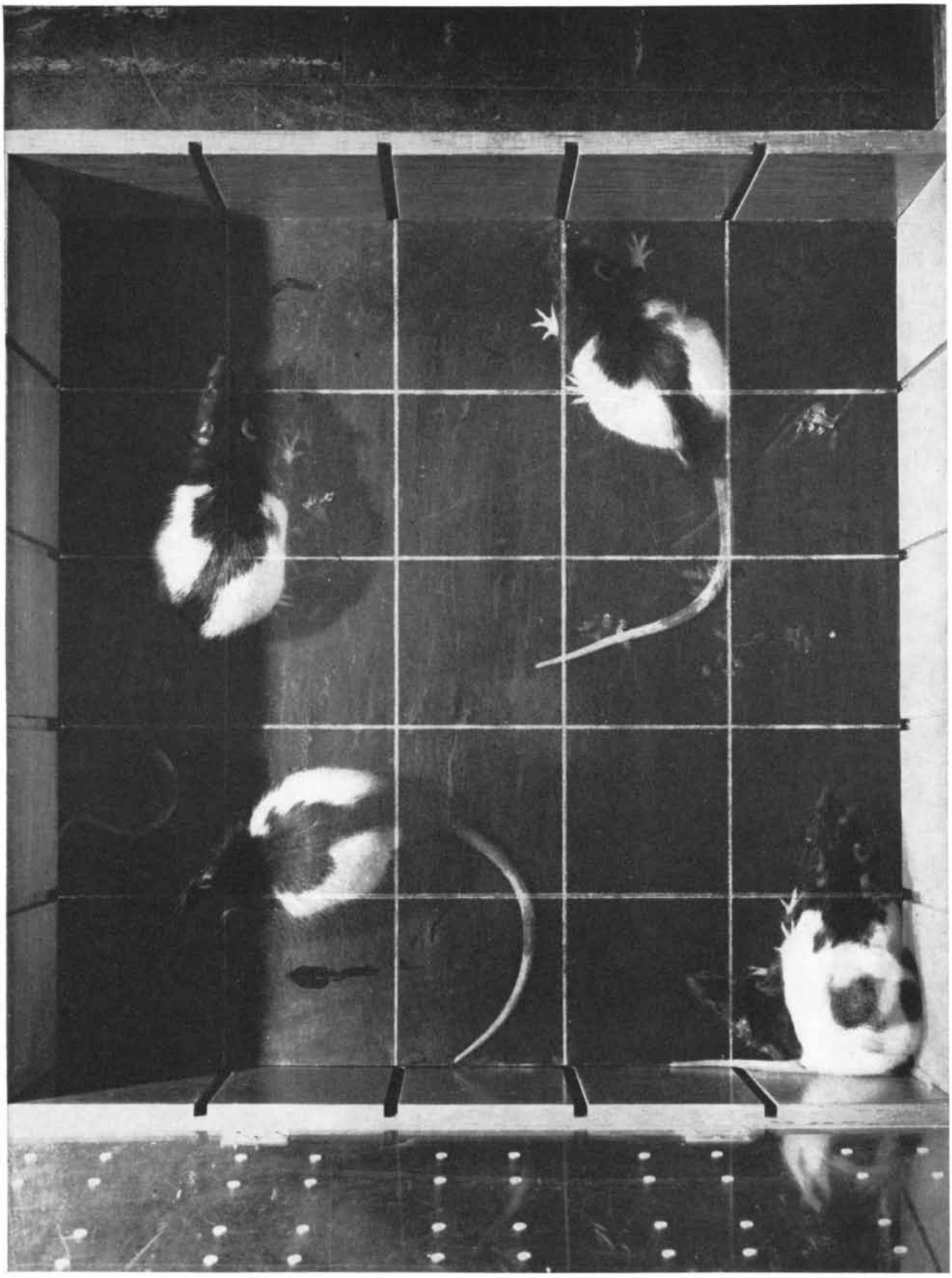
With all its variations, however, the sea-temperature curve of the Quaternary period never departs more than four degrees C. from a rather constant mean. It would follow that the sea level should oscillate about a similarly constant mean, rising to the same height after each glacial epoch. How does this deduction square with the geological evidence? At first glance it does not. Just as the last glacial maximum left traces of shorelines 330 feet below the present sea level, so previous interglacial periods left their traces on raised beaches that can be recognized on shore. The curious and disturbing fact is that each of the earlier Quaternary interglacials left raised beaches higher than the later ones. On a fairly steep coastline they appear like a flight of steps, the oldest and most poorly preserved being the highest, the youngest and clearest being the lowest [*see illustration on pages 70 and 71*]. The highest terraces place the most ancient Quaternary high-water mark roughly 330 feet above the present sea level. It might thus appear that the deluge of Scripture was dwarfed by the floods that followed earlier glaciations.

The apparent long-term fall in the sea level might be explained by the sinking of the ocean floor. But the evidence which places the rate of sinking at .02 or .2 millimeter per year could not account for a fall of about 330 feet in the sea level in 600,000 years. Tectonic processes could have brought it down only about 110 feet. (The longer-term subsidence of the sea floor, reaching back millions of years before the dawn of the Quaternary period, may reflect oscillations in the crust generated in the course of earlier ice ages, starting with the Pre-Cambrian.)

At this point the great mass of antarctic and Greenland ice must be brought into the equation. If this ice were to be melted suddenly (by who knows what catastrophic agency) and returned to the sea, it would immediately raise the sea level 330 feet, almost to the shoreline of the ocean at the opening of the Quaternary period. Naturally there would be isostatic compensation for the new redistribution of the water burden over the earth's crust; and such compensation, proceeding sluggishly over the next geologic period, might again reduce the sea level somewhat.

The history of the Quaternary ice age thus leads to one dominant conclusion: The sea level is a most variable plane, a sensitive indicator of even minor world climatic change. From this follows another somewhat more surprising conclusion. Since the geoid corresponds to the sea level at any given time, the geoid itself must vary with the cycle of world climate. It fluctuates around three norms, assuming its minimum dimension in the relatively brief glacial stages when vast ice sheets cover much of the earth, and reaching its maximum in the long periods when the earth is relatively free of ice. In interglacial periods like the present, when a large portion of the earth's water is still tied up in the Greenland and antarctic icecaps, the sea level, and hence the geoid, oscillate between these extremes.

The Quaternary ice age now appears to be drawing to a close. A slow swing to a warm climate could melt the last of the great glaciers. Then another great deluge will drown present shorelines and submerge many centers of whatever civilization is there to witness it.



OPEN-FIELD EXPERIMENT illustrates how the behavior of a full-grown rat stimulated during infancy differs from that of a previously nonstimulated one. This multiple-exposure photograph shows how a nonstimulated rat (*lower right*) cowers in a corner when placed in an unfamiliar environment; the stimulated animal is much more willing to run about and explore his surroundings.

Stimulation in Infancy

Both painful shocks and gentle handling enhance the development of normal stress responses in infant animals. The absence of such treatment leads to behavioral disorders when the animal matures

by Seymour Levine

When the Emperor of Lilliput accepted Lemuel Gulliver into favor, His Most Sublime Majesty first secured Gulliver's solemn oath upon an agreement to observe certain rules of etiquette. The fourth article of the agreement stipulated that Gulliver should not take any Lilliputian subjects into his hands without their consent. Gulliver learned later to appreciate the sentiments behind this article in an intensely subjective way. In the country of Brobdingnag he was himself picked up in the huge hand of a Brobdingnagian. He recalled his reactions: "All I ventured was to raise my eyes towards the sun, and place my hands together in a supplicating posture, and to speak some words in an humble melancholy tone, suitable to the condition I then was in."

What Jonathan Swift describes here is the essence of an experience that befalls children and small animals every day. It happens whenever a parent picks up a baby, or a child tussles with his puppy. Almost all experiences of infancy involve some handling by a parent or some other larger and supremely powerful figure. Even the tenderest handling must at times be the occasion of emotional stress. Perhaps the only children insulated from such experience are those reared in orphanages and other institutions, and the only animals those that live in laboratories. Certainly the laboratory animal must find a minimum of stress and little stimulation of any other kind in an environment controlled for temperature, humidity, light and so on. In the ordinary world the infant must grow under the changing pressures and sudden challenges of an inconstant environment. One may well wonder how the stressful experiences of infancy affect the behavior and physiology of the adult organism later on.

When in 1954 we began our investigations into the broad area defined by this question, we naturally turned first to the presumably more obvious effects of early painful or traumatic experience. We subjected a group of infant rats to mild electric shocks, scheduled at the same hour each day. For control purposes we routinely placed the members of another group in the shock cage for the same length of time each day but did not give them shocks. A third group of infant rats was left in the nest and not handled at all. We expected that the shocked rats would be affected by their experience, and we looked for signs of emotional disorder when they reached adulthood. To our surprise it was the second control group—the rats we had not handled at all—that behaved in a peculiar manner. The behavior of the shocked rats could not be distinguished from that of the control group which had experienced the same handling but no electric shock. Thus the results of our first experiment caused us to reframe our question. Our investigation at the Columbus Psychiatric Institute and Hospital of Ohio State University has since been concerned not so much with the effects of stressful experience—which after all is the more usual experience of infants—as with the effects of the absence of such experience in infancy.

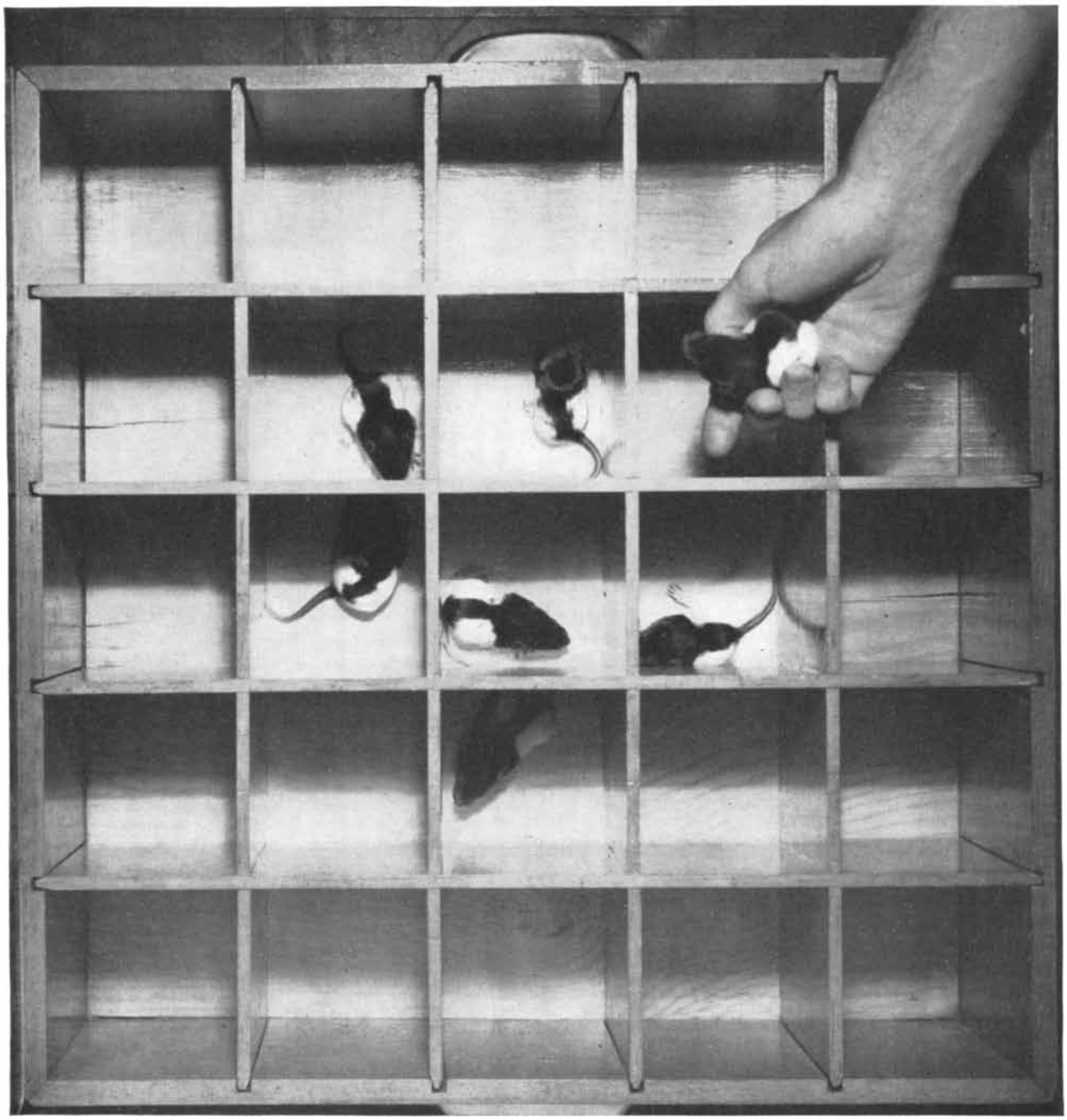
We have repeated our original experiment many times, subjecting the infant animals to a variety of stresses and degrees of handling. Invariably it is the nonmanipulated "controls" that exhibit deviations of behavior and physiology when they are tested as adults. Significantly these deviations involve the organism's response to stress, and they show up in most of the diverse aspects of that response. In a standard behavioral test, for example, the animal is placed in the unfamiliar, but otherwise neutral, surroundings of a transparent plastic box. The nonmanipulated animals crouch in a corner of the box; animals that have been handled and subjected to stress in infancy freely explore the space. The same contrast in behavior may be observed and recorded quantitatively in the "open field": an area three feet square marked off into smaller squares. In terms of the number of squares crossed during a fixed time period, shocked and manipulated animals show a much greater willingness to run about and explore their surroundings. In both situations the nonmanipulated animals, cowering in a corner or creeping timidly about, tend to defecate and urinate frequently. Since these functions are largely controlled by the sympathetic nervous system, and since certain responses to stress are principally organized around the sympathetic nervous system, this behavior is a sure sign of reactivity to stress.

Another objective and quantitative index of stress response is provided by the hormones and glands of the endocrine system. Under stress, in response to prompting by the central nervous system, the pituitary releases larger quantities of various hormones, one of the principal ones being the adrenal-corticotrophic hormone (ACTH). Stimulation by ACTH causes the outer layer, or cortex, of the adrenal gland to step up the release of its several steroids; distributed by the bloodstream, these hormones accelerate the metabolism of the tissues in such a way as to maintain their integrity under stress. The activity of the endocrine system may be measured conveniently in a number of ways: by the enlargement of the adrenal glands, by the volume of adrenal steroids in circulation

or by the depletion of ascorbic acid (vitamin C) in the adrenals. By some of these measurements the nonstimulated animals showed a markedly higher reactivity when subjected to a variety of stresses, including toxic injection of glucose, conditioning to avoid a painful stimulus and swimming in a water maze.

The conclusion that these animals are hyperreactive to stress is, however, an oversimplification that conceals an even more important difference in their stress response. Recently we measured the steroids in circulation in both stimulated and nonstimulated animals during the period immediately following stress by electric shock. Whereas the two groups showed the same volume of steroids in circulation before shock, the animals that had been exposed to stress in infancy showed a much higher output of steroids in the first 15 minutes after shock. The nonstimulated animals achieve the same output but more slowly, and appear to maintain a high level of steroid secretion for a longer period of time. There is thus a distinct difference in the pattern of the stress response in the two kinds of animal.

This observation acquires its full significance when it is considered in the light of the biological function of the stress response. The speed and short duration of the response in the stimulated animal obviously serve the useful purpose of mobilizing the resources of the organism at the moment when it is under stress. The delay in the endocrine response of the nonstimulated animal

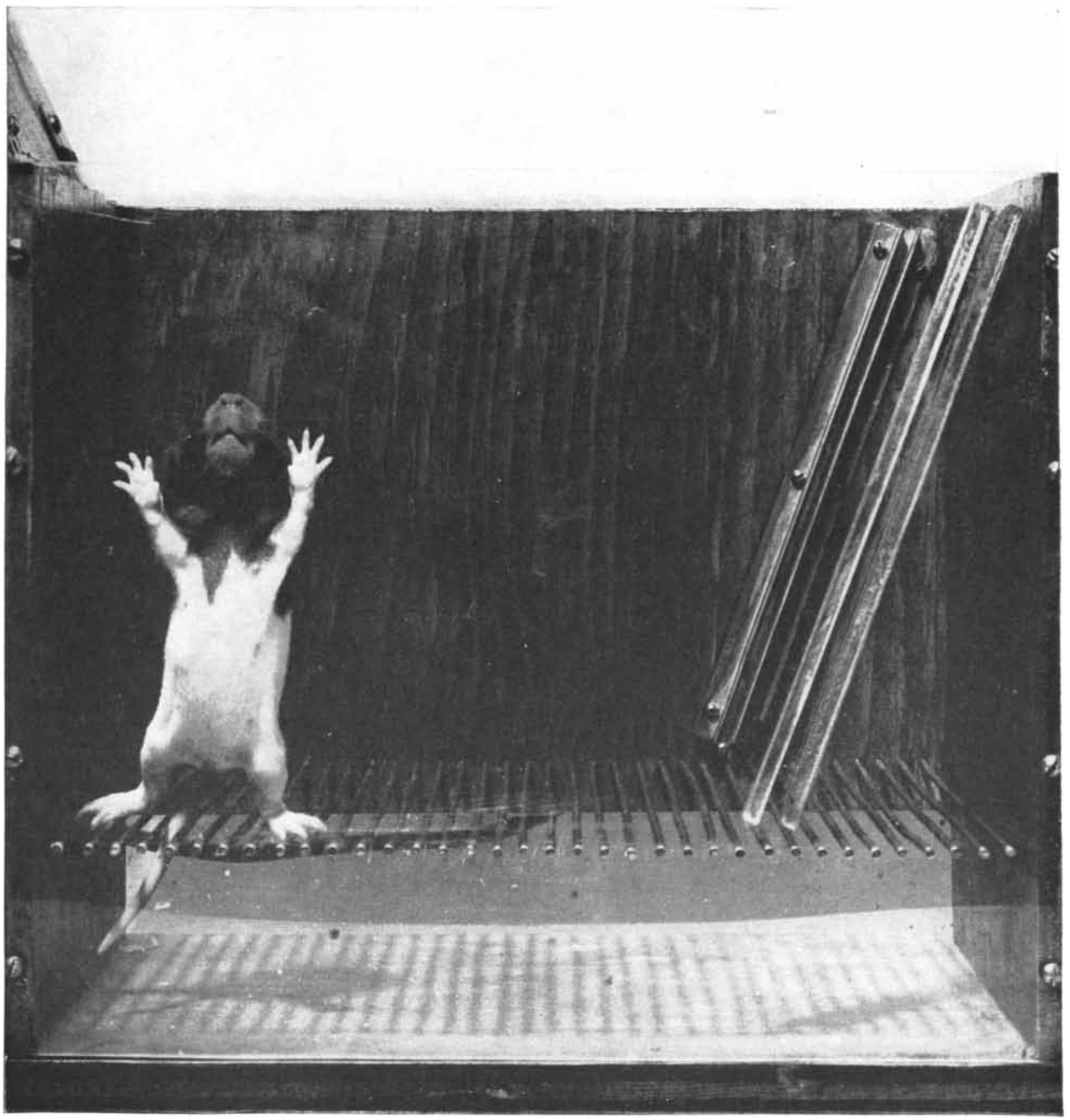


MILD STIMULATION consisted of picking up the infant rats, removing them from their breeding cage and enclosing them in a small compartment for three minutes a day. The rats were then returned to their nests. The rats shown here are about 11 days old.

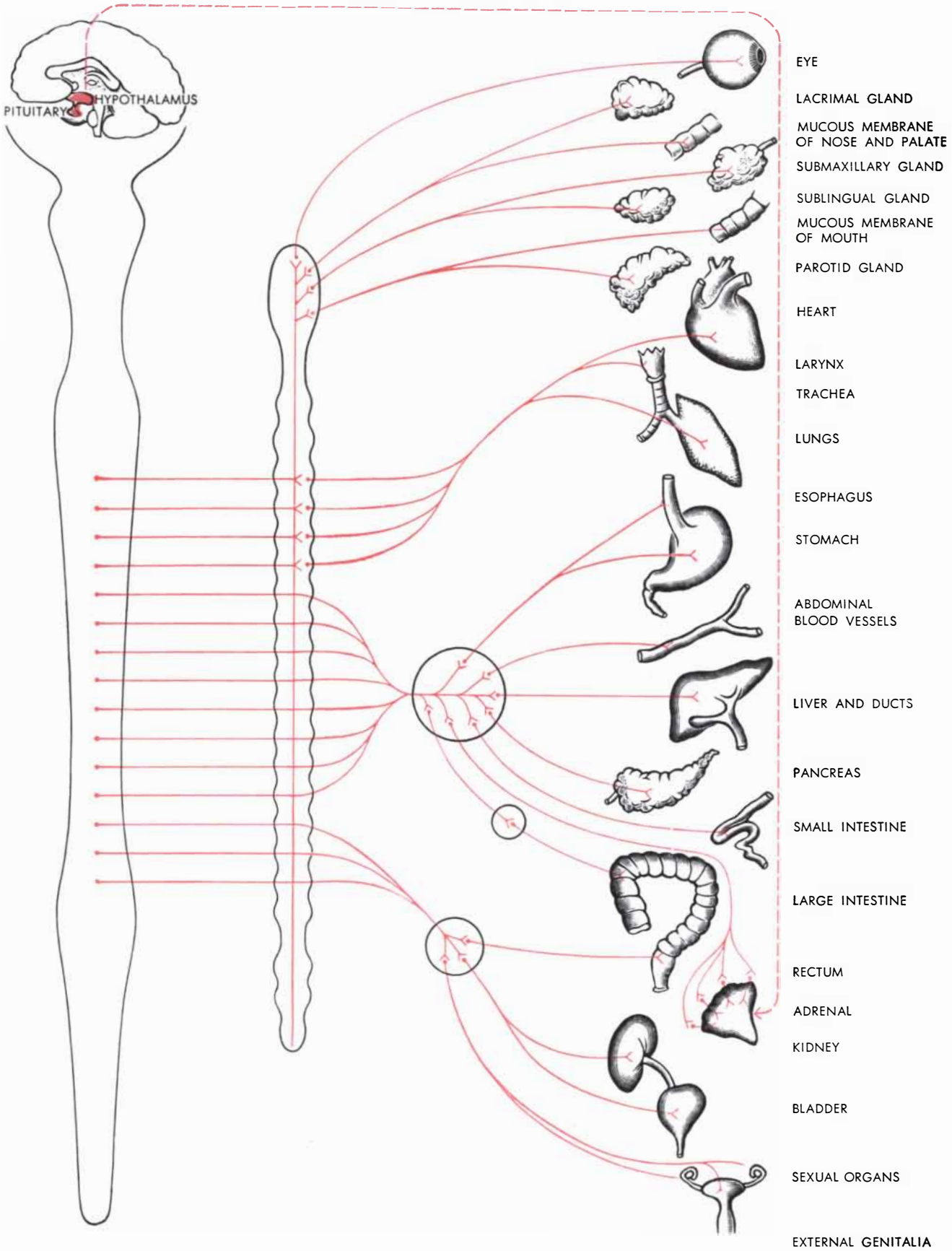
is thus, by contrast, maladaptive. Moreover, the prolongation of the stress response, as observed in these animals, can have severely damaging consequences: stomach ulcers, increased susceptibility to infection and eventually death due to adrenal exhaustion.

The maladaptive nature of the stress response in the nonmanipulated animal is further manifested in the fact that it may be elicited in such a neutral situation as the open-field test. The animal that has been manipulated in infancy shows no physiological stress response in this situation although it exhibits a vigorous and immediate endocrine response when challenged by the pain and threat of an electric shock.

In this connection we have made the interesting discovery that stimulation by handling and stress hastens the maturation of the stress response in the infant animal. Although the adrenal glands begin to function shortly after birth and the pituitary appears to contain ACTH early in the course of development, the nerve mechanism that controls the release of ACTH does not seem to come into operation until the rat is about 16 days of age. When we exposed infant rats that had been handled from birth to severe cold stress, however, they showed a significant ACTH response as early as 12 days of age. This four days' difference represents a considerable acceleration of development in the rat, equivalent to several months in the growth of a human infant. The manipulated animals, more-



PAINFUL STIMULATION consisted of subjecting the infant rats to an electric shock lasting from several seconds to several minutes. The effects on the rat's behavior as an adult were indistinguishable from those produced by the routine shown on the opposite page.



RESPONSES TO STRESS are partly controlled by the pathways shown in this diagram of the human sympathetic nervous system. Sympathetic fibers (*solid colored lines*) originating in the spinal cord (*far left*) innervate the internal organs via the chain ganglia (*left center*) and the ganglia of the celiac plexus (*right center*). Extreme stress upsets the normal rhythm of this system, causing disturbances such as loss of bladder control and increased pulse rate. Stress also stimulates the hypothalamus and the pituitary to produce ACTH, which reaches the adrenals via the bloodstream (*broken line*) and stimulates them to produce steroid hormones.

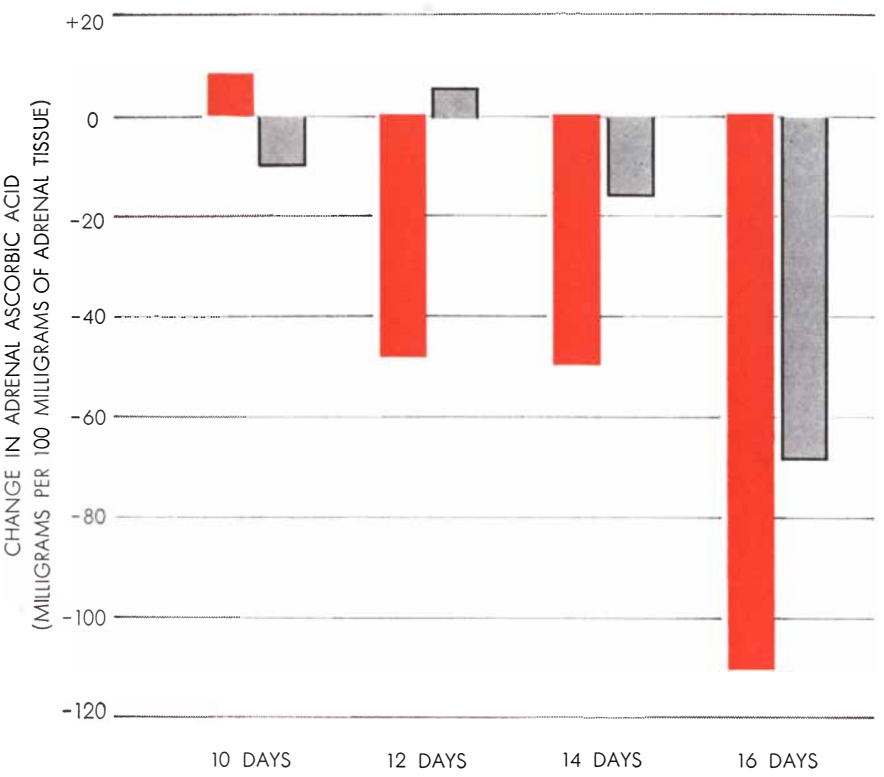
over, reached an adult level of response considerably earlier than their untreated litter mates.

From the evidence it may be inferred that stimulation must have accelerated the maturation of the central nervous system in these animals. We have direct evidence that this is so from analysis of the brain tissue of our subjects. The brains of infant rats that have been handled from birth show a distinctly higher cholesterol content. Since the cholesterol content of the brain is related principally to the brain's white matter, this is evidence that in these animals the maturation of structure parallels the maturation of function.

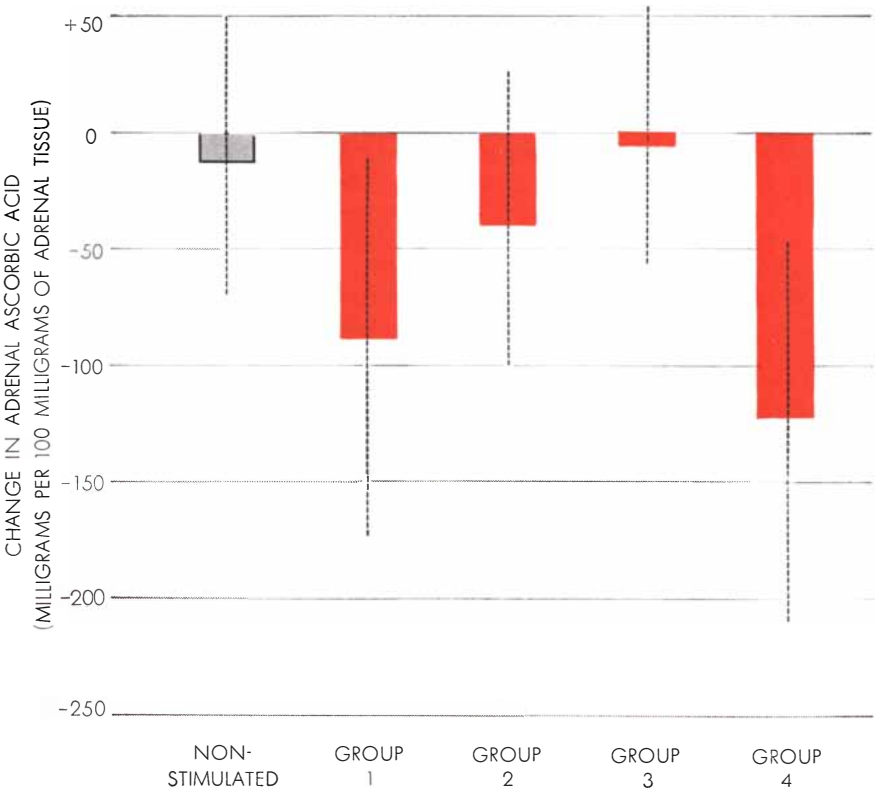
In all respects, in fact, the manipulated infants exhibit a more rapid rate of development. They open their eyes earlier and achieve motor coordination sooner. Their body hair grows faster, and they tend to be significantly heavier at weaning. They continue to gain weight more rapidly than the nonstimulated animals even after the course of stimulation has been completed at three weeks of age. Their more vigorous growth does not seem to be related to food intake but to better utilization of the food consumed and probably to a higher output of the somatotrophic (growth) hormone from the pituitary. These animals may also possess a higher resistance to pathogenic agents; they survive an injection of leukemia cells for a considerably longer time.

Another contrast between the stimulated and unstimulated animals developed when we electrically destroyed the septal region of their brains, the region between and under the hemispheres of the midbrain. Such damage makes an animal hyperexcitable, vicious and flighty. It will attack a pencil extended to it, react with extreme startle to a tap on the back, is exceedingly difficult to capture and upon capture will bite wildly and squeal loudly. In systematic observation of these responses we found that manipulated animals are far tamer postoperatively than nonmanipulated ones. The latter rank as the most excitable and vicious rats we have ever observed in the laboratory; it was not unusual for one of these animals to pursue us around the room, squealing and attacking our shoes and pants legs.

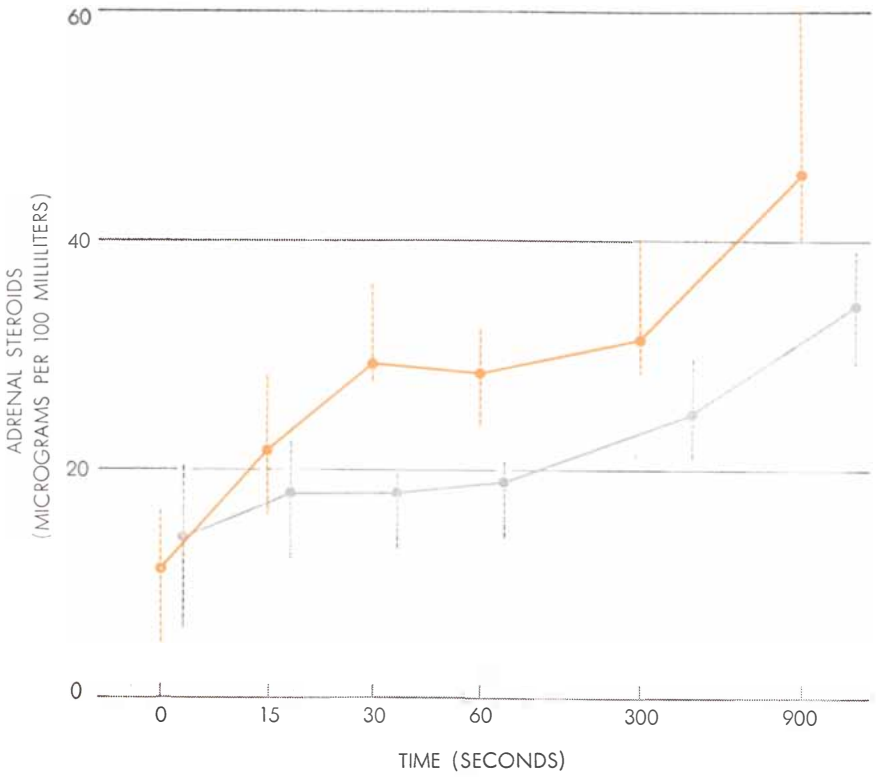
At the very least our experiments yield an additional explanation for the variability among laboratory animals that so often confuses results in experimental biology. This has been attributed to genetic differences, unknown factors and sometimes to experimental error. It



EXPOSURE TO COLD produced a marked drop in the ascorbic acid (vitamin C) concentration in the adrenal glands of stimulated rats more than 10 days old (*colored bars*), but produced no significant effect on the nonstimulated rats until they were 16 days old.



CRITICAL PERIOD in the development of the stress response was determined by stimulating infant rats at different stages of life. They were then exposed to cold and the drop in their adrenal ascorbic acid level was analyzed. Rats in Group 1 (stimulated from the second to the fifth days of life) and in Group 4 (stimulated from the second to the 13th days) responded better than both the nonstimulated rats and those in Groups 2 and 3 (stimulated from the sixth to the ninth and from the 10th to the 13th days, respectively). The bars show the average drop in the concentration and the broken lines the range.



SLUGGISH RESPONSE to an electric shock is indicated by the slow rise in the concentration of circulating steroid hormones in previously nonstimulated rats (*gray curve*). In the stimulated animals (*colored curve*) the level increases rapidly for about 15 minutes. The points on the curve indicate the average level and the broken lines the range of values.

is apparent that the character of early infant experience is another important determinant of individual differences in animals.

The same consideration leads to the broader question of "nature *v.* nurture," that is, the contribution of genetic factors as opposed to the influence of the environment. Both sets of factors are essential and they interact to give rise to the individual organism. The basic patterns of development are most likely determined by heredity. But the genetic determinants do not find expression except in interaction with various aspects of the environment. In the normal course of events the environment provides the substance, energy and milieu for the unfolding of the organism's potentialities; in the extreme, environmental influences can determine whether the process of development will continue and produce an organism. In other words, organisms do not grow in a vacuum. This is true even of our nontreated animals: litter mates and the routine laboratory procedures furnish stimulation of all kinds. Such stimulation does not compare, however, with that provided by our experimental treatments. We have dealt with only a limited range of effects, and have focused primarily on the physiological and behavioral responses to stress. But our results clearly indicate that stimulation of the infant organism has quite universal consequences upon the behavior and physiology of the adult.

One must be careful in attempting to bridge the gap between animal experimentation and human biology. The effects of early experience have proved to be significant, however, in many species of mammal, including the monkey, dog, cat, guinea pig and mouse, and in such nonmammals as fish and fowl. It cannot be said that the phenomenon is species-limited. A great deal of clinical evidence, moreover, clearly indicates that infant experience in humans has a profound effect in shaping the character and constitution of the adult. Investigators concerned with maternal deprivation report that children raised in foundling homes develop at a retarded rate and are more susceptible to disease. These observations are similar to those we have made in our animal experiments. It may be that the detrimental effects of the foundling home have less to do with maternal deprivation than with the simple lack of stimulation that is inevitable in most such environments. The character of early experience may thus also underlie many problems in psychosomatic medicine and may explain in part why one individual develops ulcers, another migraine headaches and yet another shows little or no psychosomatic involvement under the same pressures of living.

One of the most encouraging aspects of our research is that it has raised more questions than it has answered. We have not yet, for example, identified the critical element in our stimulation procedures that leads to such predictable and profound effects. Painful and extreme forms of stimulation seem to have effects indistinguishable from those produced by merely picking up an animal and placing it in another location for a brief period of time. Is picking up an infant organism as casual and insignificant a procedure as it appears? Or is the experience of the infant closer to that of Gulliver in Brobdingnag? Mere handling may, in fact, constitute a stimulation as compelling and severe as the more obviously traumatic forms of stimulation. It may be that some degree of stressful experience in infancy is necessary for successful adaptation of the organism to the environment it encounters in later life.

Another important question is whether there is a critical infantile period (or periods) during which stimulation is most effective. The evidence so far points to a period following immediately after birth. In one study we handled the animals in three separate groups for four days each, from the second through the fifth day, from the sixth through the ninth day and from the 10th through the 13th day. When we tested them for stress response on the 14th day, only the first group showed any evidence that they were capable of an endocrine response. Other investigators have had similar results. This should not be taken to mean, however, that stimulation has no effect after the critical period is past or that one critical period sets all responses.

Still other questions have not yet been satisfied by even partial answers. There is, for example, the question of therapy: Can the effects of lack of stimulation in the critical period be counteracted by stimulation of any sort after the critical period has passed? The most pressing question—the most "stimulating" question—is how stimulation causes change in the infant organism. The answer to this question should lead to a fuller understanding of the differences between individual constitutions and of the physiological mechanisms that are involved in behavior.

Kodak reports on:

walking a .030″ fence to communicate by sight and sound . . . lenses for the new phosphors

The paradox of 8

How would you like a good sound recorder that also shows movies? For $345 list.

Make your movies with a regular 8mm camera. If you want a suggestion, it could be a Brownie Movie Camera, which starts as low as $24.50 list. Have your film processed. Either then or after editing, have the dealer send it to us for *Kodak Sonotrack Coating*, a magnetic stripe .030″ wide between the sprocket holes and the edge of the film. Project with the new *Kodak Sound 8 Projector* and into the little microphone speak your comments. In case of afterthoughts, solecism, or fuzzy rhetoric, hit the knob (excellent brakes) and the "record" switch, reverse, throw into forward, and record

again. This takes care of erasing. Start again in the middle of a sentence if you wish. No waiting to reach recording speed. Project again to listen back. When completely satisfied with telling the story in English, you can erase and retell it on the same film in the Luganda tongue.

This is quite a system of communication. Use it to instruct your Swaziland branch office. Report to the home office on whether the breakwater at Pago Pago needs rebuilding and how the swallows come in for the landing at Capistrano. Save days of literary toil. What few words the movies leave to be said are more convincing when heard in accompaniment to the sight of the action. (As for combined records of the children's voices and swiftly changing ways, shame on sentiment!)

We owe you an explanation of why you have heard very little hitherto about 8mm sound movies. A paradox bedevils the manufacturer. To yield accustomed quality of performance, he has to build the machine more than twice as good as a 16mm sound rig, but he is expected to sell it for less than half the price. For accomplishing this, they don't even award Nobel Prizes.

Because of the very small width of the magnetic stripe and the relatively high tracking force, the magnetic head must be hard physically so that the gap shall not wear down to another dimension and thus lose sound quality. At the same time it must be soft magnetically to conduct but not retain flux.

We wish we could boast that the practically wear-proof aluminum-iron alloy we use for the .020″-wide head was developed by us, but actually it was developed by the Naval Ordnance Laboratory for their own purposes. We do, though, lay claim to the credit for a system that gives 70 to 5500 cycles/sec frequency response while running at only 2.4 inches/sec—as at 16 frames/sec. It does even better at 24 frames/sec speed. We went to some lengths, engineeringwise, to provide the latter speed when we heard that some segments of the motion picture industry might be offering 8mm rental prints of their theater releases.

Demonstrations cheerfully given where the "Kodak" sign is displayed. Say distinctly: Kodak Sound 8 Projector.

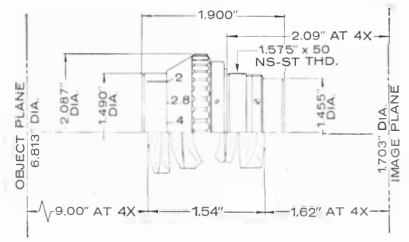
Heat from the tubes

Create a stream of electrons, focus them into a sharp pencil, and write or draw with it. Great Zeus! *There* is an idea worth noting in the history of man's climb upward from the slime! Whither it will lead tomorrow can only be guessed at. Today there are contracts to be fulfilled (and possibly money to be made) by finding a lens to image some smart writing from a cathode-ray tube to photographic material and then doing something further smart from there.

A lens? It so happens that you have come to the right place, you there with the black boxes. Your suspicion may well be justified that the old photoenlarging lens which images your c-r tube on a piece of drugstore film could be missing some of the voluminous detail being poured forth so ferociously by your black boxes. (Better not to disclose what happens in them. Kodak, too, makes mysterious black boxes. It's the American way.)

Formula M-236 is our designation for a beaut of a lens. It represents our response to the heat being put on our end of the c-r recording business by the tube makers. As long as their phosphors couldn't show any finer detail than 10 lines per millimeter on the tube face, it was silly to fuss over the lens. Now that they can put down 100 lines per millimeter, a basic fact of lens design must be faced. A lens designed for distant objects, as most photographic lenses are, cannot function at its best for 4:1 reduction.*

M-236 is designed for 4:1 reduction. Here, for the guidance of the man who needs to design equipment around the finest cathode-ray tube lens currently available on special order, and to the intense boredom of the man who doesn't, are the dimensions:



The lens is achromatized for P-16 phosphor. When the diaphragm is wide open to the *f*/2.0 mark, the edge of the 1.700″-diameter image gets 35% as much illumination as the center. If that image size is too small, or if you use P-11 instead of P-16, we have several other c-r lens designs of longer focal length and for lesser reduction.

As to the resolution, we could quote a lot of numbers that are obviously supposed to make your jaw hang slack but don't mean a thing until you pick the film to use with the lens. For this you must be prepared to answer questions on how much voltage to light the tube, how much time to record, how many seconds to process (!), how to be read, etc.

Then you get in touch with Eastman Kodak Company, Special Products Division, Rochester 4, N. Y. No obligation, of course, but what did you say the color of your money was?

*Visitors to Rochester are sometimes permitted a glimpse at a mathematician of ours who thinks, after some years of immersion in matrix algebra, that by and by he will be able to write a computer program which, for any set of circumstances whatever, will design the best possible lens.

Prices quoted are subject to change without notice.

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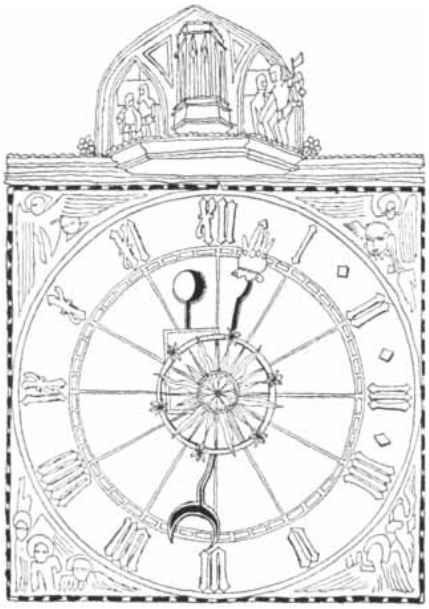
This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science



Satellites

The launching of *Pioneer V* into its solar orbit and of *Tiros*, the weather observer, and *Transit I-B*, the beacon, brought to 13 the number of man-made vehicles still intruding on space. Ten of them are traveling around the earth and three around the sun.

Tiros, following the most nearly circular orbit yet achieved, and carrying television cameras and automatic positioning equipment, is the first satellite adapted to systematic observation of the earth. In its first two days aloft it returned 1,200 pictures of the earth's cloud cover as seen from an altitude of 450 miles. It can make and transmit 120 such pictures on each 99-minute revolution. From future vehicles of the same type meteorologists may acquire valuable information for weather forecasting, especially for tracking storms that originate over the oceans. Perhaps the most notable feature of the vehicle is the excellent performance of its complex electronic devices.

The circuitry on *Pioneer V* was also working well. As the satellite moved farther out on its orbit between the earth and Venus, its five-watt transmitter continued to send information from distances beyond two million miles. In its first days *Pioneer V* confirmed the existence of two phenomena, each of which has been detected only once before. The first is the "ring current," a stream of low-energy protons and electrons circling the earth at a distance of 20,000 to 28,000 miles. It had previously been encountered by *Explorer VI*. The second was a region of magnetic turbulence where the "solar wind" of protons streaming from the sun meets the earth's magnetic field. Evidence of this turbulent boundary region had come earlier from *Pioneer I*. On about May 15 a larger transmitter with a power of 150 watts will start to operate in *Pioneer V*. This transmitter is expected to maintain contact out to 50 million miles.

Still beeping after two years in space is the grapefruit-sized *Vanguard I*. During nearly 8,000 circuits of the earth completed by its second anniversary, it has wandered about a mile off its predicted course. The discrepancy has been traced to the pressure of sunlight. Calculations indicate that light pressure will exert an even greater effect on large, lightweight satellites.

An earlier result of studies of the *Vanguard I* orbit has recently been challenged. J. L. Brenner of the Stanford Research Institute and R. Fulton and N. Sherman of the University of California write in *American Rocket Society Journal* that perturbations in the satellite's path do not warrant the conclusion that the earth is pear-shaped. Their analysis shows that a symmetrical earth could also give rise to the observed motion.

A Red-Shift Confirmed

The principle of equivalence, the foundation on which the general theory of relativity rests, has been confirmed by laboratory test. R. V. Pound and Glen A. Rebka, Jr., of Harvard University have found that electromagnetic waves change frequency when they rise or fall in the earth's gravitational field.

This effect was predicted by Albert Einstein when he postulated that inertial force (*i.e.*, force arising from accelerated motion) should be equivalent in every way to gravitational force. Applied to electromagnetic radiation, the principle implies that photons, or quanta of radiation, lose energy in moving up against gravity, and gain it in falling down, just as material bodies do. Since a photon's energy is proportional to its frequency, the change will be reflected as a shift in frequency. Thus visible light moving outward from a massive star is expected to decrease in frequency, its color shifting toward the red end of the spectrum. However, several other influences also change the frequency of starlight, so

astronomers are unable to measure the gravitational red-shift unambiguously.

On a terrestrial scale the predicted effect is so small that, until recently, there was no hope of finding it at all. To do so requires a beam of waves of very nearly uniform frequency as well as a means of detecting a tiny shift in the frequency. Then R. L. Mössbauer, a German physicist, discovered that radioactive nuclei in certain crystals emit gamma rays with an extremely narrow band of frequencies. Furthermore, the ability of nonradioactive nuclei of the same species to absorb the radiation is highly sensitive to a change in frequency [see "The Mössbauer Effect," by Sergio De Benedetti; SCIENTIFIC AMERICAN, April].

Pound and Rebka made use of this property in nuclei of iron 57. They placed an emitter of the material at one end of a 70-foot tower and an absorber at the other, and observed the frequency-shift in the photons that traveled up or down. In their early experiments they found that variations from other sources, particularly temperature changes, masked the small effect they were looking for. After the sources of error were discovered and taken into account, they measured a gravitational frequency-shift just 5 per cent greater than the predicted value, with a statistical error of 10 per cent. Reporting their result in *Physical Review Letters*, they say that further trials should reduce the error by a factor of four.

While the experiment appears to confirm the principle of equivalence, it says nothing about the specific theory that Einstein built upon the principle. According to L. I. Schiff of Stanford University a definitive test of this theory would be provided by the precessional motion of a gyroscope mounted in an artificial earth satellite. Also writing in *Physical Review Letters*, he suggests that a sufficiently sensitive gyroscope might be made of a superconducting sphere spinning on a virtually frictionless magnetic bearing.

Food-Additives Curb

Since March 6 the addition of chemicals to foods has been under the regulation of the 1958 Food Additives Amendment to the Food, Drug and

Cosmetics Act. The Amendment puts the burden of proving safety on processors who wish to introduce a new food additive, in much the way that drug manufacturers are required to prove the safety of new drugs. Chemicals in packaging materials, as well as those added directly to foods, are covered by the Amendment. An additional provision, the Delaney clause, flatly bars any substance shown to have induced cancer in any animal. It was under this clause that the Food and Drug Administration last fall banned cranberries contaminated with the weed-killer aminotriazole.

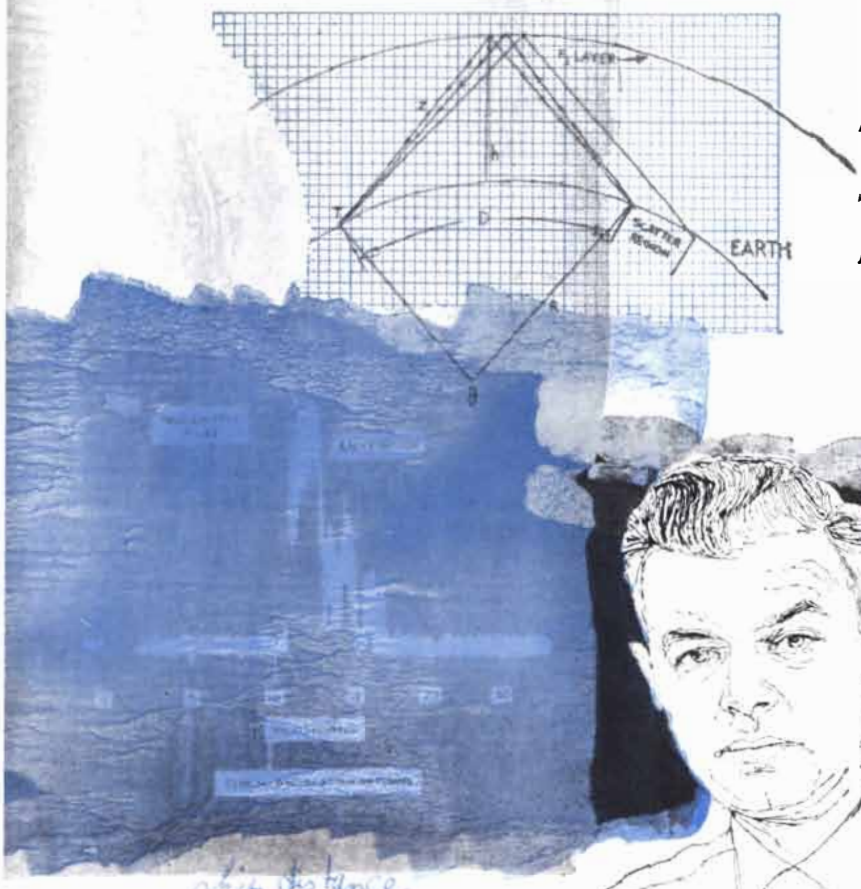
Molecular Crossbreeding

Chemists at Harvard University have learned how to make hybrid molecules of the genetic material deoxyribonucleic acid (DNA) in the test tube. With a simple heating and cooling treatment they can pull apart the strands of the double-stranded molecule and then either rejoin them or cause them to pair up with strands from different individuals to form biologically active molecular hybrids. The new technique is a powerful tool for investigating the mechanism of heredity.

It had long been known that DNA is inactivated by heating. Measurements showed that heating cut in half the molecular weight of the material, presumably by separating its strands. On cooling, however, the preparation usually regained a small fraction of its biological activity. Investigating this process at Harvard, Paul Doty and Julius Marmur discovered that when a heated sample of DNA is cooled very quickly, practically all of the strands remain separate (and inactive). On the other hand, slow, controlled cooling results in the recombination of most of the strands into normal, biologically active DNA molecules.

In *Proceedings of the National Academy of Sciences* the chemists describe how they made hybrid DNA from two bacterial strains. One strain was grown on a medium containing ordinary nitrogen of atomic weight 14. The other was grown on a nitrogen-15 medium. DNA extracted from both organisms was heated and quickly cooled. Then the preparations were combined and cooled slowly. The resulting mixture contained molecules of DNA whose weight showed that half of their nitrogen was N-14 and half N-15.

In a biological test Doty and Marmur crossed the DNA from a streptomycin-resistant strain of bacteria with that from a normal streptomycin-sensitive strain. More than half of the new DNA was of



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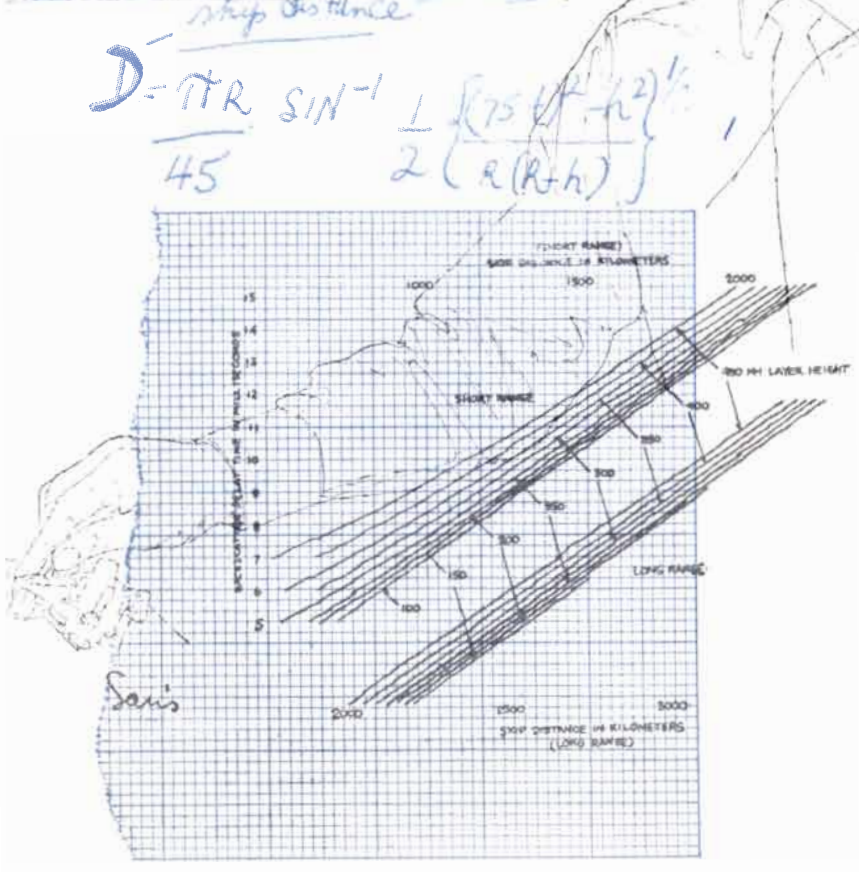

Modern long range communication and detection systems require a detailed knowledge of the charged portion of the upper atmosphere known as the ionosphere. For the past ten years Raytheon scientists and engineers have been engaged in experimental and theoretical studies of ionospheric effects on electromagnetic propagation.

A key factor in successful long range radio communication is the selection of the frequency that, after reflection by the ionosphere, will provide the strongest signal at the receiving terminal. Choosing the optimum frequency for transmission requires determination of "skip distance"—the minimum distance from a transmitter at which ionospheric propagated signals will be received—as a function of operating frequency.

To provide this information Raytheon designed and developed COZI, a communication zone indicator which instantaneously measures skip distance in the 5-30 mc band at the transmitting site. It records the time interval between a transmitted signal and a portion of a signal that has been doubly reflected back (back-scattered) to the transmitting site by the earth's surface and the ionosphere. The interval is then converted to skip distance and from this data optimum frequencies can be selected for communicating with any desired point in a range of 2,000 miles or more.

Among the scientists who have initiated and carried out the basic propagation research responsible for COZI are L. C. Edwards and D. A. Hedlund of Raytheon's Equipment Division.

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the resistant type, as proved by the fact that, when incorporated by other normal bacteria, it conferred resistance. Evidently both halves of the original resistant DNA carried the trait, and each strand was capable of producing it in a hybrid.

The new technique will be valuable in tracing the effects of various gene combinations and of mutations. It suggests the possibility of designing DNA to carry out specific functions in living cells. Participating with Doty and Marmur in the experiments thus far have been Joseph Eigner, Carl Schildkraut and Dorothy Lane.

Riddle of the Ridge

The most striking feature of the earth's surface discovered in recent decades is the mid-ocean ridge running beneath all the oceans except the North Pacific. The ridge is far longer than any mountain system on land, with a total length of 45,000 miles. Along its crest there is a pronounced rift, as though the earth's crust were cracking apart on the line of the undersea range. Now seismic evidence indicates that the ridge may be composed of rock thrust upward from the earth's mantle rather than of the sedimentary rock that characterizes continental mountain masses. Earthquake waves travel through it at the same speed as through mantle rock close to the earth's surface.

The seismic data were reported by W. Maurice Ewing of the Lamont Geological Observatory in a lecture delivered after he had received the first Vetlesen prize, a new $25,000 biennial award for work in the earth sciences. The lecture was followed by a sharp debate on the origin and significance of the crack in the ridge. Ewing and F. A. Vening Meinesz of the Netherlands think that the rift results from convection currents in the earth's mantle. Bruce C. Heezen of the Lamont Observatory attributes the cracks to the expansion of the earth, perhaps as the result of an intrinsic weakening of the force of gravity.

That the universal gravitational attraction may be decreasing with time was first suggested in 1937 by the British physicist P. A. M. Dirac. R. H. Dicke of Princeton University has calculated the effect of the suggested change upon the size of the earth; he concludes that the circumference of the earth might have grown by 1,100 miles in 3.25 billion years. Recently J. Tuzo Wilson of the University of Toronto pointed out in *Nature* that the increase in the surface area of the earth resulting from an

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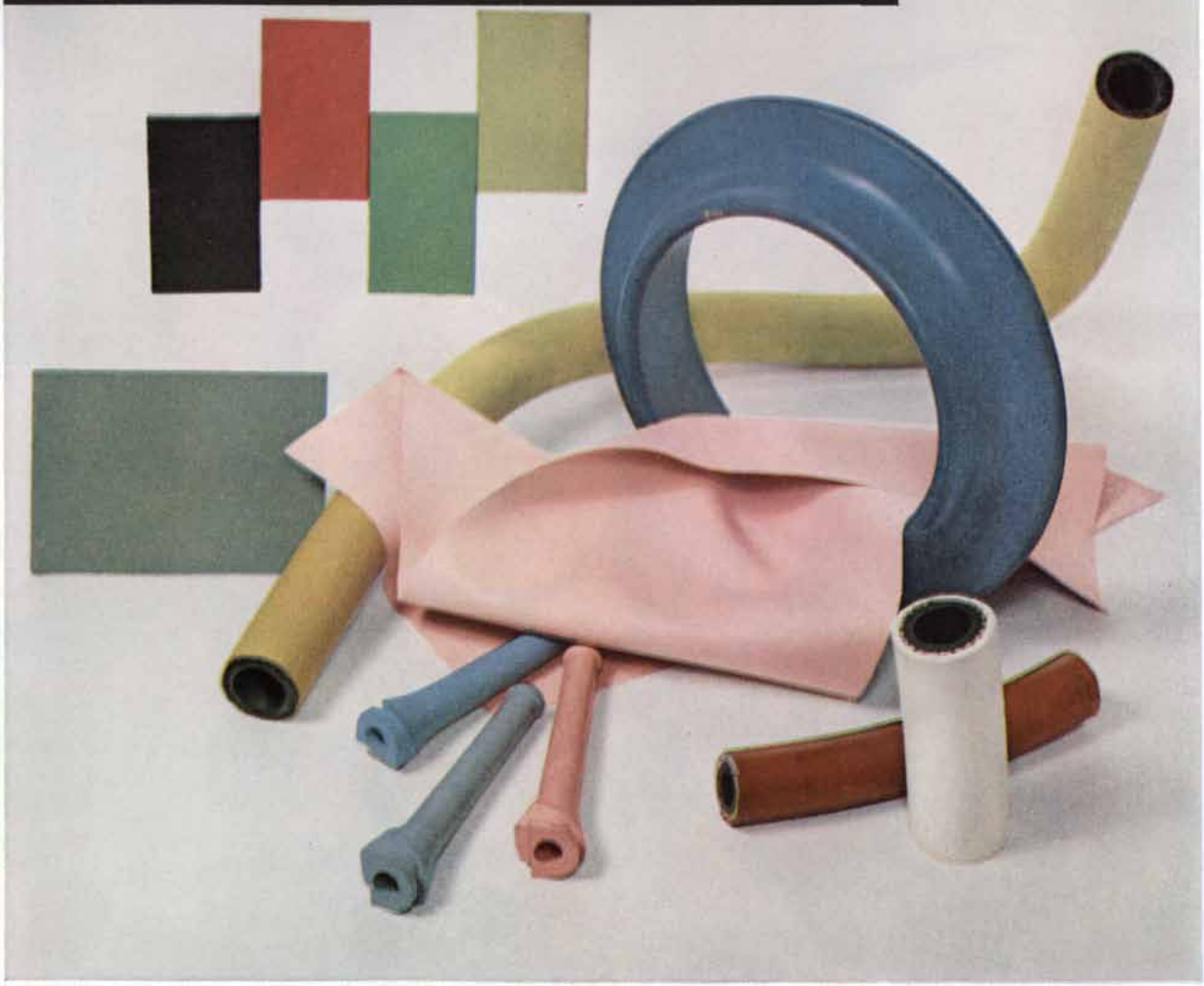

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Photograph by William Richards

WALT SICHA CASTS THE UNCASTABLE

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1,100-mile increase in circumference would be nearly equal to the total area of the mid-ocean ridges. Other geophysicists have suggested that variations in the density of matter in the earth's interior could have made the earth expand without any change in the gravitational constant.

In February Australian oceanographers discovered a new feature of the ocean floor: a deep trench in the Indian Ocean running parallel to the mid-ocean ridge 800 miles to the west. It is at least 250 miles long and 10 to 20 miles wide at the top.

Reversal of Resistance

A large London hospital has reduced the incidence of antibiotic-resistant staphylococcal infections in its wards by forcing the bacteria back into an antibiotic-sensitive form. This was accomplished by reversing one of the key procedures followed by most hospitals in combatting the staphylococcal plague. Instead of reserving the newer antibiotics exclusively for patients ill with resistant infections, Mary Barber and her colleagues at Hammersmith Hospital prescribed full doses of two of these drugs for all patients requiring antibiotic treatment. One was a broad-spectrum agent such as tetracycline or chloramphenicol and the other was either erythromycin or novobiocin.

The new method was tested in wards to which 5,239 patients were admitted during a 15-month period. In addition, some of the more conventional anti-staphylococcal measures were employed. Vigorous steps were taken against cross-infection. Routine prophylaxis with antibiotics before surgery was discontinued. Penicillin was used as sparingly as possible, and, when prescribed, was administered in such a way that it did not get into the air.

At the start of the experiment 88 per cent of the staphylococci recovered from patients were resistant to penicillin, and 70 per cent were resistant to the tetracyclines as well. At the end only 36 per cent were resistant to both penicillin and tetracyclines, and an additional 16 per cent were resistant to penicillin alone.

Oldest Rocks

The proved age of the earth is finally approaching the known age of meteorites—4.5 billion years—believed on astronomical grounds to have been formed at the same time as the earth. Samples of basement rock recovered in South Africa have been found by the uranium-lead dating method to be at least four billion years old. The oldest rock previously known was a specimen of mica, estimated to be 3.4 billion years old, found near Murmansk in the U.S.S.R. in 1958.

The new oldest rock was reported by A. L. Hales of the Bernard Price Institute in Johannesburg to a conference on geological dating at the New York Academy of Sciences. The conferees also constructed the outline of a more accurate geological time-scale, based on a number of recently determined reference points. For example, G. H. Curtis of the University of California provided a new breakdown of the Tertiary period (the age of mammals) through his dating of volcanic ash from the western U. S. containing a graded series of vertebrate fossils.

The revised chronology pushes back several of the major subdivisions of past scales: The beginning of the Cambrian period (the era of the earliest marine fossils) is now set at 600 million years ago instead of 560 million. The Devonian (the time of the first fishes) has been pushed to between 360 million and 400 million years ago; the Permian (when many insects appeared) has been lengthened to 50 million years and moved back; the end of the Triassic (the age of the first dinosaurs) has been fixed at 190 million years ago.

The new times were arrived at with the aid of improved procedures for measuring the radioactive decay of uranium 238, rubidium 87 and potassium 40, and with improved half-life determinations for rubidium 87 and potassium 40. Techniques now available can date suitable specimens of almost any period in the earth's history with an error of a few per cent. The principal remaining difficulties are encountered with samples more than 50,000 and less than a million years old. Those younger than 50,000 years can be dated by radiocarbon procedures; those older than a million years can be dated by several methods. Specimens in between can be dated accurately only if they contain enough potassium for potassium-40 determinations.

Whose Tools?

Is *Homo sapiens* the only animal that has used tools and fire? In disagreement with many anthropologists, Raymond A. Dart of South Africa has for several years been insisting that he is not, claiming the distinction also for *Australopithecus prometheus,* the man-ape whose remains were discovered 11

years ago at Makapansgat in South Africa. Now Dart offers further evidence in favor of his view.

In *The American Journal of Physical Anthropology* Dart writes that he has combed through 40,000 tons of rubble at Makapansgat for bone fragments. From the first seven tons he recovered more than 35,500 fragments. Included are many animal humerus bones employed, Dart believes, as clubs, and numerous other pieces that he considers to be knives, chisels, gouges, scrapers, saws and scoops.

Dart and an associate, James W. Kitching, think that they have learned how the diminutive man-ape (adult Australopithecines were only four feet tall) made one of his most distinctive tools. One Sunday Kitching saved the femur from his family's roast of mutton. In the laboratory he struck the shaft of the bone with the point of a stone and twisted the ends apart. He obtained a pair of spiral blades exactly like many that have been found in the rubble. Because no stones have been encountered in the remains, Kitching then demonstrated that the result can also be obtained by hitting a mutton bone against any sharp edge and twisting it.

Australopithecus, who presumably used the same technique, also had an ingenious way of obtaining sharp bone-fragments of smaller size. He rammed the core of a gazelle horn or similar piece of bone into the narrow space of a larger bone until the latter splintered. In this way he may even have invented tools with handles. One specimen found by Dart is a tibia flake jammed into a metatarsal bone, forming, he suggests, a cutting tool fitted purposely with a handle.

Soundings Declassified

The U. S. Navy has declassified all ocean depth-soundings obtained by its ships traveling on routine operations and using conventional methods of navigation. Hitherto only Navy scientists and a small circle of civilians had access to the data. Other maritime nations, with the exception of the U.S.S.R., have generally released this type of information. The large body of new data is expected to be a substantial aid to studies of the ocean floor.

Extragalactic Radio Sources

In less than three months of full-scale operation a radio telescope at the California Institute of Technology has located nine new discrete sources of radio waves outside the Milky Way, at dis-

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tances up to a billion light-years from the earth. Only five other extragalactic sources had previously been located by all the world's radio telescopes.

The new instrument, situated in Owens Valley, 250 miles north of Los Angeles, consists of two 90-foot antennas mounted on a 1,600-foot railroad track. According to the Office of Naval Research, which supplied most of the funds for its construction, it has "a resolving power greater than any radio telescope in operation or under construction."

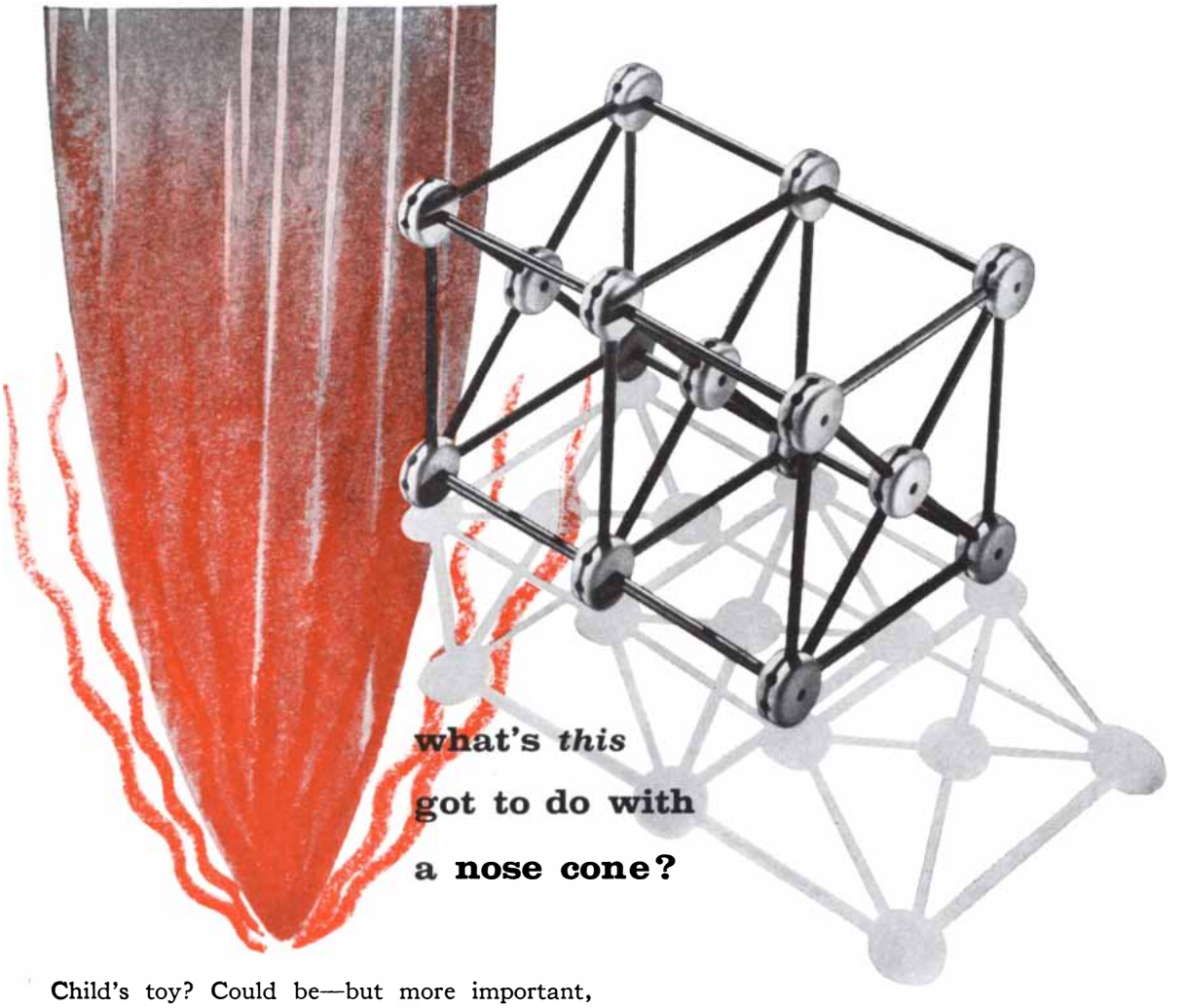
Antisigma Minus

After a long tuneup the 10-billion-electron-volt synchrotron in the U.S.S.R. has begun to turn out scientific results. An announcement in *Pravda* last month said the accelerator had created a negative antisigma particle. This is the first charged antiparticle to be identified among the hyperons (particles heavier than protons and neutrons). In agreement with theoretical predictions the antisigma was about 2,300 times heavier than the electron, and decayed in 10^{-10} second to an antineutron and a pi meson.

A few months ago workers at Dubna, where the accelerator is located, reported the discovery of a new meson, which has been nicknamed the dubnion. Physicists generally are awaiting further evidence before accepting it as a member in good standing of the particle family.

Archaeological Emergency

A program to salvage archaeological treasures threatened by the Aswan High Dam in Egypt has been launched under the auspices of the United Nations Educational, Scientific and Cultural Organization. So far institutions in Belgium, France, Sweden, the U.S.S.R. and the U. S. have indicated that they will take part in the effort to dig out and record as many antiquities as possible before the "open-air museum" of the upper Nile Valley is covered, about five years hence, by the waters to be impounded behind the dam. The threatened area stretches 292 miles from Aswan in Egypt to the Third Cataract of the Nile in the Sudan and contains many well-known monuments, such as the temple of Rameses II at Abu Simbel, as well as hundreds of known but still unexplored sites. To encourage digging before the waters rise, the United Arab Republic and Sudanese governments are reversing past policies and will allow excavators to keep at least 50 per cent of their finds.



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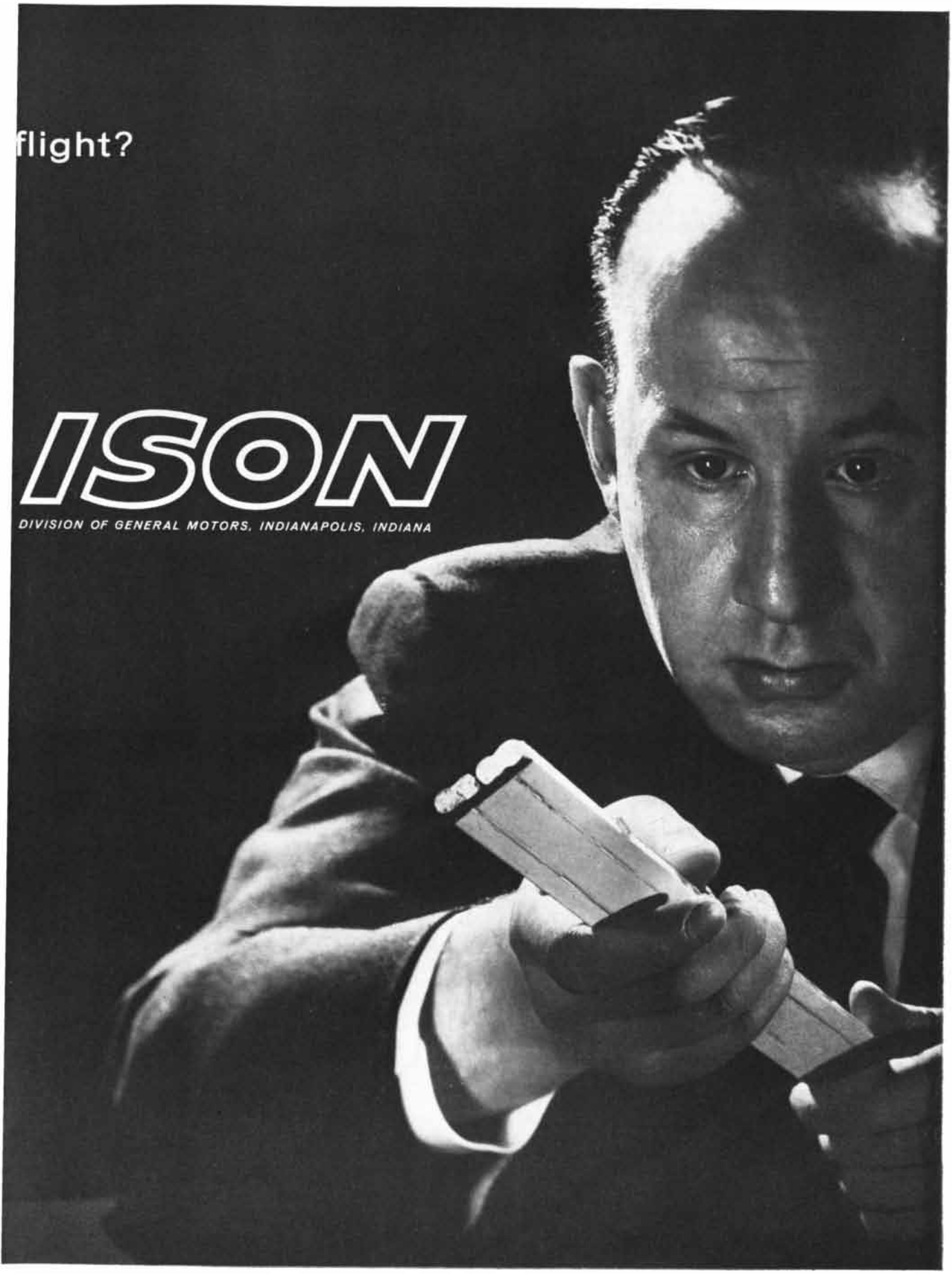


Energy Transformation in the Cell

How does the living cell convert the energy of foodstuff into a form that can be utilized and stored? The process involves the sequential action of many enzymes, some of which are part of the cell membranes

by Albert L. Lehninger

A flame and a living cell both burn fuel to yield energy, carbon dioxide and water. The flame, in one step, transforms the chemical energy of the fuel into heat. The cell, in many steps and with little loss to heat, converts this chemical energy into a variety of forms: into the energy of the chemical bonds in the molecules of its own substance, into the mechanical energy of muscle contraction, into the electrical energy of the nerve impulse. In luminescent organisms special cells transform the energy into light.

From the standpoint of thermodynamics the very existence of living things, with their marvelous diversity and complexity of structure and function, is improbable. The laws of thermodynamics say that energy must run "downhill," as in a flame, and that all systems of atoms and molecules must ultimately and inevitably assume the most random configurations with the least energy-content. Continuous "uphill" work is necessary to create and maintain the structure of the cell. It is the capacity to extract energy from its surroundings and to use this energy in an orderly and directed manner that distinguishes the living human organism from the few dollars' (actually $5.66 in today's inflated market) worth of common chemical elements of which it is composed.

The past few years have seen great advances in the investigation of the transformation of energy by the cell. This historic enterprise has engaged the talents of some of the ablest investigators of the century. In its present stage our understanding encompasses not only some of the chemical and physical aspects of the process, but has begun to take in the arrangement of the molecules in the cell that conduct it. Many of the active molecules—the enzymes—have been identified. The intricate chains and cycles of activity by which they extract, trap, exchange and distribute energy have been worked out in sufficient detail to illuminate their principles of operation. And the molecular machinery of these energy-transforming functions has been securely located in the mitochondria, structures found in all cells that burn their fuel in oxygen.

It is, of course, the food intake of the organism that supplies the fuel—sugars, fats and proteins—to the energy-transforming system of the cell. Every student of elementary chemistry learns that a given weight of an organic compound contains a fixed amount of potential energy locked up in the bonds between the atoms of its molecule; for example, the bonds between the carbon, hydrogen and oxygen atoms in the sugar glucose. The energy can be liberated by burning the sugar in oxygen, with the carbon and hydrogen evolving from the flame in the relatively simple, energy-poor molecules of carbon dioxide (CO_2) and water (H_2O). This oxidation yields 690,000 calories per mole of glucose. (A mole is the weight of a substance in grams that is numerically equal to its molecular weight. A mole of glucose weighs 180 grams.) Now it is one of the fundamental principles of thermodynamics that the same total amount of energy is always liberated upon combustion of a given weight of a substance, no matter what the mechanism or pathway of the process. Thus the cellular oxidation of glucose to carbon dioxide and water makes a total of 690,000 calories of energy available to the energy-harnessing activities of cells.

There is an important reason why oxidation in the cell, as contrasted with the uncontrolled combustion that goes on in a flame, must proceed under rigorous control. Living cells are unable to utilize heat in the performance of functions such as muscle contraction, because heat energy can do work only if it flows from a warm region to a cooler one. This is the principle of a heat engine, in which the temperature of the working fluid undergoes a large drop between the combustion chamber and the exhaust. For all practical purposes there is no such temperature differential in the living cell, and the cell cannot function as a heat engine. The cell recovers the energy liberated by the oxidation of foodstuff not primarily as heat, but rather as chemical energy, a form of energy that can do work in a constant-temperature system. To obtain energy in this useful form the cell oxidizes its fuel in a stepwise manner. The agents of this controlled combustion are the enzymes: large molecules that function as catalysts, or promoters of chemical reactions. The cell employs dozens of oxidative enzymes, each specialized to catalyze one reaction in the series that ultimately converts the fuel into carbon dioxide and water.

Investigators have broken down the

MITOCHONDRION, the site of energy transfer in the living cell, is enlarged some 235,000 diameters in this electron micrograph of a rat liver-cell. Cristae, the flattened infoldings of the lining membrane, have been cut at different angles. One lying almost in the plane of the cut forms the wide V at top. Several near the center, cut at right angles, project like fingers from the outer wall. The connections to the wall do not show in those cut at oblique angles. The micrograph was made by Michael L. Watson of the University of Rochester while conducting research under a contract from the Atomic Energy Commission and a grant from the National Institutes of Health.

labyrinthine succession of reactions into three major stages. In the first stage enzymes break down the sugar and fat molecules (and protein fragments) into a simpler unit that represents a kind of common denominator of the distinctly different structures of these fuels. In the next two stages other enzymes take this unit apart and oxidize carbon and hydrogen. But the biologically significant product of the whole chain of transactions is energy, not water and carbon dioxide, which are mere waste or exhaust products. As the energy is liberated in the breakdown and oxidation reactions, it is captured in the chemical bonds of a special energy-storing molecule and is delivered thereby to the energy-consuming activities of the cell.

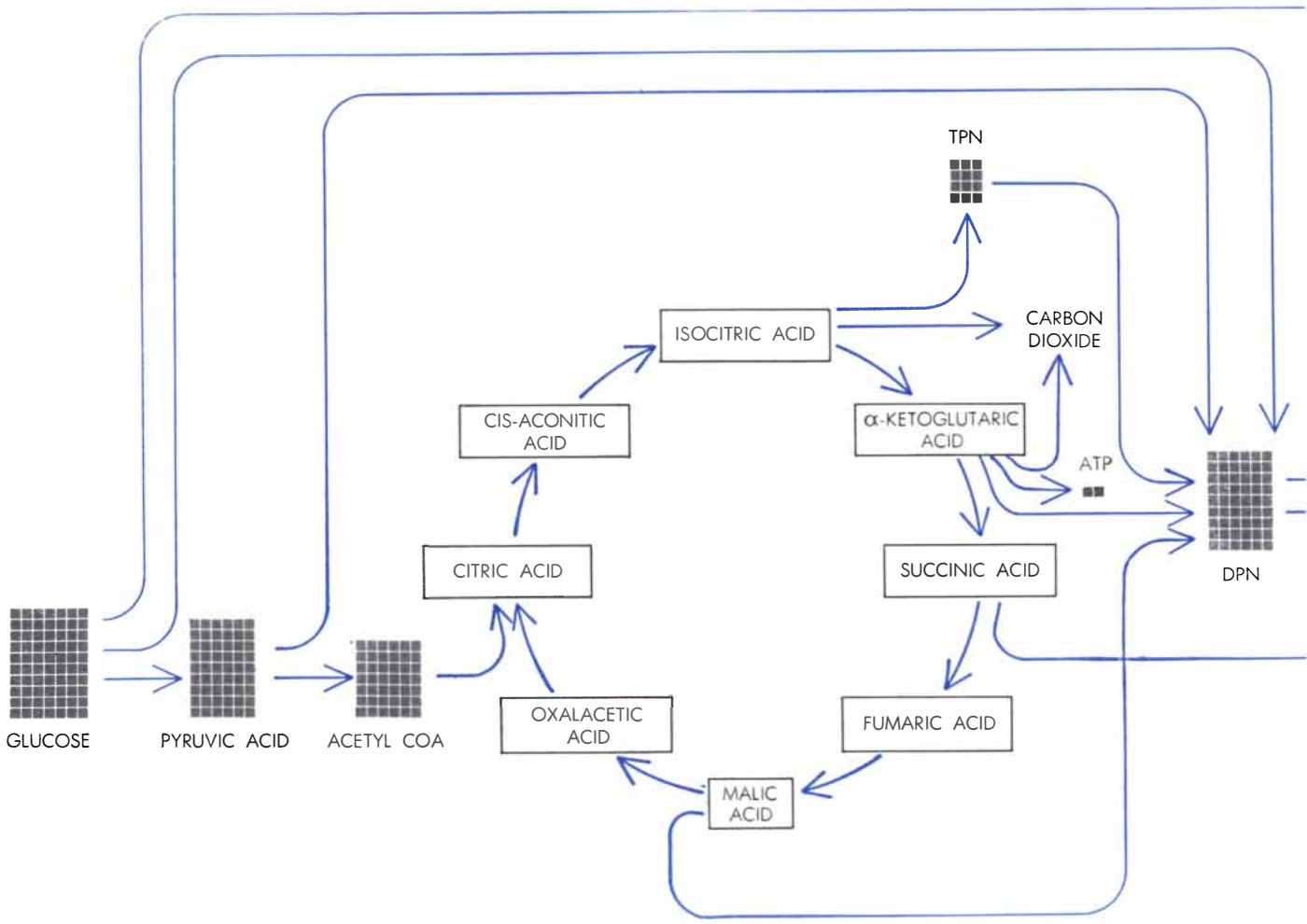
The Stages of Oxidation

In the first-stage breakdown of the glucose molecule, which has six carbon atoms, the enzymes split it into two molecules of pyruvic acid, each of which has three carbon atoms. This conversion is not so simple as it sounds. It involves the sequential action of a dozen specific enzymes [*see top illustration on pages 106 and 107*]. Some 40 years of intensive research went into the resolution of the details of this process and the isolation of the enzymes in pure form.

The intermediate pyruvic acid molecules become the center of activity in the second stage. They are converted to the two-carbon compound acetic acid, in a combined or "activated" form with coenzyme A, a substance that contains pantothenic acid, one of the B vitamins. It is at this point that fats and proteins—broken down to acetic acid by enzyme systems specifically adapted to their structures—also join the common pathway of oxidation. Another set of enzymes acting sequentially and cyclically links up acetic acid with oxalacetic acid, a four-carbon compound, to form citric acid, a six-carbon compound. The second stage is often called the citric acid cycle, after this important intermediate; it is also known as the Krebs cycle in recognition of Sir Hans Krebs of the University of Oxford, who first postulated it in 1937. As the cycle continues, the citric acid undergoes a series of rearrangements and degradations, in the course of which oxalacetic acid is regenerated for the next round, and the two carbons from the acetic acid molecule are oxidized to form two molecules of carbon dioxide. Half of the task of oxidation is now completed.

Meanwhile, during the dismemberment of the pyruvic acid molecule in the citric acid cycle, intermediate compounds have picked up the pairs of hydrogen atoms that are attached to carbon atoms. The hydrogens are carried over into the third major multi-enzyme sequence to be combined with oxygen, which in higher animals is brought from the lungs via the bloodstream. This so-called respiratory cycle thus yields water, the second of the two end products of the biological oxidation.

As elementary as the combustion of



POTENTIAL ENERGY OF GLUCOSE (*far left*) is passed from compound to compound; finally more than 60 per cent is recovered in the form of adenosine triphosphate, or ATP (*top right*). Most of the energy is transferred by the citric acid cycle (*circle*) to en-

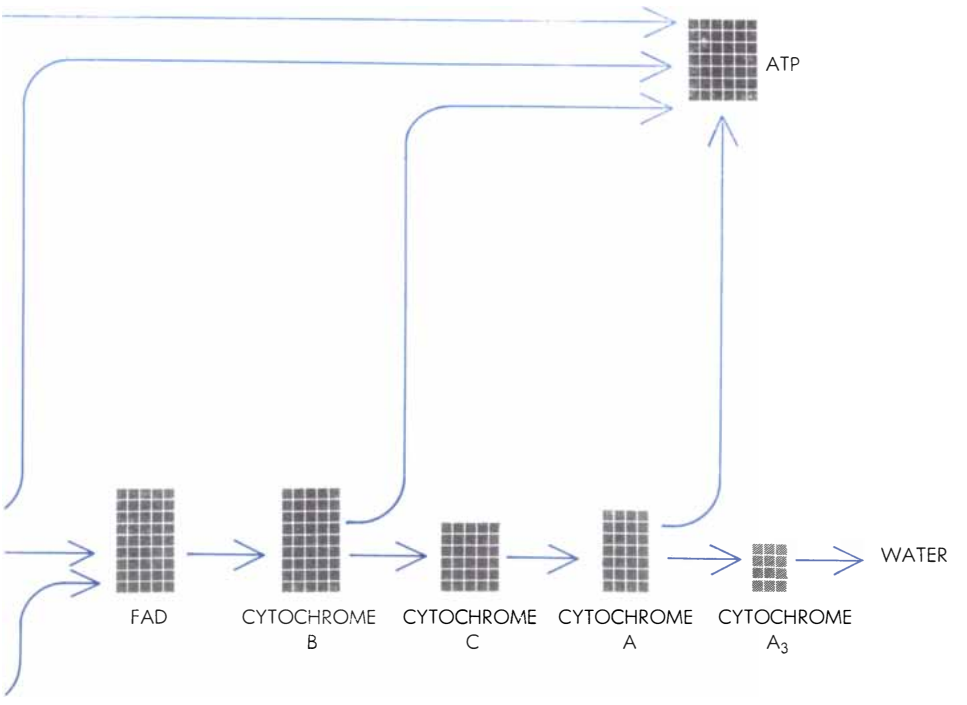
hydrogen and oxygen may seem, the unraveling of the chain of enzyme activity in the respiratory cycle is the goal of a 50-year campaign of investigation. The contributions of Otto Warburg of Germany and David Keilin of England to this work place them among the major figures in biochemistry. The hydrogen atoms do not by any means enter directly into combination with the oxygen. They or their equivalent electrons, set free when the hydrogen is ionized, travel to this terminus along a chain of hydrogen- and electron-transferring enzyme molecules in the cell. Each of these enzymes possesses a characteristic and specific "active group" that is capable of accepting electrons from the preceding member of the chain and of passing them along to the next. The chemical nature of the active groups explains why animals must have certain minerals and vitamins in their diet; all the groups contain either a metal, such as iron, or a vitamin, such as riboflavin (vitamin B_2). The lack of any of these essential activators may interrupt the chain and cause faulty or incomplete oxidation of foodstuff in the cell. Not all the links in the chain of enzymes have been identified. Recent work indicates that as many as three additional enzymes may be involved, one containing vitamin K (also essential to the clotting of blood); another containing tocopherol, or vitamin E (also essential to maintenance of muscle tone and to reproduction), and a third containing a newly isolated active group called ubiquinone, or coenzyme Q.

The Storage Battery

With the fuel completely oxidized, what has become of the potential energy it contained? This question began to yield to investigation in the late 1930's. Herman M. Kalckar of Denmark and V. A. Belitser of the U.S.S.R. then independently recognized the significance of a chemical event that occurs along with the oxidation of the fuel. They incubated simple suspensions of ground muscle or kidney with glucose in the presence of oxygen and observed that phosphate ions present in the suspension medium disappeared as the glucose was oxidized. Further investigation revealed that the phosphate was being incorporated into organic compounds, in particular the compound adenosine triphosphate. Biochemists at once recognized the great significance of this finding. Adenosine triphosphate, now universally known as ATP, had been identified a few years earlier as the energy source in the contraction of muscle. Today it is known that ATP is the universal intracellular carrier of chemical energy.

ATP may be regarded literally as a fully charged storage battery. When the energy of this battery is withdrawn to make muscle contract, for example, the energy-rich ATP molecule transfers its energy to the contracting muscle by losing its terminal phosphate group. ATP thus becomes adenosine diphosphate (ADP)—the storage battery in its discharged state. To "recharge" the battery it is obviously necessary to supply a phosphate group plus the energy required to effect the uphill reaction that couples the phosphate to ADP. It was found that ADP as well as free phosphate ions disappear during biological oxidation, and that the two are combined in ATP. Kalckar postulated that this coupled phosphorylation, often called oxidative phosphorylation, provides the means for converting the energy released by oxidation into a readily usable form. The energy-rich ATP molecule can travel wherever energy is needed in the cell to drive energy-consuming functions, from the contraction of muscle to the synthesis of protein.

This conversion of the energy liberated by the combustion of fuel into the third phosphate bond of ATP proceeds with extraordinary efficiency. For each molecule of glucose completely oxidized to water and carbon dioxide in a tissue preparation, approximately 38 molecules of free phosphate and 38 molecules of ADP combine to form 38 molecules of ATP. In other words the oxidation of each mole of glucose produces 38 moles of ATP. It has been shown that the formation of one mole of ATP from ADP in this reaction as it occurs in the cell requires about 12,000 calories. The formation of 38 moles of ATP therefore requires the input of at least 38 times 12,000 calories, or about 456,000 calories. Since the oxidation of one mole of glucose yields a maximum of 690,000 calories, the recovery of 38 moles of

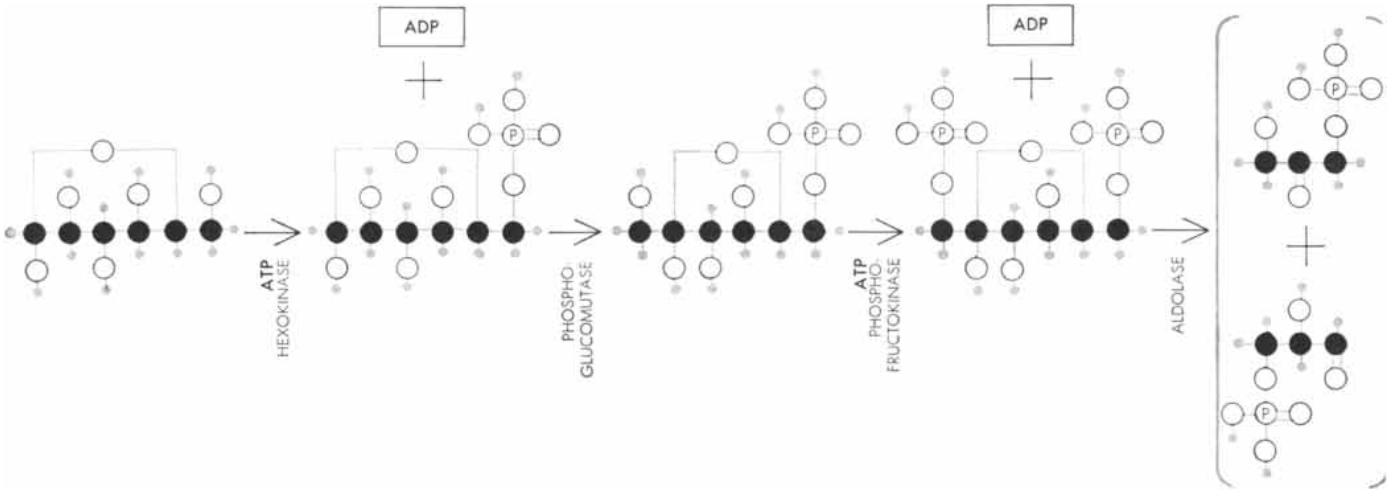


zymes of the respiratory chain (*TPN, DPN, FAD and the cytochromes*), which then pass it to ATP. Gray rectangles indicate approximate amounts of energy reaching various compounds.

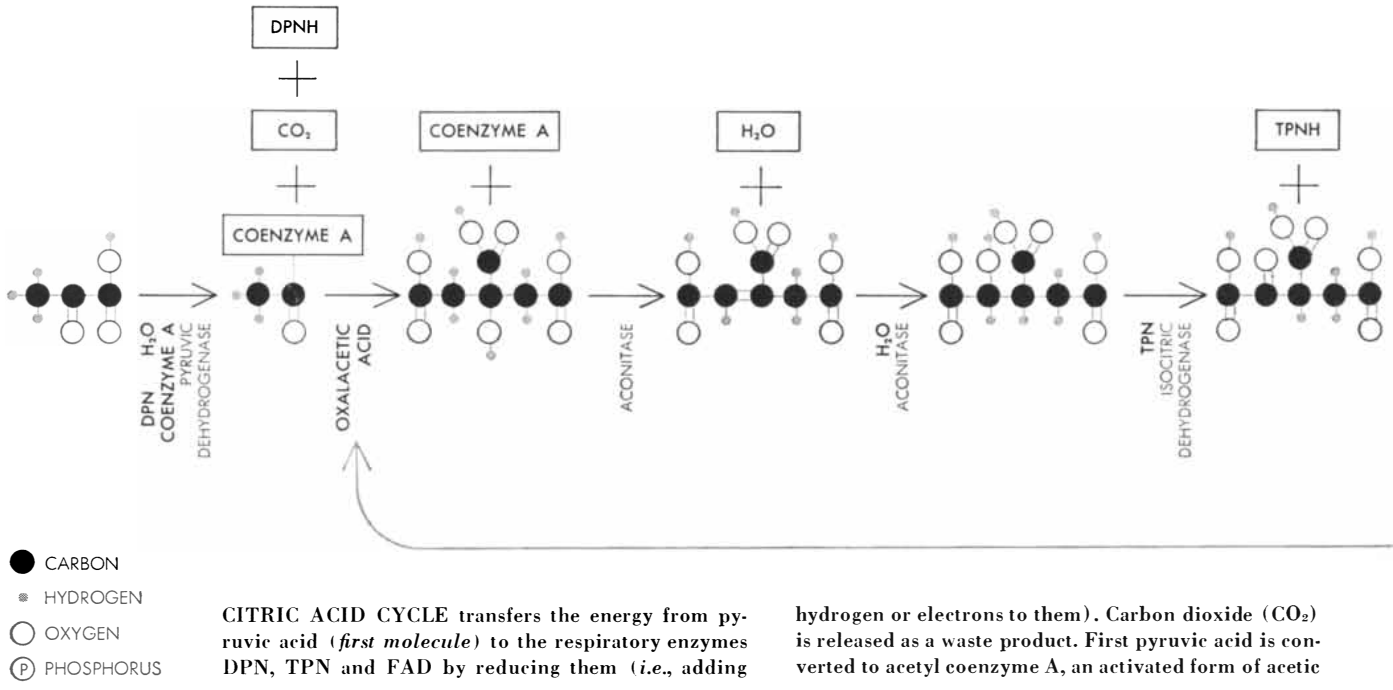
ATP represents a conversion of 66 per cent of the energy. As a comparison, a modern steam-generating plant converts about 30 per cent of its energy input to useful work.

Just how the energy is transferred from the fuel molecules to ATP is a problem that has preoccupied many biochemists over the past 10 years. One early clue to the mechanism of oxidative phosphorylation came from the theoretical calculation of the energy exchanges at each major stage in the oxidation of glucose. Thermodynamics shows, for example, that the first stage in the process—the breakdown of glucose to pyruvic acid—yields little more than 5 per cent of the total energy. From such calculations Belitser predicted over 20 years ago that the combination of hydrogen with oxygen in the third phase—the respiratory cycle—must yield most of the energy. As a matter of fact, the oxidation of one mole of hydrogen to produce one mole of water releases some 52,000 calories. Since the biological oxidation of one mole of glucose reduces 12 atoms of oxygen in the respiratory cycle, the latter must account for 12 times 52,000 calories, or 624,000 calories—90 per cent of the total of 690,000 calories. Conclusive as these calculations seemed to be, it was another dozen years before direct evidence could be adduced to prove that the phosphorylation of ADP is coupled to the respiratory chain. In fact, experimental results seemed if anything to argue against this conclusion.

In 1951 our group, then at the University of Chicago, perfected an experiment that demonstrated unequivocally the presence of supplementary energy-converting enzymes at three points in the respiratory chain. These enzymes har-



GLYCOLYSIS, the process by which glucose (*first molecule*) is broken down into two molecules of pyruvic acid (*last molecule*), requires the catalytic aid of many enzymes (*light-face type*). Two molecules of ATP are needed to prime the process, but four are

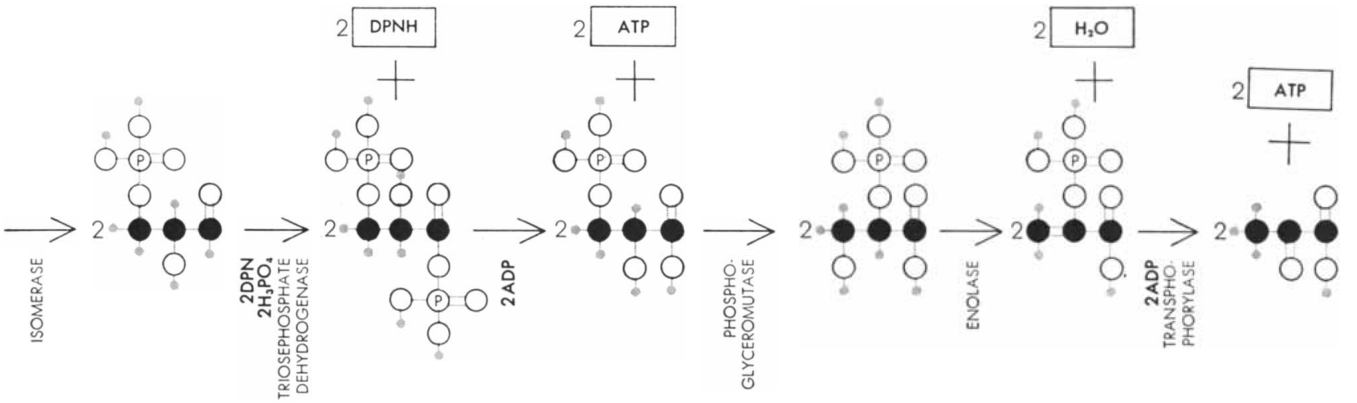


CITRIC ACID CYCLE transfers the energy from pyruvic acid (*first molecule*) to the respiratory enzymes DPN, TPN and FAD by reducing them (*i.e.*, adding hydrogen or electrons to them). Carbon dioxide (CO_2) is released as a waste product. First pyruvic acid is converted to acetyl coenzyme A, an activated form of acetic

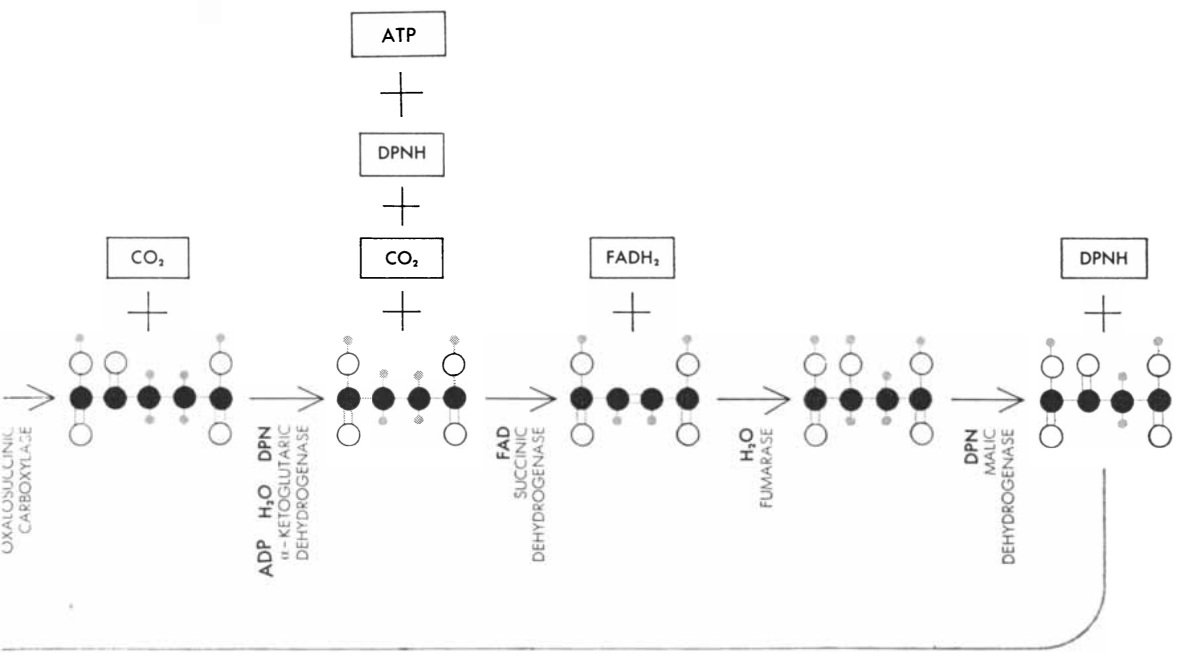
ness the energy liberated by the passage of electrons from one link to the next in the chain to phosphorylate ADP to ATP. We found that the passage of each pair of hydrogen atoms or equivalent electrons yields one molecule of ATP at each of three enzymic energy-transfer stations. Since the oxidation of one molecule of glucose sets 12 pairs of hydrogen atoms moving down the chain, the total yield is three times 12, or 36, molecules of ATP. Two additional molecules of ATP are formed in the breakdown of glucose to pyruvic acid. The grand total is then 38 moles of ATP per mole of glucose. These findings fulfilled the prediction from thermodynamic considerations and satisfied the over-all energy balance-sheet of biological oxidation, showing that the respiratory chain is the primary site of energy conversion.

From more recent work we have been able to postulate the probable form of the mechanism by which the energy is coupled at each of the energy-transfer points in the respiratory chain [*see top illustration on pages 110 and 111*]. The chain is apparently a series of wheels within wheels, characterized by a cyclic process at each molecule in the chain. Each of these molecules is reduced by the addition of a hydrogen or an electron at one point, and is restored to its original form by oxidation when it delivers the hydrogen or electron to the next point. In three of the cycles there is an intermediate step by which the energy is transferred from the reaction to a coupled reaction that forms ATP from ADP.

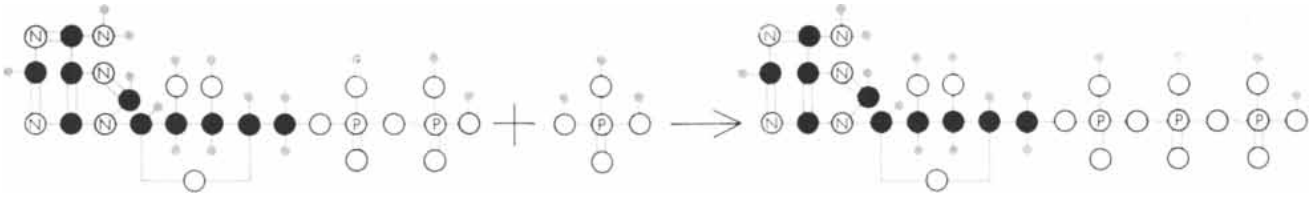
This picture has been modified by the finding that one pair of hydrogen atoms enters the respiratory chain at the middle, and so yields only two molecules of ATP. The deficit is made up,



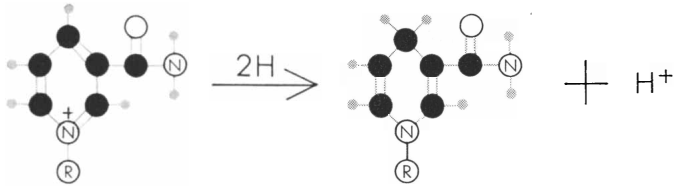
generated, yielding a net gain of two molecules of this energy-rich compound. Energy from glucose is also conserved by the reduction of the respiratory coenzyme DPN to DPNH (*sixth step*). The glycolytic reactions are reversible with the aid of appropriate enzymes.

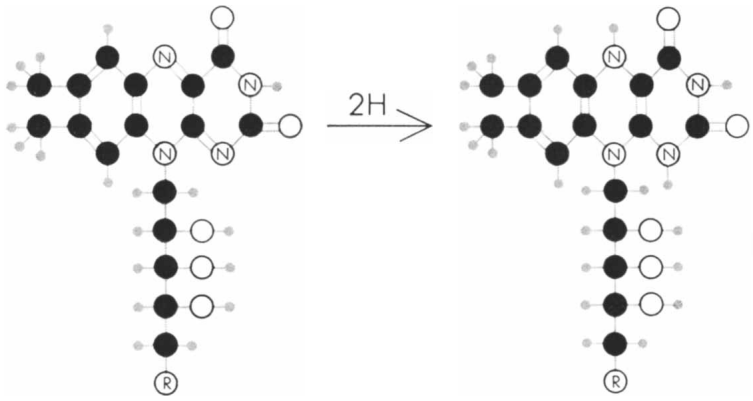


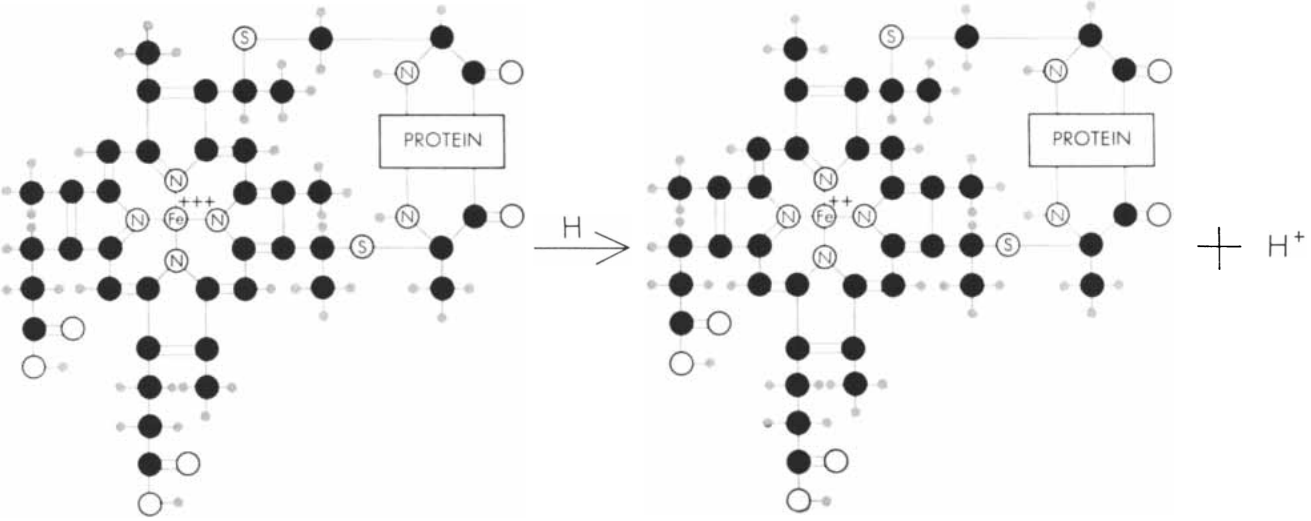
acid (*second molecule*). This reacts with oxalacetic acid to form citric acid (*third molecule*). After a series of rearrangements and oxidations, oxalacetic acid is regenerated (*last molecule*) and can participate in the cycle again. The substances necessary for each step are named below the arrows (*catalytic enzymes are in lightface type*); side products of the reactions are shown in boxes.



ADENOSINE DIPHOSPHATE, or ADP (*first molecule*), adds the phosphate group from phosphoric acid to generate adenosine triphosphate, or ATP (*right of arrow*). Energy is required to forge the high-energy bond (*wavy line*) that links the phosphate groups.







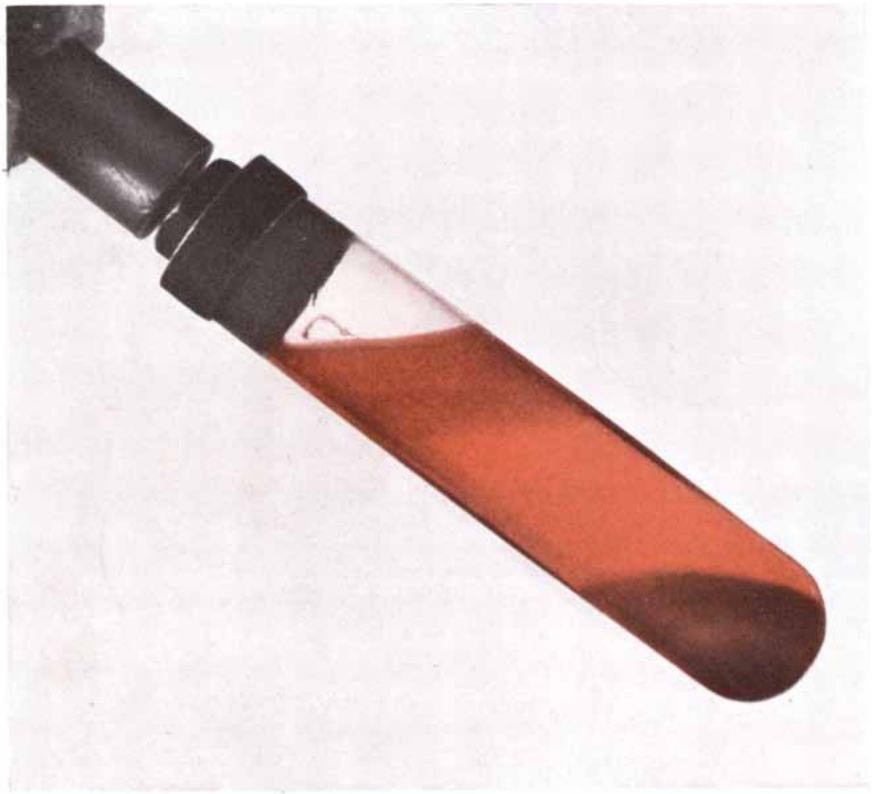
CARBON
OXYGEN
RADICAL
IRON
HYDROGEN
NITROGEN
SULFUR

ACTIVE GROUPS of respiratory enzymes are shown oxidized (*left of arrows*) and reduced (*right*). "R" or "protein" indicates the rest of the molecule. In TPN or DPN (*top*) one hydrogen is joined to a carbon atom; the electron from the other neutralizes the charge on nitrogen. Riboflavin, the active group of FAD (*center*), adds hydrogens to two nitrogen atoms. The active group of cytochromes is heme (*bottom*); an electron from a hydrogen reduces the charge on iron.

however, by the conversion of ADP to ATP in one of the reactions of the citric acid cycle. The respiratory chain nonetheless remains the primary site of energy conversion.

The purpose that is served by the stepwise character of the oxidation process in the cell now becomes clear. Nature usually chooses simple ways to do things, and it would be simpler to accomplish the combustion in one step. The many-membered respiratory chain serves, however, to break up or quantize the 52,000 calories liberated by the oxidation of each pair of hydrogens into three smaller packets. Each of these packets contains the approximate amount of energy, namely 12,000 calories, required to phosphorylate ADP to ATP. The process thus achieves efficient conversion of energy in terms of the energy currency of the cell.

Such a program of sequential and cyclic reactions requires that many different enzymes act in proper order and in an integrated, well-controlled way. This suggests that the participating enzymes, perhaps hundreds in number, must have a specific geometric orientation with respect to one another within the cell.

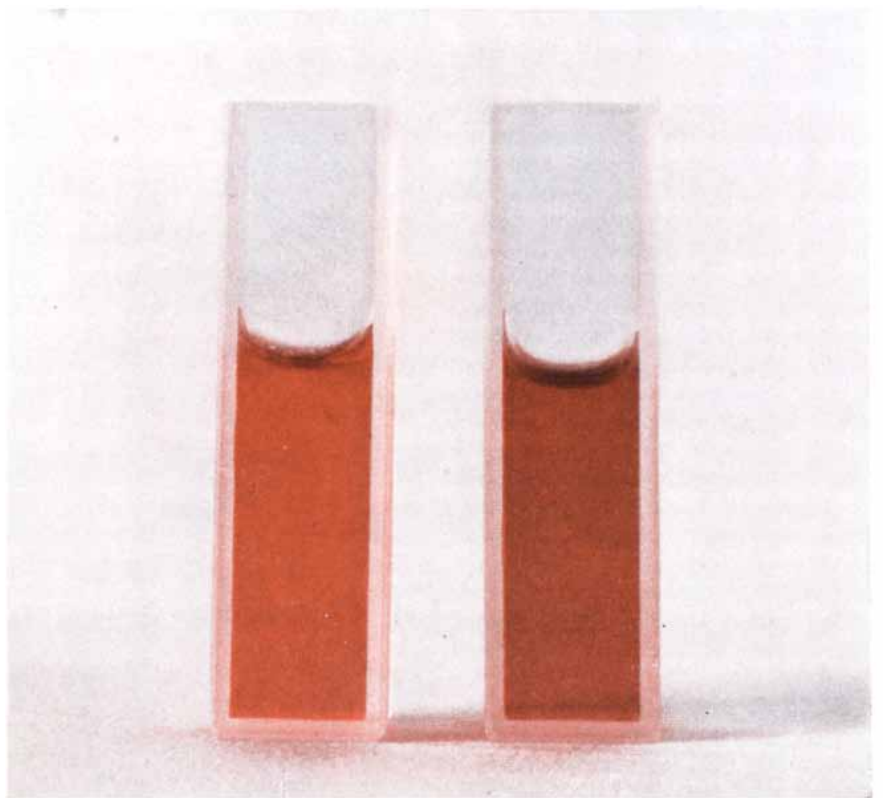


SEPARATION OF MITOCHONDRIA from disrupted cells requires centrifugation at high speed. The tube used for this is made of plastic and has a locking metal cap. The mitochondria are present in the pale middle layer of sediment. The dark layer at the bottom contains cell nuclei; the top layer contains microsomes, the smallest particles of the cell.

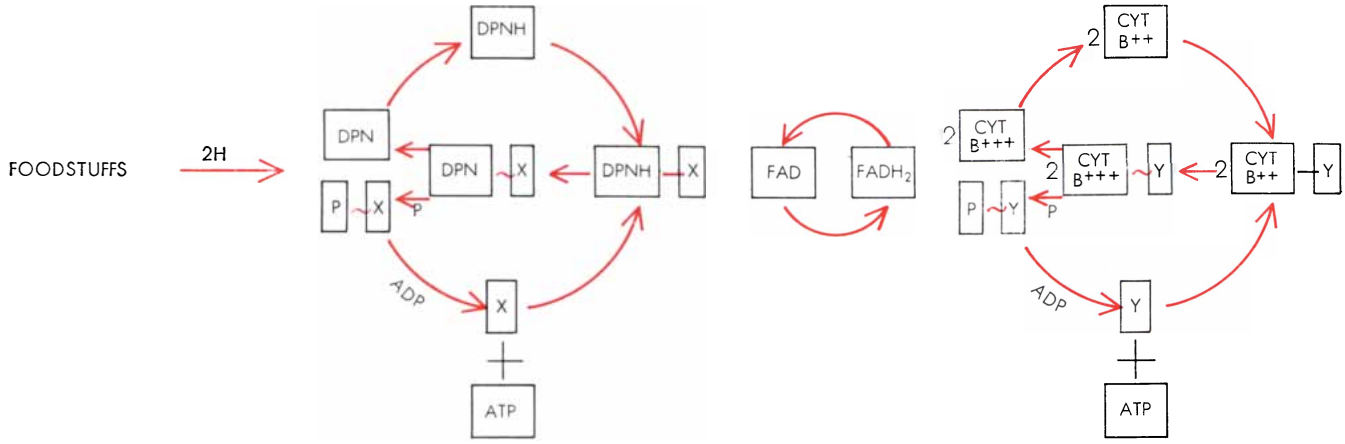
The Geometry of Oxidation

In 1948 Eugene P. Kennedy and I were able to show that enzymes involved in both the citric acid and the respiratory cycles are located in the mitochondria. These tiny oblong or rodlike structures, much smaller than the cell nucleus, occur in the cytoplasm: the extranuclear portion of the cell. A single liver-cell may contain several thousand such bodies; together they may account for about 20 per cent of the total weight of the cell. Earlier in 1948 George H. Hogeboom, Walter C. Schneider and George E. Palade of the Rockefeller Institute had perfected a method for isolating mitochondria intact and in large quantities by spinning down cell extracts in the ultracentrifuge.

When we incubated mitochondria with pyruvic acid and other intermediates of the citric acid cycle in the presence of oxygen, we found that all of the complex reactions of the citric acid and respiratory cycle proceeded at a high rate and in an orderly manner. On the other hand, we found that nuclei and other cell structures were incapable of conducting the oxidation process. We also discovered that the mitochondria carry out the vital energy-recovery process of oxidative phosphorylation,



CYTOCHROME C in solution changes color visibly when it is oxidized (*left*) or reduced (*right*). A sensitive spectrophotometer measures the color differences accurately by registering the transmission of light of various wavelengths through the solution. Special quartz containers of high optical quality, here somewhat enlarged, are used in this instrument.



RESPIRATORY ENZYMES transfer energy by a series of cyclic reactions, each set in motion by the one preceding it, like a system of interlocking gears. A pair of hydrogen atoms released in the citric acid cycle reduces one enzyme; this is oxidized again by reducing the next enzyme, and so on. At the end of the chain the hydrogen combines with oxygen to form water. The known carriers in the chain are diphosphopyridine nucleotide (DPN), flavin adenine dinucleotide (FAD), attached to a protein, and four cytochromes. Coupled with the reduction-oxidation cycles of three carriers (DPN, cytochromes B and A) are reactions with unidenti-

generating ATP from ADP. The mitochondria are thus the "power plants" of the cell.

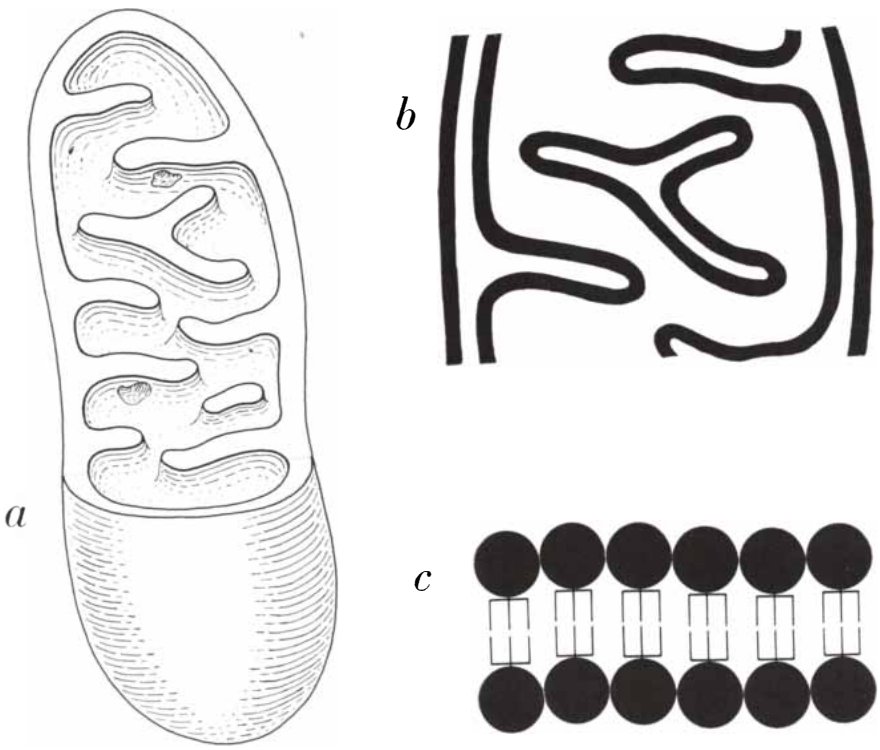
These bodies are so small that they are barely recognizable as oblongs or rods when they are viewed in the light microscope. Yet recent advances in instrumentation have made it possible to sketch a molecular description of the mitochondrion and to discern at least dimly the spatial arrangement of the many enzymes concerned with biological oxidation.

The first approach was to look at the ultrastructure of the mitochondrion under the electron microscope. In 1952 Fritiof S. Sjöstrand in Sweden and Palade in New York began to apply a newly perfected means of obtaining ultrathin sections of tissue to study mitochondria. Their pictures of thin sections cut at different angles through single mitochondria demonstrated that the mitochondrion is not just an amorphous blob of protoplasm, but rather a highly organized structure with much fine detail—almost a cell within the cell. It consists of an outer enclosing membrane separated by a thin space from an inner membrane which at intervals apparently folds inward to form the so-called cristae. The semicompartmented space inside is filled with a semifluid "matrix."

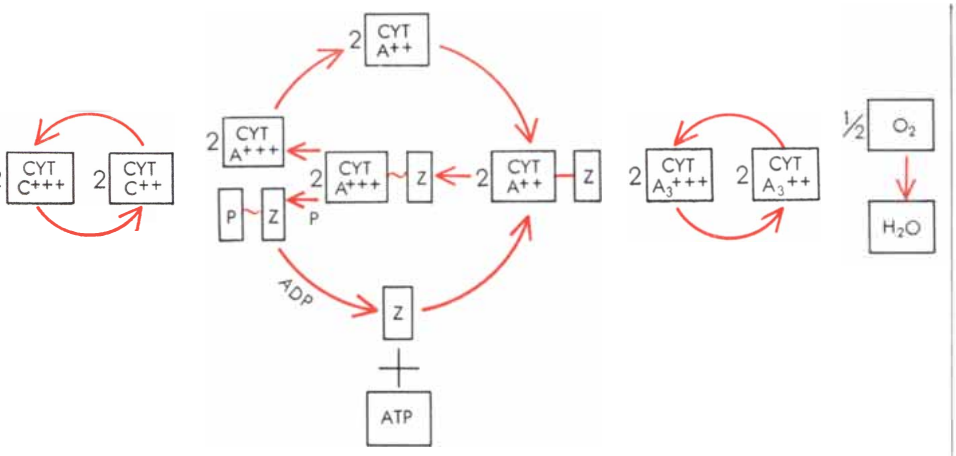
From electron micrographs it is possible to estimate the dimensions of these structures. The membranes have a thickness of from 60 to 70 angstrom units. (An angstrom unit is a hundred millionth of a centimeter.) The space between the membranes and across the cristae measures about 60 angstroms. Mitochondria of all cells, regardless of the tissue or the species, have the same structural plan, in accord with their similarity of function.

The constant thickness of the membrane has significance from another point of view. It happens to approximate the dimension of a single protein molecule plus a lipid (fat) molecule. Chemical analysis shows that the membrane consists of about 65 per cent protein and 35 per cent lipid. These findings suggest that the membranes are arranged in a sandwich: The single layer of protein molecules that forms the outer membrane is apparently lined with oriented lipid molecules abutting a similar layer of lipid molecules on the outer surface of the layer of protein that forms the inner membrane.

When mitochondria are subjected to intense sound waves or to chemical agents such as detergents, the mem-



MITOCHONDRIAL STRUCTURE is basically that of a fluid-filled vessel with an involuted wall (*a*). Closer analysis shows that the wall consists of a double membrane (*b*). Each membrane approximates the thickness of a single layer of protein molecules (*spheres at c*),

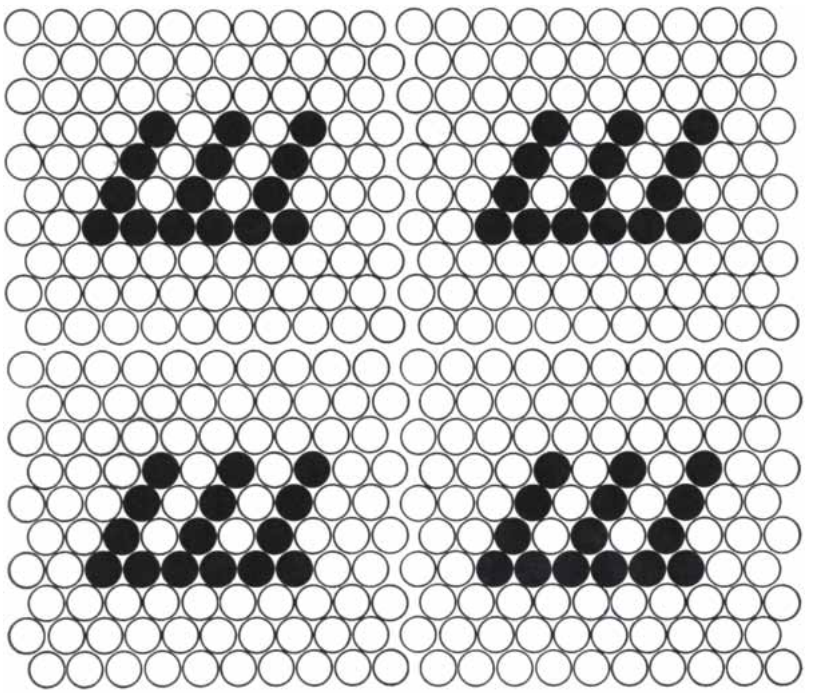


fied enzymes (*designated* X, Y *and* Z) that transfer energy released in the cycles to ATP. The transfer is not fully understood; it is believed to involve the formation of a high-energy bond (*wavy line*) to the transfer enzyme, then combination of this enzyme with a phosphate group (P) and finally the addition of the phosphate to ADP to form ATP. When two hydrogen atoms are passed down the whole chain, they give rise to three molecules of ATP.

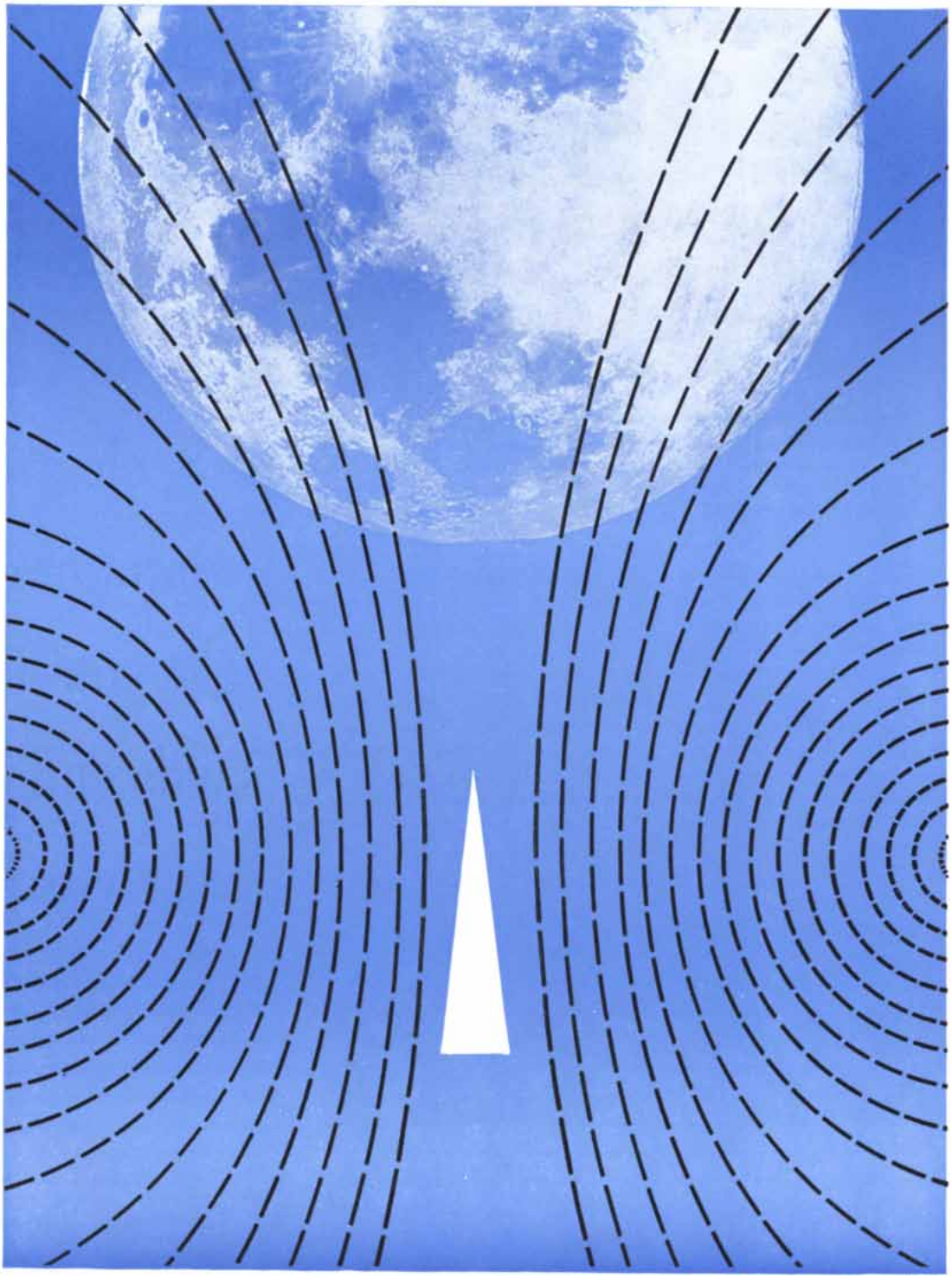
branes break up, and the internal matrix escapes. The insoluble membrane fragments can easily be separated by centrifugation from the soluble matrix material, and the two fractions can then be analyzed separately. By these procedures we have found that the matrix contains most of the enzymes of the citric acid cycle, and that the enzymes of the respiratory cycle turn up exclusively in the membrane fragments.

Britton Chance of the University of Pennsylvania has employed spectroscopic techniques to study the respiratory enzymes in intact mitochondria. Each of the respiratory enzymes, having a characteristic active group, possesses a distinctive "color" and spectrum. Chance has succeeded in establishing not only the number of molecules of each type in the mitochondria but also the sequence in which the electrons

d



and the space between them equals the thickness of a double layer of fat molecules (*prongs*). The respiratory-chain enzymes (*black spheres at d*) form part of the membranes; they are evidently arranged in sets distributed at regular intervals in the membranes' protein layers.



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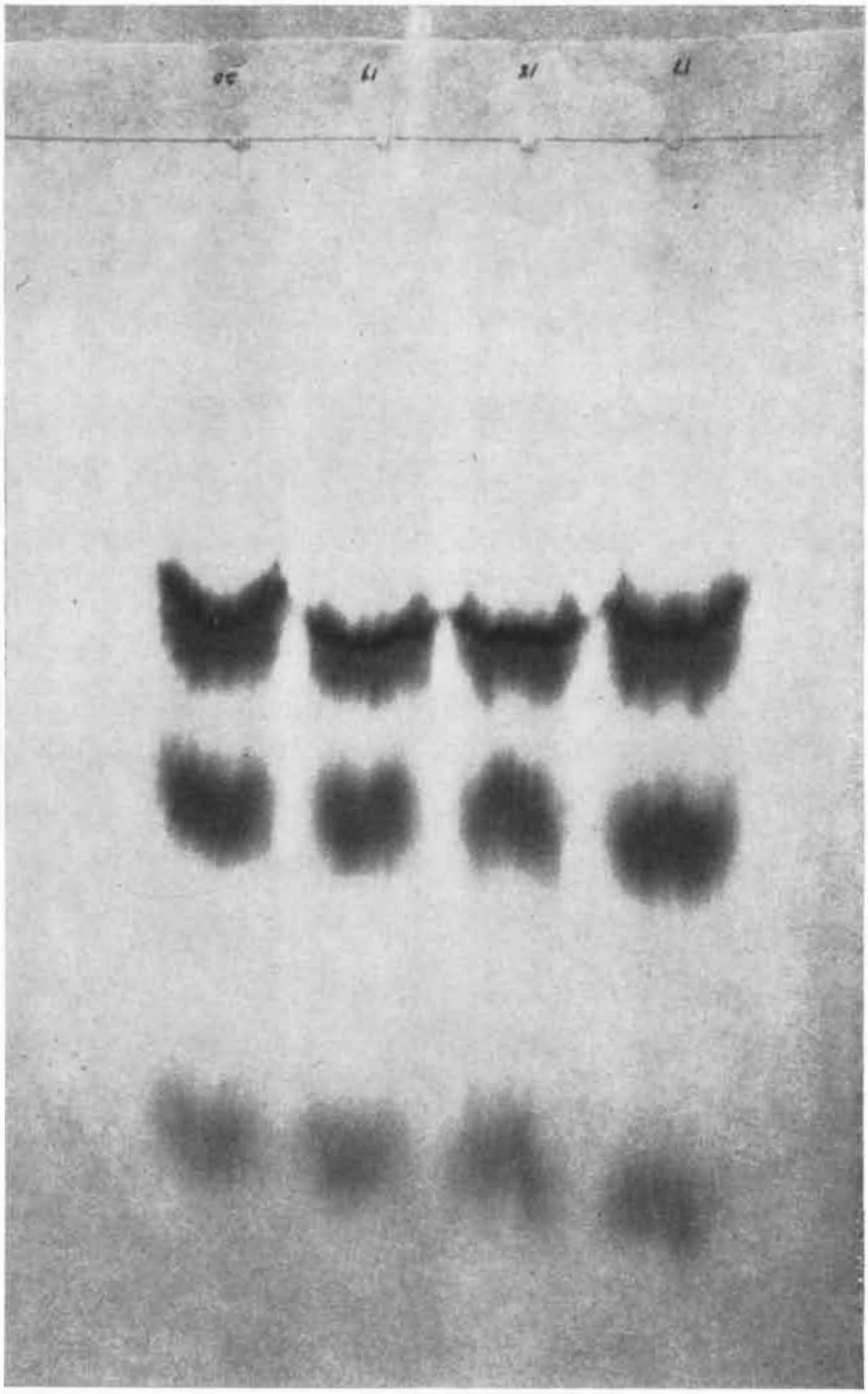
move from one carrier to another in the respiratory chain.

The Enzymes Assembled

Such information, supplemented by our chemical studies, leads me to believe that the respiratory-chain enzymes are organized in assemblies or sets containing only one molecule of each of the enzymes. One such set would be made up of perhaps eight different molecules. Attached laterally to these would probably be six (perhaps nine) other catalytically

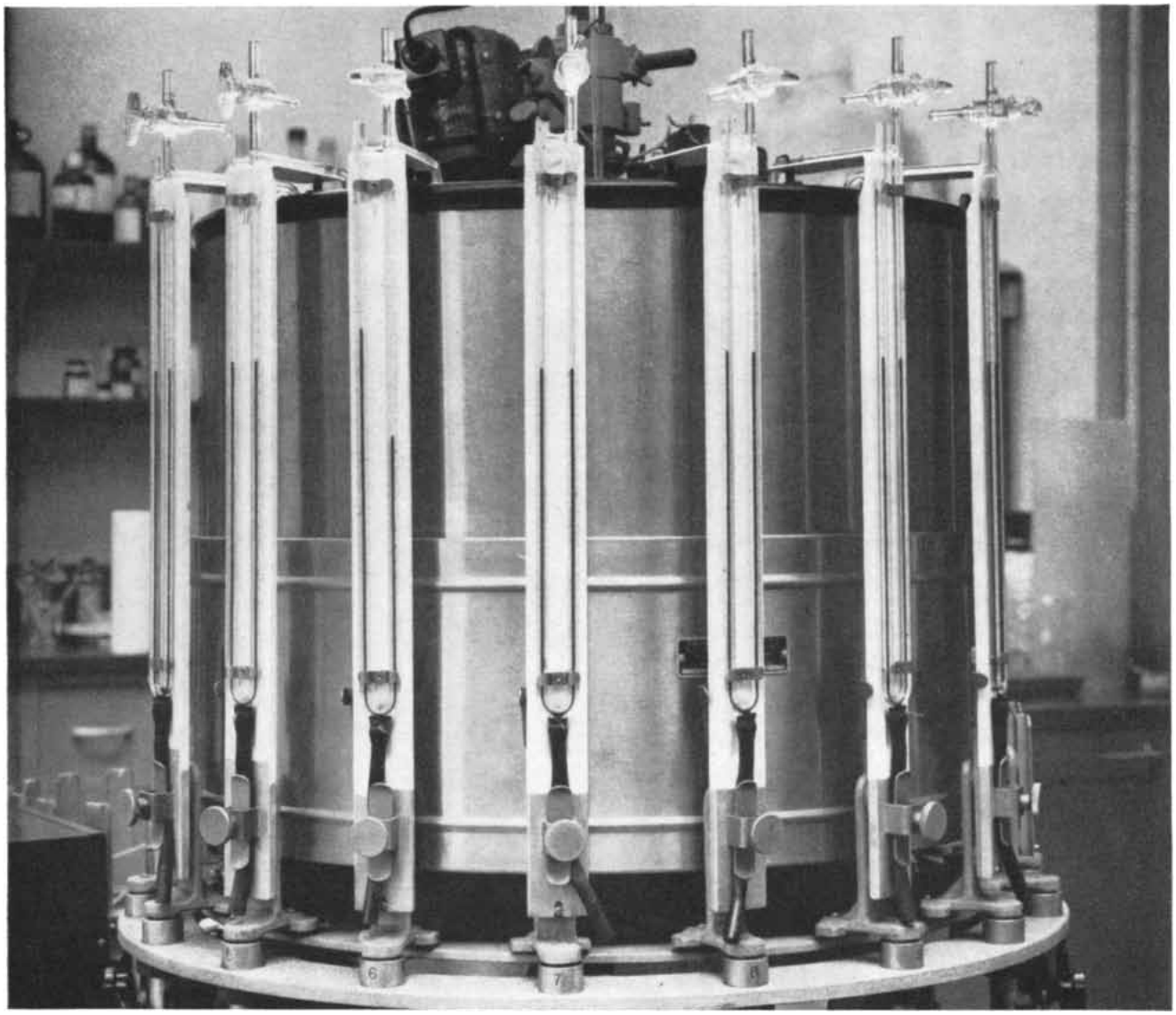


CHROMATOGRAM separates ATP (*top row of spots*) from ADP (*second row*) and AMP (*bottom*). These substances are hard to separate by other methods. In this experiment samples from a flask containing mitochondrial fragments incubated with ADP and DPNH were placed on the numbered marks. A solvent, allowed to flow downward from the top edge of the paper by capillary action, then carried the compounds with it at varying speeds. The paper was later viewed in ultraviolet radiation, under which the compounds show up at characteristic sites as dark spots against the fluorescent paper. ATP spots confirm that fragments formed ATP from ADP. Spots can be cut out and ATP dissolved for testing.

active protein molecules, the function of which is to carry out the coupled formation of ATP. A complete assembly would thus contain 15 or more active protein molecules arranged in close geometric array. An individual liver mitochondrion might contain several thousand such units. Since the total mass and the protein content of the mitochondrial membrane are known, it is possible to calculate that these assemblies comprise as much as 40 per cent of its substance. This calculation, along with our recent finding that the assemblies are evenly distributed in the membrane, show that the membrane is not an inert wall or container but an active molecular machine. The highly ordered arrangement of the specialized enzyme molecules determines the organization and programming of the enzymatic activity of the living cell.

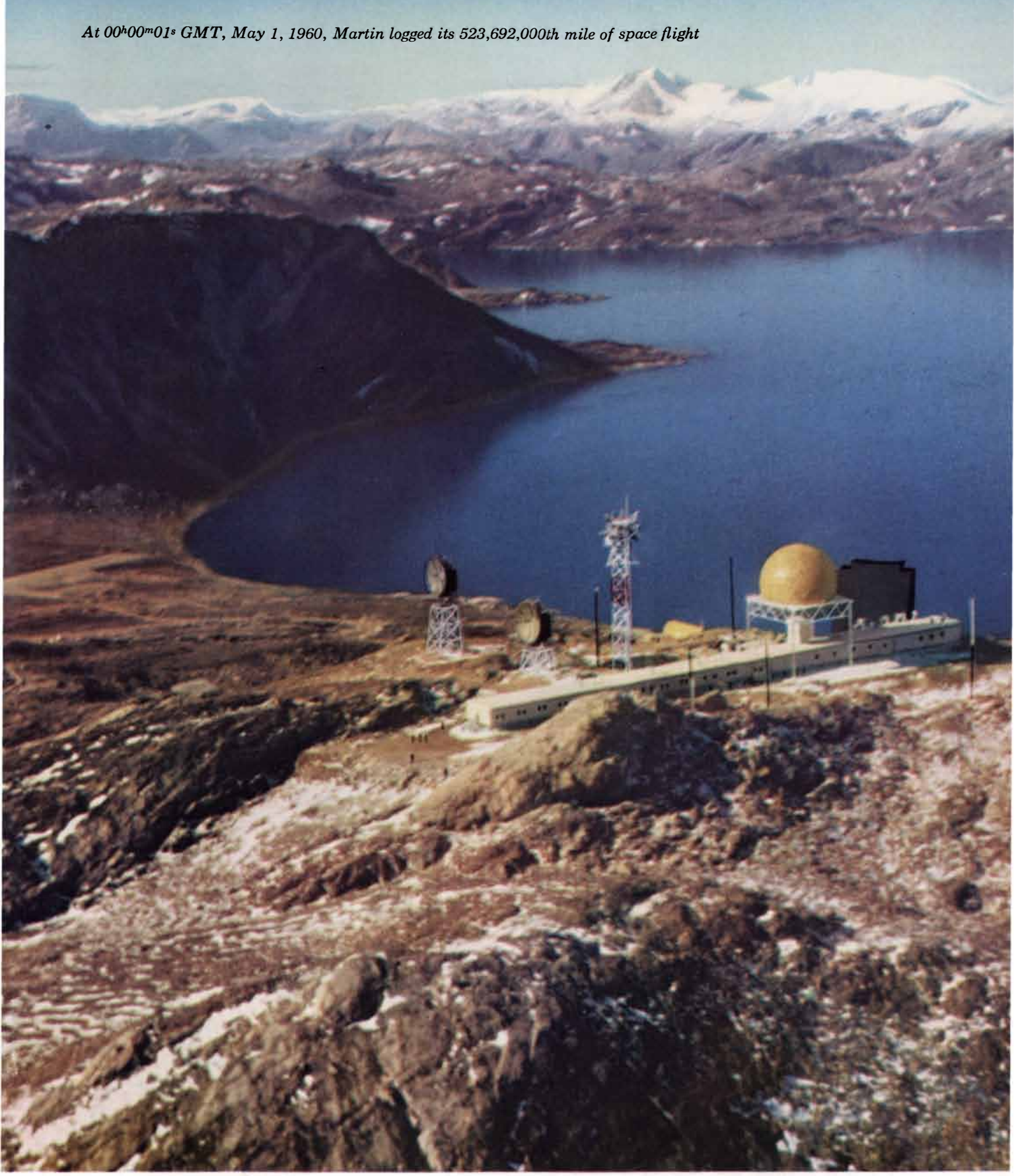
Mitochondria in intact cells have been observed to swell and shrink, apparently by the uptake of water from the cytoplasm. This activity may serve mainly to move water and other substances through the cell. In this connection we have made the interesting discovery that the membrane itself changes its dimensions in the course of its activity. Like a sheet of muscle tissue, it can relax or contract. We have found that this change in dimension is related to the concentration of ATP; the membrane contracts when the concentration is high and relaxes when it is low. This suggests that the rate of oxidation (and of energy recovery in the mitochondria) may be regulated by the local concentrations of ATP and ADP, which occur in inverse relationship to each other. Overproduction of ATP may thus automatically throttle down this mechano-chemical system and gear its rate of power production to the demands of the cell. This same mechano-chemical system may also be responsible for "pumping" water and for the remarkable motility of mitochondria in some cells.

The integration of chemistry and geometry in the structure of the power plant of the cell poses new challenges to the investigator. It sets as the supreme goal not only the duplication of the catalytically active enzyme assemblies by proper linkage of the individual energy-transferring enzyme molecules, but also the reconstitution of the detailed structure of the mitochondrial membrane.



WARBURG APPARATUS is used in biochemical experiments to test for oxidative activity. Flasks containing the mitochondria and a solution of pyruvate are incubated inside the drumlike water bath. Each flask is connected to the top of one arm of a U-tube, containing colored fluid. As oxygen is used up by the test material, the change in gas pressure forces the fluid to rise in one arm and fall in the other. The rate and amount of oxygen consumption can be calculated by taking readings of the levels at various times.

At 00h00m01s GMT, May 1, 1960, Martin logged its 523,692,000th mile of space flight



To keep the lonely vigil . . . *Martin PM-1 air-portable nuclear reactor, to supply electricity and heat at remote Air Force stations, is now being developed and produced for the AEC.*

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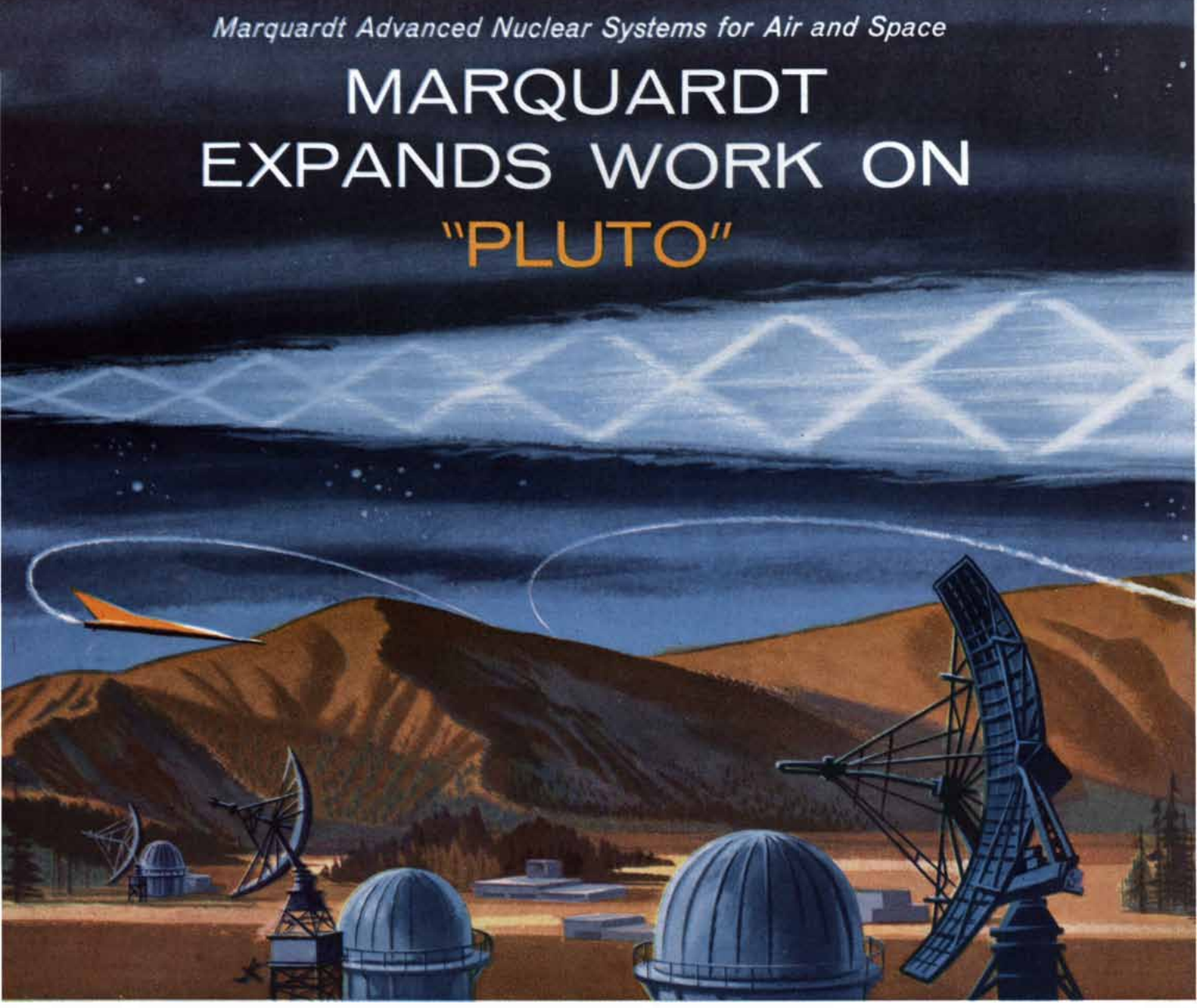


Broadened team effort with University of California's Lawrence Radiation Laboratory aims toward early feasibility demonstration of a nuclear ramjet reactor (Project PLUTO).

As an integral part of the team which is contributing to this country's all-out race for supremacy in weapons, The Marquardt Corporation is working with the University of California's Lawrence Radiation Laboratory on the nuclear ramjet program, known as Project PLUTO.

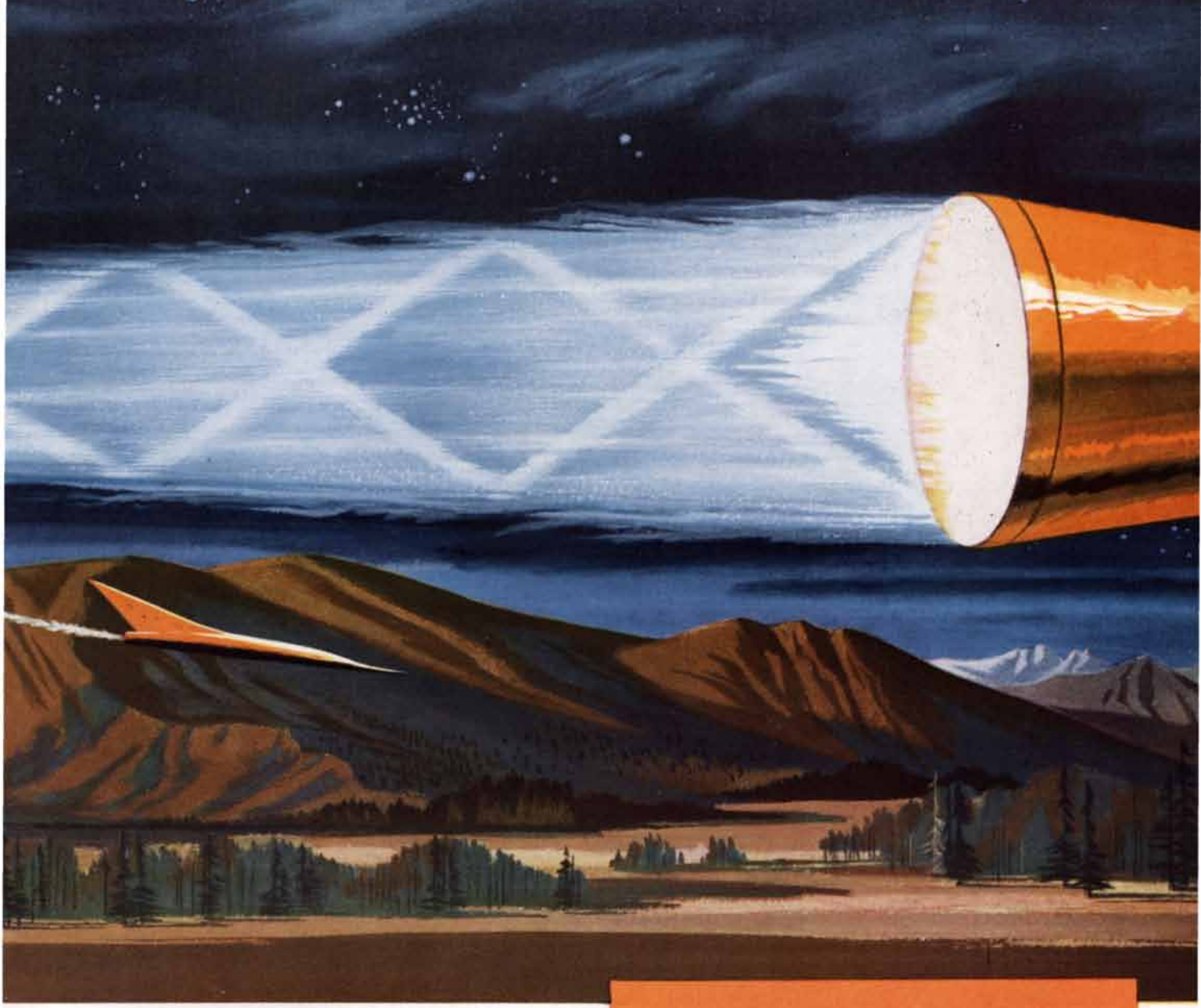
The multi-million dollar contract supports a multi-phase effort by the Corporation's Nuclear Systems Division, supported by Marquardt's Controls and Accessories, Propulsion, Test, ASTRO, Facilities Engineering and Pomona Divisions.

Marquardt's basic PLUTO effort concerns preliminary design of the nuclear ramjet and development of airborne reactor controls and other components for severe temperature and radiation environments.

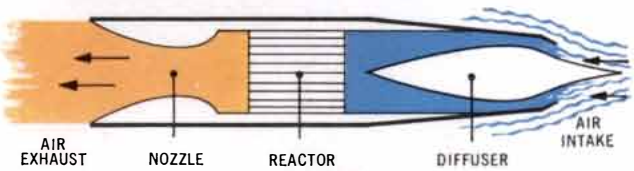
Other aspects of Marquardt's PLUTO effort include: support of LRL's feasibility tests on the non-flyable Tory IIA reactor; design and fabrication of significant portions of the reactor's control system, air ducts, flow instrumentation and remotely operated disconnects; fabrication and test of reactor core structural components; architect-engineering on the test air supply system; participation in a supporting program of environmental tests; and preliminary design of test facilities for full-scale power-plant development.

Highlights of the Corporation's other current nuclear programs include: exploration of both military and non-military applications for transportable reactors of advanced design, including their use for space power; development of the engine control system for the G-E nuclear turbojet; research studies of advanced space propulsion devices utilizing nuclear concepts; materials and processes work with molybdenum, other refractory metals and ceramics; and development of original nuclear instrumentation.

For a copy of Marquardt's new "Nuclear Systems" brochure, write to Mr. Aikman Armstrong, Chief Application Engineer — Nuclear Systems, The Marquardt Corporation, Van Nuys, California.



THE NUCLEAR RAMJET



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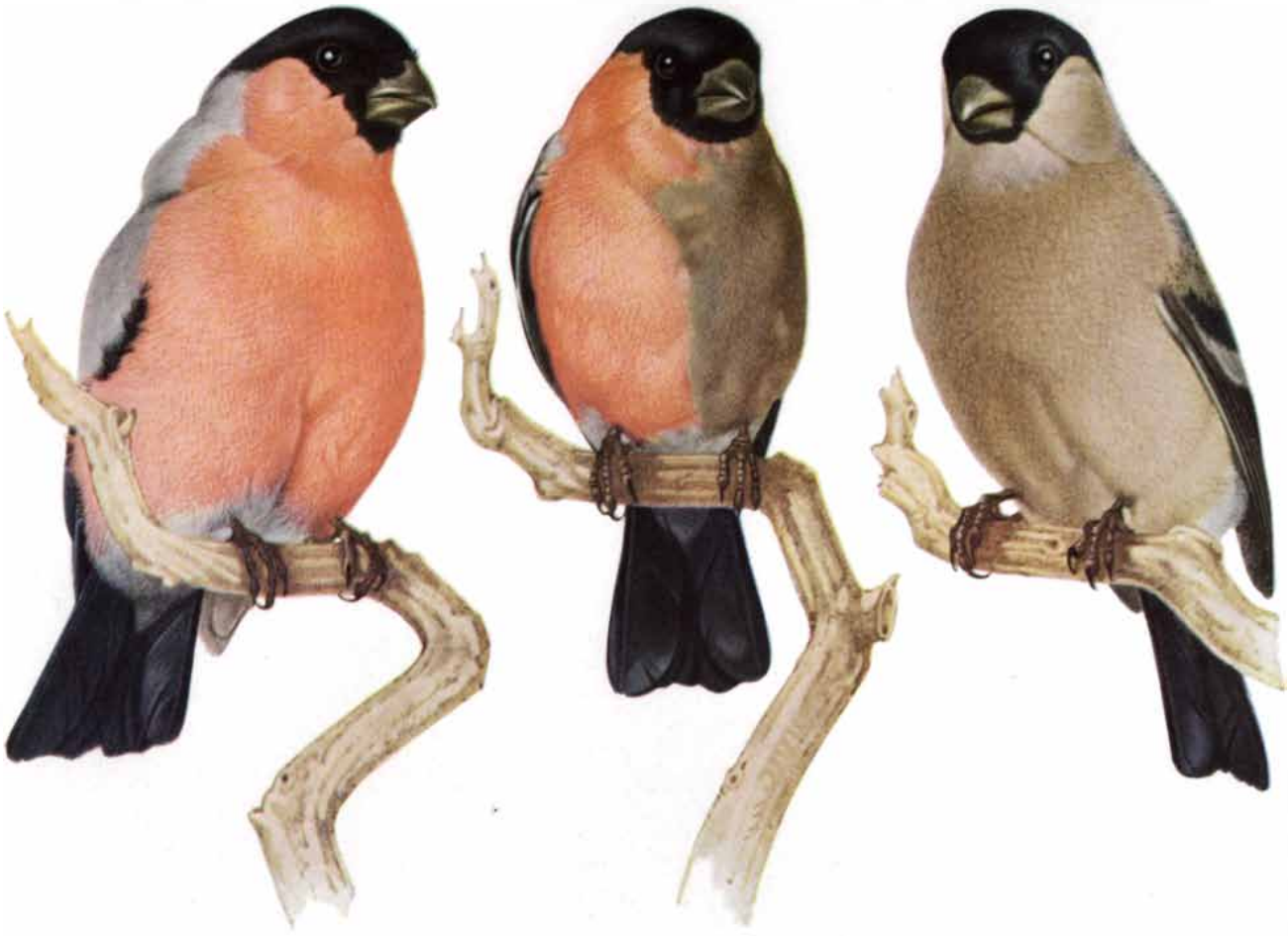


GYNANDROMORPH, or sexual mosaic, in the European bullfinch (*center*) has male coloring on one side and female coloring on the other side as a result of a genetic change in an embryonic cell. The normal male has an orange breast (*bird at left*); the female, a grayish breast (*right*). The drawings are based on skins in the collection of the American Museum of Natural History in New York.

GYPSY-MOTH GYNANDROMORPHS (*lower left and lower right*) have the light-colored wings and thin antennae of the female on one side of the body and the brown wings and feathery antennae of the male on the opposite side. For comparison, the normal female gypsy moth is shown at upper left; the male, at upper right. The moths are in collection of National Museum in Washington.

GENETIC MOSAICS

Normally each cell of a many-celled organism has the same set of genes. Occasionally, however, the organism is composed of cells with different genes. Some of these genetic mosaics are even half male and half female

by Aloha Hannah-Alava

Glory be to God for dappled things—
For skies of couple-color as
a brindled cow;
For rose-moles all in stipple upon
trout that swim;
Fresh-firecoal chestnut falls; finches'
wings; . . .

The delight and wonder in "pied beauty" expressed by the poet Gerard Manley Hopkins have surely been felt by men since earliest times. In nature mottling, spotting and striping serve the vital function of protective coloration. But even among domestic animals and plants, which have nothing to gain from such protection, only the variegated—that is, varicolored—strains of many species now remain. The original solid color of the species vanished long ago under the influence of selective breeding.

The trait of variegation has been something of a riddle ever since genetics became a science. According to the first principle of Mendelian genetics, each characteristic of an organism is determined by a gene inherited from one or both of its parents. If only one gene for a characteristic, say hair color, can assert itself, how explain the appearance of a mosaic of two or more colors in the offspring?

The question is posed more sharply by the occurrence of sexual mosaics, that is, individuals which appear to be mixtures of male and female tissues. These too were known to the ancients. The Assyrians and Babylonians worshiped deities that were half-man and half-woman. In the figure of Hermaphroditos the Greeks celebrated the synthesis of Hermes, the god of worldly success, and Aphrodite, the goddess of beauty. Actual hermaphrodites may have been accorded similar awe and veneration. In the Middle Ages, however, they were burned at the stake, and they are still the subject of morbid curiosity. Until recently the occurrence of hermaphrodites was attributed to glandular causes, in line with the idea that human sexual characteristics, especially such secondary sexual characteristics as the distribution of hair on the body, are governed by the sex hormones.

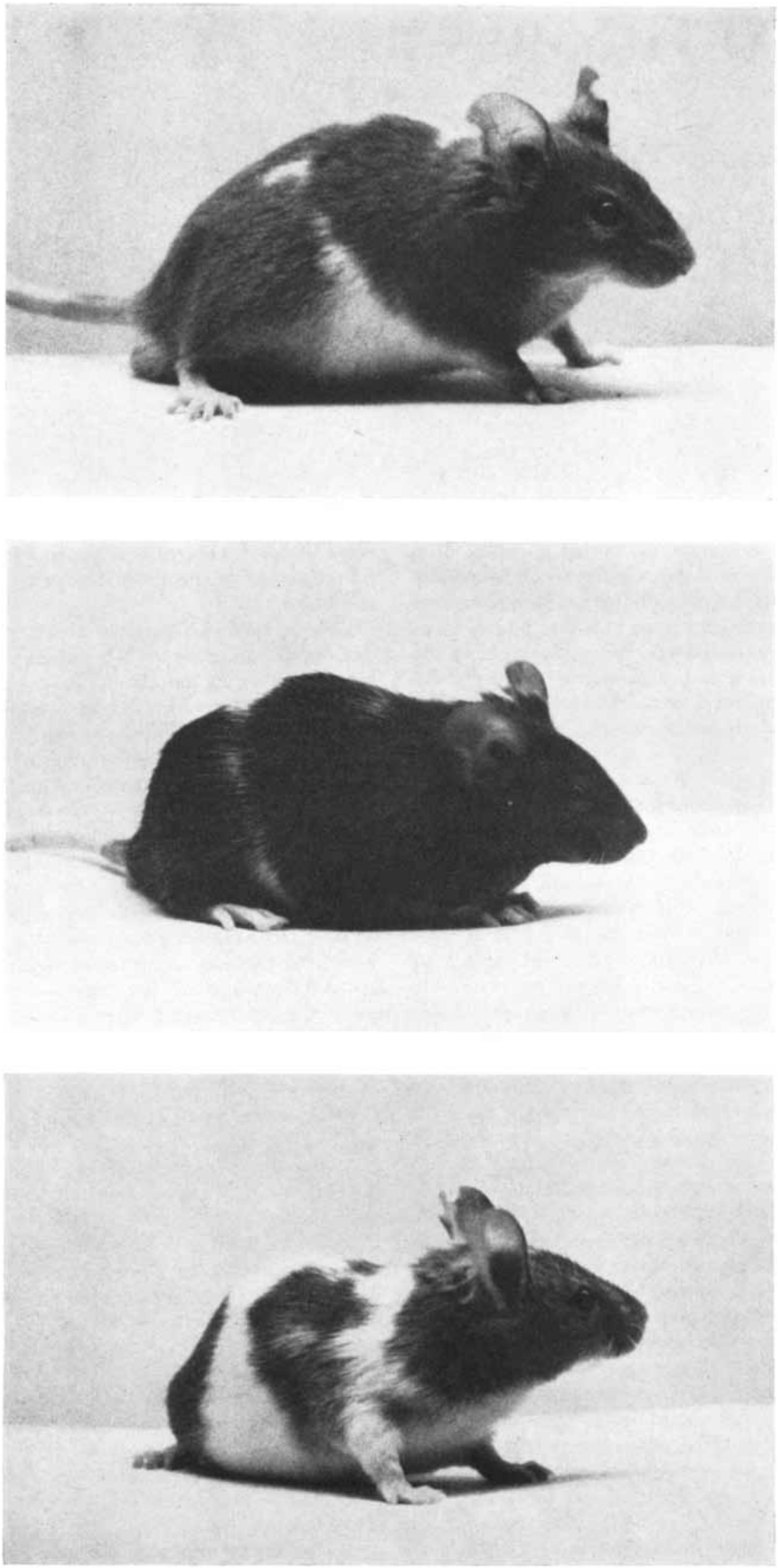
Today the questions and the misconceptions that surround living mosaics have largely been resolved. This new understanding reflects substantial progress in a neglected branch of genetics: the branch concerned with the transfer of hereditary characteristics from the single-celled zygote (the fertilized egg) to the myriads of specialized body cells that comprise the adult organism. Genetic mechanisms, it appears, account for mosaics of all kinds, except for certain plant mosaics caused by viruses and other environmental factors. These are the same mechanisms that are responsible for the variety and novelty in the hereditary succession from one generation to the next. The occurrence of sexual mosaics is thus explained as an aberration of the genetic mechanism that determines sex in normal individuals.

One can graft part of one organism onto another to create an artificial mosaic. This technique is of great practical importance in horticulture and is an important experimental technique in embryology. Trees bearing several kinds of apple, or rose bushes with several kinds of bloom, have become fairly common. Recently Tamikazu Seno and Saburo Saito of Gunma University in Japan have reported the grafting of a chick's head to a duck's body, a feat that recalls the centaur, the sphinx and other mosaics of mythology. Another kind of mosaicism is traceable to virus infection. Plant viruses cause mottling of leaves and of other tissues; such a virus is responsible for the attractive streaks of color in certain tulips.

Genetic mosaics are more difficult to explain. Theoretically all the cells in a many-celled organism should have an identical hereditary constitution derived from the fertilized egg that gave rise to them by successive divisions. The unfertilized egg and the sperm cell each endows the fertilized egg with one set of chromosomes, the threadlike bodies in the nucleus of the cell. It is the resulting double set of chromosomes that the fertilized egg passes on to its daughter cells, to be duplicated at each subsequent cell division so that every body cell of the organism has the same double set. In the fertilized egg and in the body cells each chromosome derived from the sperm lines up with the complementary chromosome derived from the egg.

At a corresponding site on each chromosome in a pair is a gene for a given hereditary characteristic—to use a human example, let us say eye color. The paired genes may be homozygous (for instance, they are both associated with blue eyes) or heterozygous (one is associated with blue eyes and the other with brown). If they are heterozygous, only one gene, the "dominant," is expressed; the other, the "recessive," is dormant. In this light one would expect that all the skin cells of an animal, bearing the same hereditary plan, would have identical characteristics such as color. In the mosaic animal, however, characteristics transmitted from both parents—even entirely new characteristics—may appear in the skin and other tissues of the body.

Early investigators of the inheritance of variegation found to their surprise



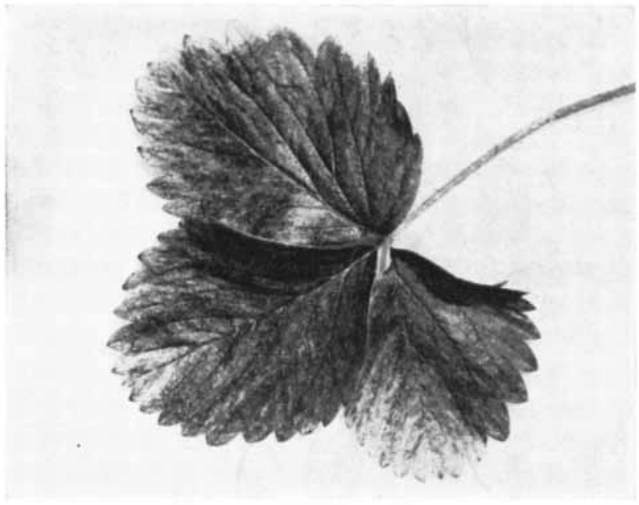
THREE PIEBALD MICE of one litter inherited the same recessive gene for mottling, but are marked quite differently. Two have large patches of white; the other is almost all black. These mice were photographed in the laboratory of L. C. Dunn at Columbia University.

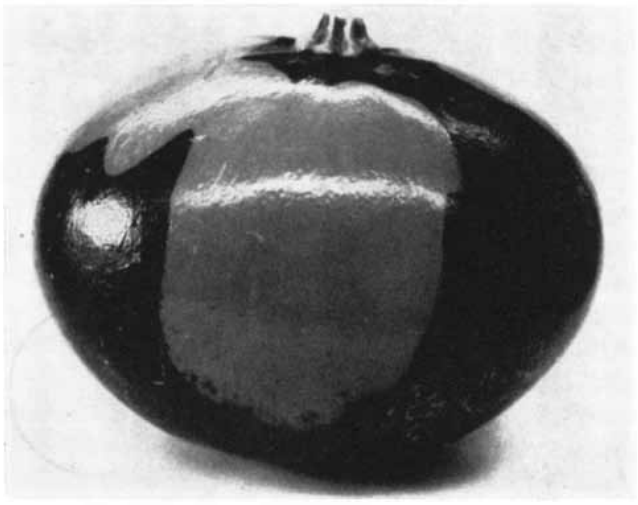
that there are genes for pattern just as there are genes for eye color, and that these genes follow the Mendelian laws just as faithfully. Thus mosaicism may be a recessive trait and appear only in organisms that inherit the trait from both parents, or it may show up with the greater frequency characteristic of a dominant trait. A single species may have both recessive and dominant genes affecting pattern. In addition, several genes may work together to produce the pattern, or there may be factors that modify the main pattern-gene but have little or no effect if that gene is absent.

Some 40 years ago W. E. Castle, who was then at Harvard University, demonstrated these principles in a classic investigation of the "hoodedness" of hooded rats. He determined that the characteristic hood of black hair on the head of this strain of rats is inherited through a simple recessive gene. But the size of the hood is not always exactly the same, some rats having a larger area of black hair than others. By selecting and interbreeding for small hoods and for large ones over many generations, Castle produced one strain that had a very small hood and another strain that was all hood, that is, all black. He showed that the variation in pattern was due to the influence of other genes that modify the action of the main gene for hoodedness. Thus the actual expression of a trait depends not only on the presence of a particular gene but also on the interaction of the gene with the total genetic endowment. This accounts for the fact that such patterns tend to vary from individual to individual.

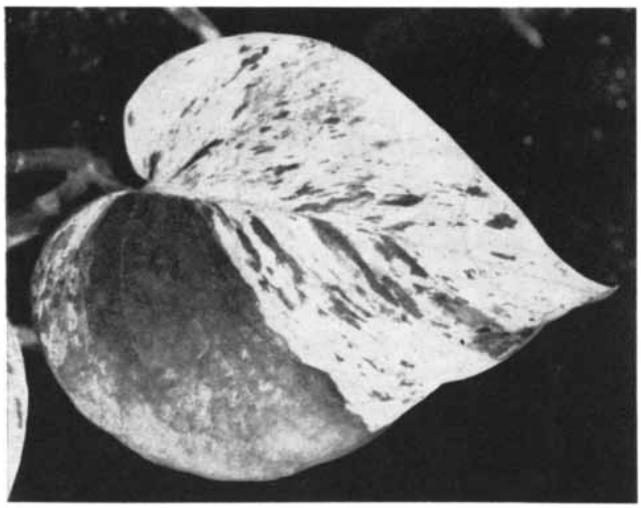
But the demonstration that genetic factors control the pattern of hair color did not explain how the genes for such a pattern produce their effects. Patterning could in many cases be traced to variable biochemical factors that cause the same gene to be expressed differently under different circumstances and even in different parts of the body. Thus in the Himalayan rabbit the darkening of the hair on the tips of the ears, the nose and the paws is caused by the lower temperature of these extremities. At one temperature the genes for hair color give rise to black hair; at another temperature the same genes produce no pigment, and the hair is white. If the rabbit is raised in an environment that is sufficiently warm to raise the temperature of its extremities, it is all white. (Fanciers of Siamese cats will recognize the same mechanism in the color-patterning of these animals.) Undoubtedly most genes

VIRUS-INDUCED MOSAICS are common among plants. The tobacco leaf at left, infected with tobacco-mosaic virus, has irregular dark green patches in the affected area. The mottling on the blueberry leaf at right is the result of infection with a blueberry virus.





HEREDITARY MOTTLING that produced yellow patches on the strawberry leaf at left appears only in June. In summer the leaves are all green. Mottled gourd at right is the result of hybridizing a purebred green strain with a particular purebred yellow strain.

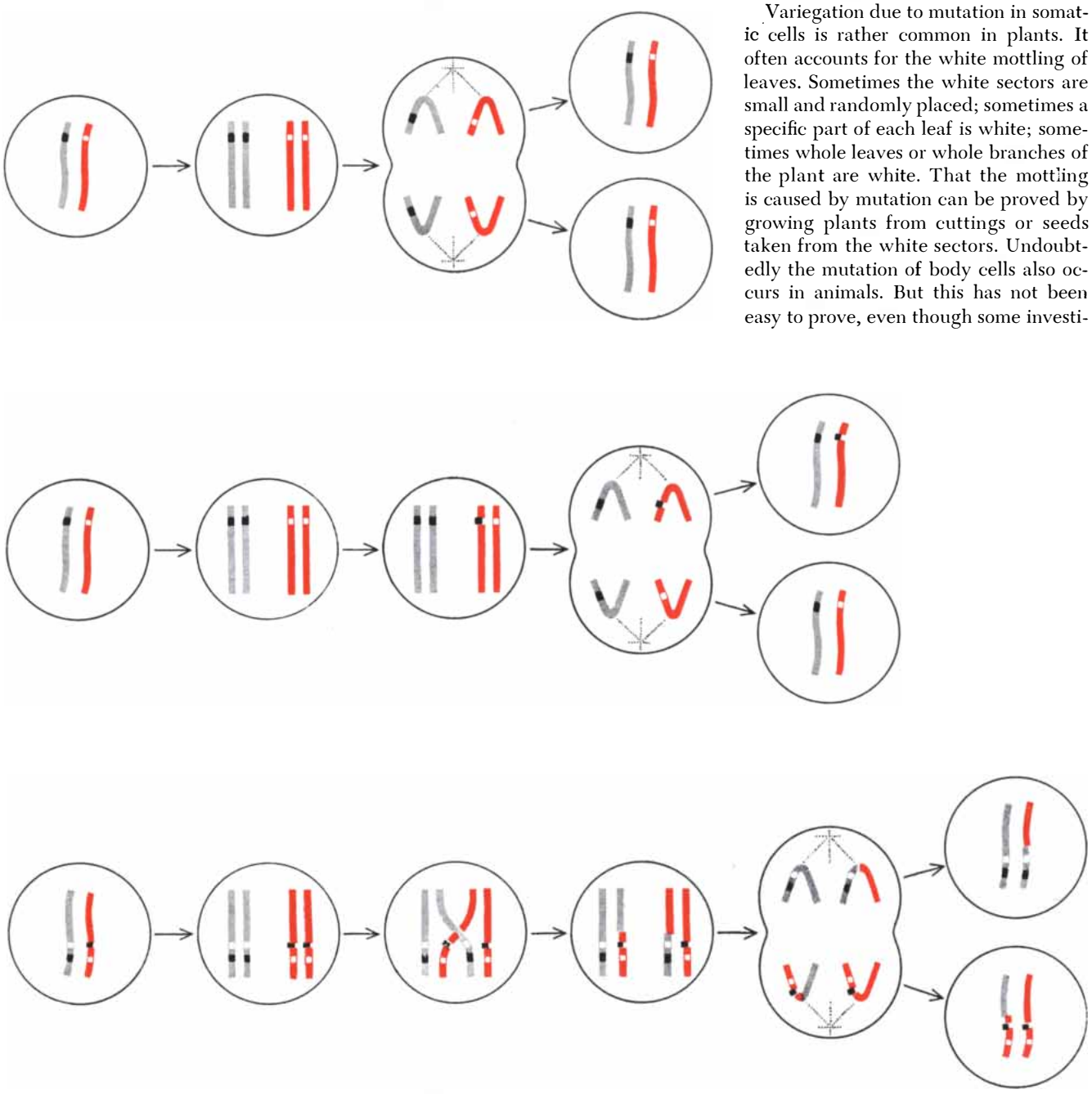


SUDDEN MUTATION in the cell of a growing leaf can cause mottling of the type seen in these house plants. At left is a leaf of the Ivy-Arum that has an irregular patch of white. The mutant leaf of Peperomia at right shows the normal green only in the middle.

responsible for pattern act through such variable biochemical systems, most of them more complex than this temperature-dependent one.

Earlier workers were also willing to accept, in principle, the notion that the genes in body cells are subject to mutation, that is, a change in the physical constitution of the gene which alters its action. As the public has learned in connection with the widespread concern about the effects of high-energy radiation, the mutation of a gene in an egg or a sperm cell of a parent can modify the heredity of the offspring. Similarly a mutation in a body cell, occurring in the course of embryonic development, can alter the constitution of the tissues descended from that cell. For example, an individual may have a pair of recessive genes (let us label them c/c), and the c gene may mutate to the dominant gene C. Wherever a c gene mutates, C/c tissue will arise. Cells bearing the mutated gene will show the dominant trait, and the rest, bearing paired recessive genes, will exhibit the recessive trait. A tendency to mutation of this kind may be inherent in the gene and so be a part of the hereditary characteristic that it controls. If it is a gene for hair color, each patch of the dominant color indicates a separate mutation, and the size of the patch depends on how early in development the mutation occurred.

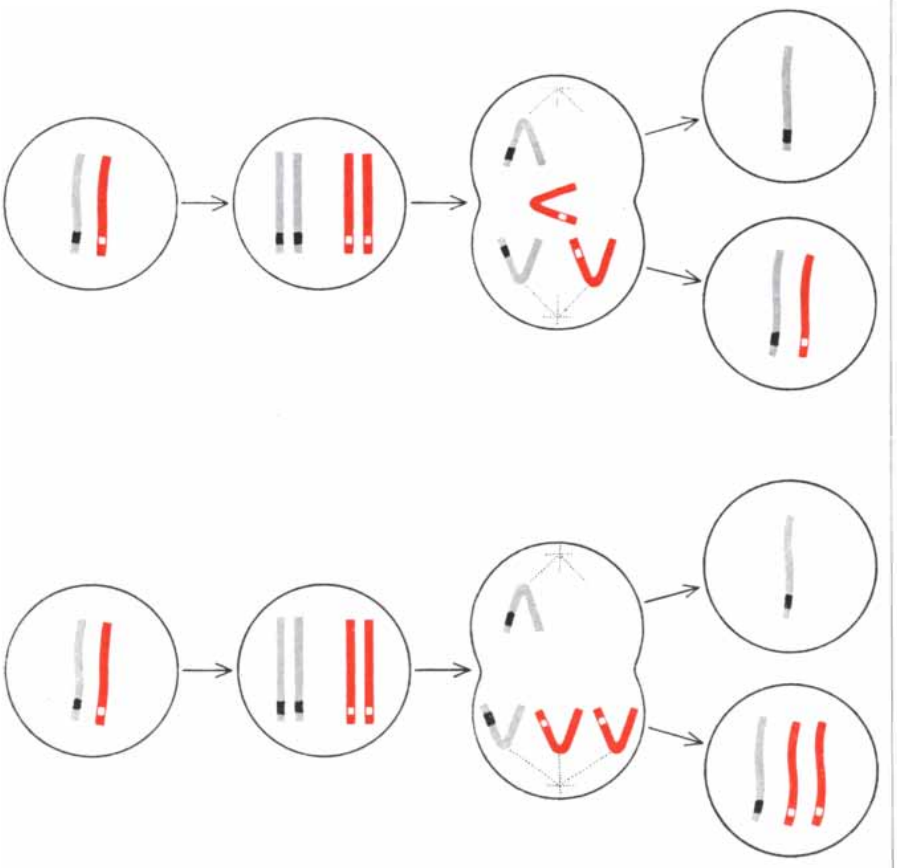
Variegation due to mutation in somatic cells is rather common in plants. It often accounts for the white mottling of leaves. Sometimes the white sectors are small and randomly placed; sometimes a specific part of each leaf is white; sometimes whole leaves or whole branches of the plant are white. That the mottling is caused by mutation can be proved by growing plants from cuttings or seeds taken from the white sectors. Undoubtedly the mutation of body cells also occurs in animals. But this has not been easy to prove, even though some investi-



GENETIC MECHANISMS account for some mosaics. Normally daughter cells receive exact duplicates of the paired chromosomes (*rods*) of the parent cell (*top row*). If corresponding genes (*squares*) of the chromosomes are unlike, that is, if one is recessive (*black*) and the other dominant (*white*), only the dominant trait is manifested. Cells having such gene pairs may produce daughter cells with matching genes, however, by mutation of one gene (*second row, third step*) or by "crossing over" between two chromosomes (*third row*). Cells thus receiving paired recessive genes may exhibit recessive traits not seen in cells of the parental type.

gators argue that it is the principal mechanism in the genesis of mosaics. Until recently there has been no satisfactory way of identifying the genetic make-up of animal tissues or cells other than the reproductive ones. New techniques for culturing whole colonies of cells from single tissue-cells and for making their chromosome complements visible bear promise that this and other questions will soon be settled [see "Single Human Cells in Vitro," by Theodore T. Puck; SCIENTIFIC AMERICAN, August, 1957].

Curt Stern of the University of California has demonstrated still another cause of mosaicism. This involves the exchange ("crossing over") of segments between two chromosomes in a body cell. Here again a process that normally occurs only in sex cells, and thereby modifies the genetic constitution passed on to future generations, can occur in a body cell and modify the genetic constitution of the individual. Before any cell divides, each chromosome duplicates itself exactly, so that the daughter cells receive chromosome pairs identical with those of the parent cell. Occasionally in a body cell and normally in one of the divisions of a sex cell the chromosomes in a pair may twist together and exchange corresponding sections before they break away from each other. In subsequent segregation of the chromosomes the two daughter cells may not receive identical sets. One member of a pair of chromosomes, for example, might bear the recessive genes *abcde;* the other, the dominant genes *ABCDE.* If, after these chromosomes have duplicated themselves, the *de* segment of an *abcde* chromosome crosses over with the *DE* segment of an *ABCDE* chromosome, the cell will contain chromosomes with the genes *abcde*, *ABCDE*, *ABCde* and *abcDE*. Upon division, one daughter cell may receive the *abcDE/ABCDE* pair, and the other the *ABCde/abcde* pair. Thus a cell originally heterozygous for a pair of genes for color (say *D/d*) can divide into two unlike cells with homozygous color genes, one having the dominant pair (*D/D*) and the other the



DIFFERING CHROMOSOME NUMBERS in cells can also cause mosaicism. If a chromosome behaves abnormally when the duplicated chromosomes separate, it may be lost (*top row*) or go to the wrong daughter cell (*bottom row*). X-ray treatment increases the incidence of such behavior. A cell lacking a chromosome may not survive, but if it does, it may produce cells exhibiting a recessive trait masked by a dominant gene in the other cells.

recessive (*d/d*). Tissues originating from the cells with *D/d* genes or *D/D* genes will have only the dominant color; tissues from cells with *d/d* genes will manifest the recessive color.

In his experiments Stern employed the familiar standby of the geneticist: the fruit fly *Drosophila melanogaster*. Ordinarily the fruit fly has long black bristles; the gene combination is labeled *B L*. However, a recessive gene (*y*) can change the color of the bristles from black to yellow, and another recessive gene (*sn*) can give the usually long bristles a singed appearance. Stern bred flies heterozygous for these genes; that is, one chromosome of a pair bore a gene for black bristles and a gene for singed bristles (*B sn*), and the other chromosome carried the genes for long yellow bristles (*y L*). A fly with this genetic make-up should have only bristles that are both long and black, these two traits being dominant, unless some genetic alteration occurs. A mutation from dominant to recessive in either gene, for example, would produce patches of singed black bristles or patches of long yellow bristles. If there were crossing over, but not mutation, Stern reasoned, it might well involve both genes rather than one. He therefore searched among his colonies for flies with paired patches of bristles, one patch with long yellow bristles (*y L/y L*) and the other with singed black bristles (*B sn/B sn*). His discovery of such patches on some flies proved that crossing over in the chromosomes of the body cells does occur, and is a cause of mosaicism.

Crossing over is of course not limited to fruit flies. Guido Pontecorvo and his co-workers at the University of Glasgow have demonstrated that it occurs in the mold *Aspergillus*. There are indications that it may also be the mechanism by which humans can have one brown and one blue eye.

Any aberration in chromosome behavior that changes the genetic endowment of some cells in the body can cause mosaicism, if the cells are capable of surviving at all. There are several accidents of this kind in addition to mutation and crossing over. For example, the duplicated chromosomes may not be divided equally between the daughter cells: one cell may receive an extra chromosome and the other be left one chromosome short. A chromosome may be lost as the cell divides, so that one daughter cell has the normal number of chromosomes but the other lacks a chromosome. The pioneer geneticists Thomas Hunt Morgan and Calvin B. Bridges, who were then at Columbia University, found that the frequency of such accidents increases when embryos are exposed to X-rays or to extremes of temperature. Morgan's wife, Lillian V. Morgan, was able to produce sexual mosaics in flies with an abnormal sex chromosome. Injury to one of the sex chromosomes (the X chromosome) of the fruit fly may cause the chromosome, which is normally rod-shaped, to become ring-shaped. In this configuration the chromosome tends to be lost during cell division. Some tissues in the fly accordingly have two X chromosomes and are female, and some have a single X chromosome and are male.

When genetic changes occur in the body cells of animals, the amount of tissue that exhibits the change will depend upon the point in the embryonic development of the organism at which the change occurs. The mosaic may be bilateral: one kind of tissue is on the right side of the midline of the animal and the other kind is on the left. This indicates that a genetic aberration had occurred before or during the first division of the fertilized egg. Usually the patches are smaller; sometimes the aberration involves only one cell.

Bilateral mosaics due to loss of a chromosome are generally rare, but another type occurs quite commonly in cer-

FRUIT FLY WITH THREE KINDS OF BRISTLE demonstrates that crossing over between chromosomes can produce mosaics. The original cells of this fly had a pair of chromosomes with two unmatching pairs of genes affecting bristles. Most of the bristles show just the dominant traits, and so are long and black. In two places bristles with the recessive color (yellow) appear adjacent to bristles with the recessive length ("singed"). The paired patches indicate that the bristle genes crossed over in two of the embryonic cells.

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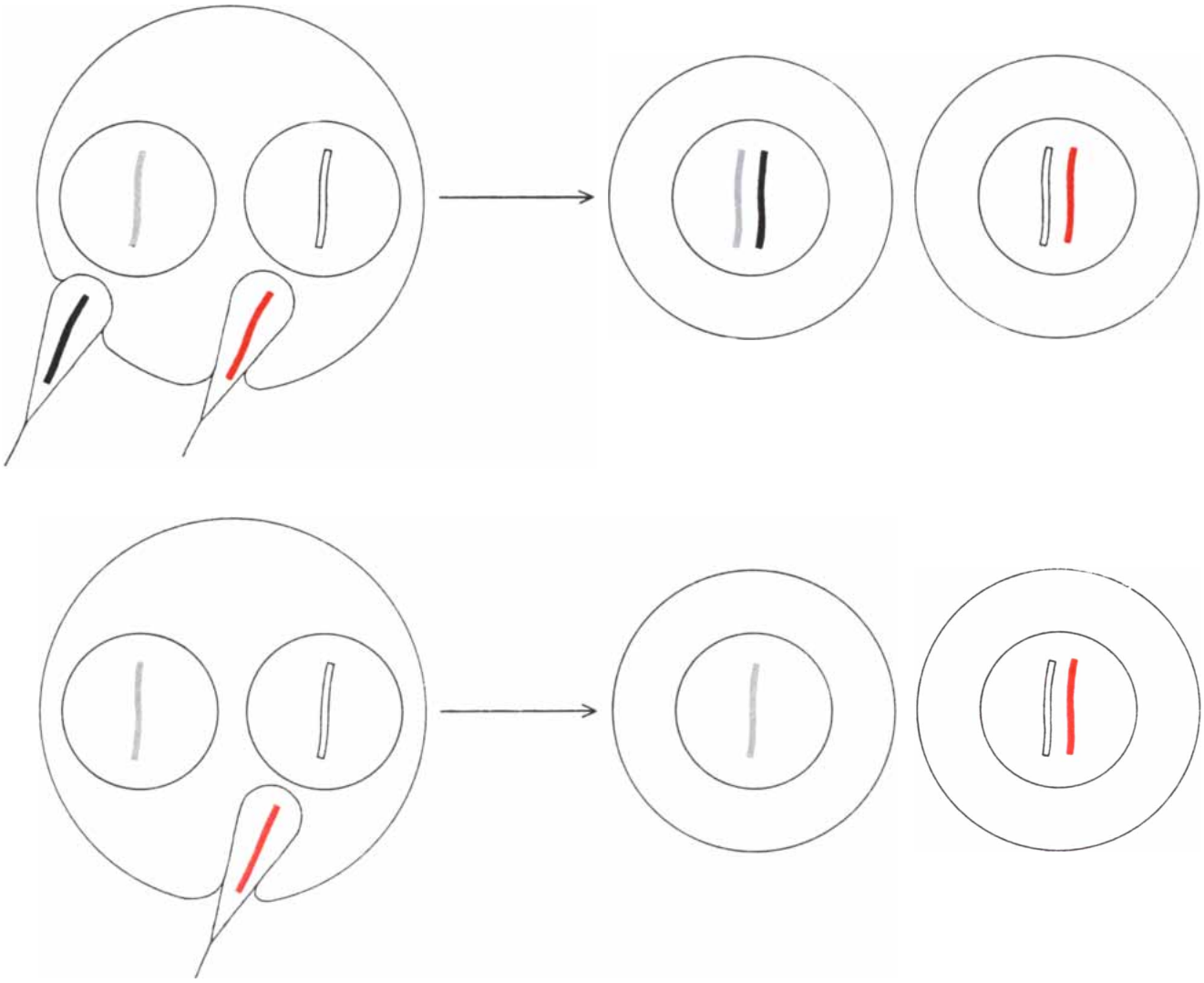
tain races of bees, ants, moths and flies that have a tendency to lay eggs with two nuclei. Because each of the two nuclei receives one chromosome of each pair of maternal chromosomes, the nuclei may acquire different sets of genes. In the first cell division after fertilization the nuclei go to separate daughter cells, and each gives rise to half of the resulting embryo.

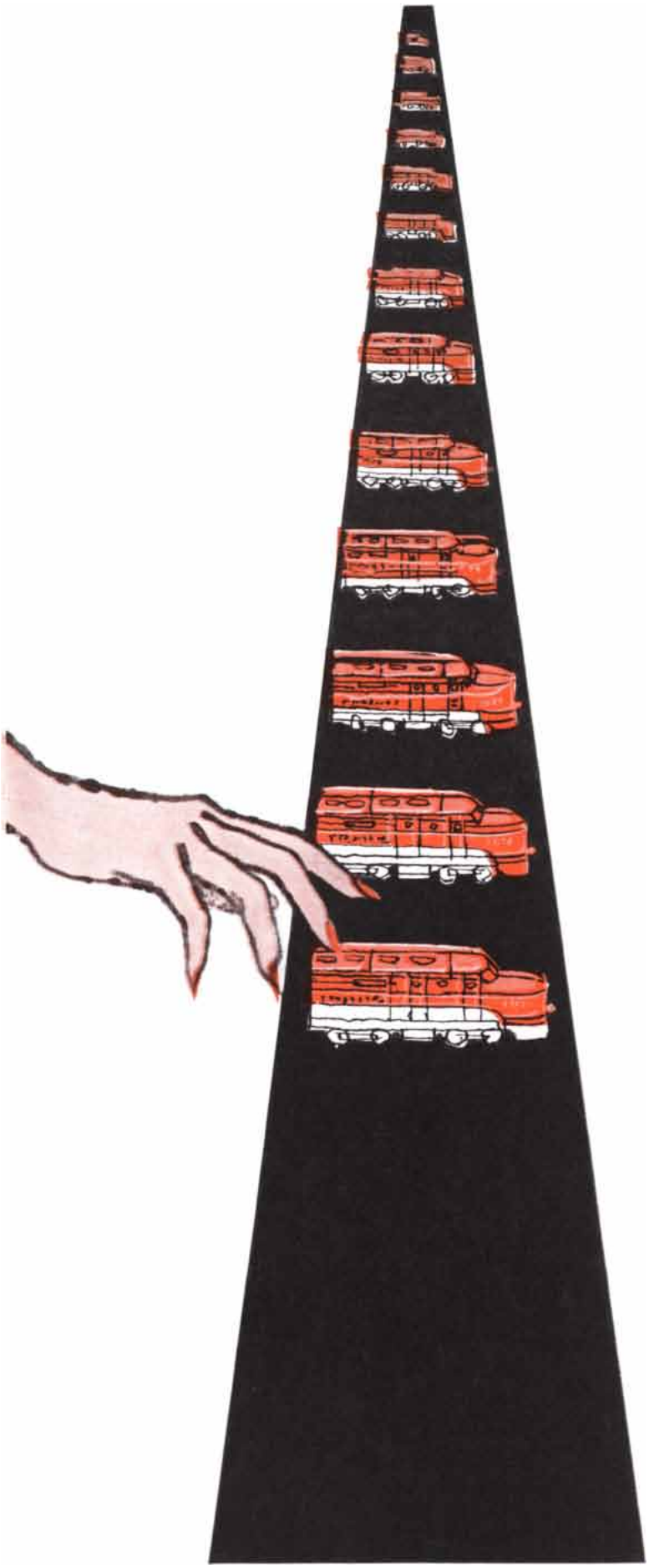
Insect mosaics are frequently sexual mosaics. These "gynandromorphs" occur in all imaginable forms, from those which possess functional organs of both sexes to those which are a mosaic of male and female tissues and possess functional sexual organs only if the gonads and related structures are genetically all female or all male. Bilateral sexual mosaics—having male coloring and form on one side and female on the other—are well known to butterfly collectors and are so highly prized that unscrupulous sellers have been known to go to the trouble of forging them.

In most insects and other members of the animal kingdom that reproduce sexually, sex is determined by the sex chromosomes. Normally one sex has two similar sex chromosomes (labeled XX) and the other has two different sex chromosomes (XY) or just one sex chromosome (XO). Which combination is male and which female varies with the species. The fact that the X chromosome can occur either paired (XX) or unpaired (XY or XO) makes it relatively easy to identify the "sex-linked" genes associated with it. These genes do not necessarily govern characteristics related to sexual function, but the characteristics are sex-linked in the sense that recessive genes will tend to manifest themselves only in one or the other sex. For this reason many studies of gene action at the cellular level have focused on the sex chromosomes.

Bilateral sexual mosaics often occur in insects that develop from eggs with two nuclei. Both nuclei in the two-nucleus egg of a fly or moth bear the X chromosome. Upon fertilization one nucleus may be joined by a sperm bearing an X chromosome and the other by a sperm bearing a Y chromosome. This will give rise to a gynandromorph with female tissue (XX) on one side and male tissue (XY) on the other. In the special case of bees or ants, in which sex is determined not by sex chromosomes but by



EGG CELLS WITH TWO NUCLEI produce bilateral mosaics in insects, one side of the animal coming from one nucleus, the other side coming from the second nucleus. Each nucleus may have a different genetic complement (*symbolized by an unpaired chromosome*), and the fertilizing sperms also may differ (*top row*). The resulting insect may be half male and half female if, for instance, one sperm carries an X chromosome and the other a Y chromosome. Among insects such as bees, sex depends on whether all chromosomes are paired or unpaired; then insect is half male and half female when only one nucleus is fertilized (*bottom row*).



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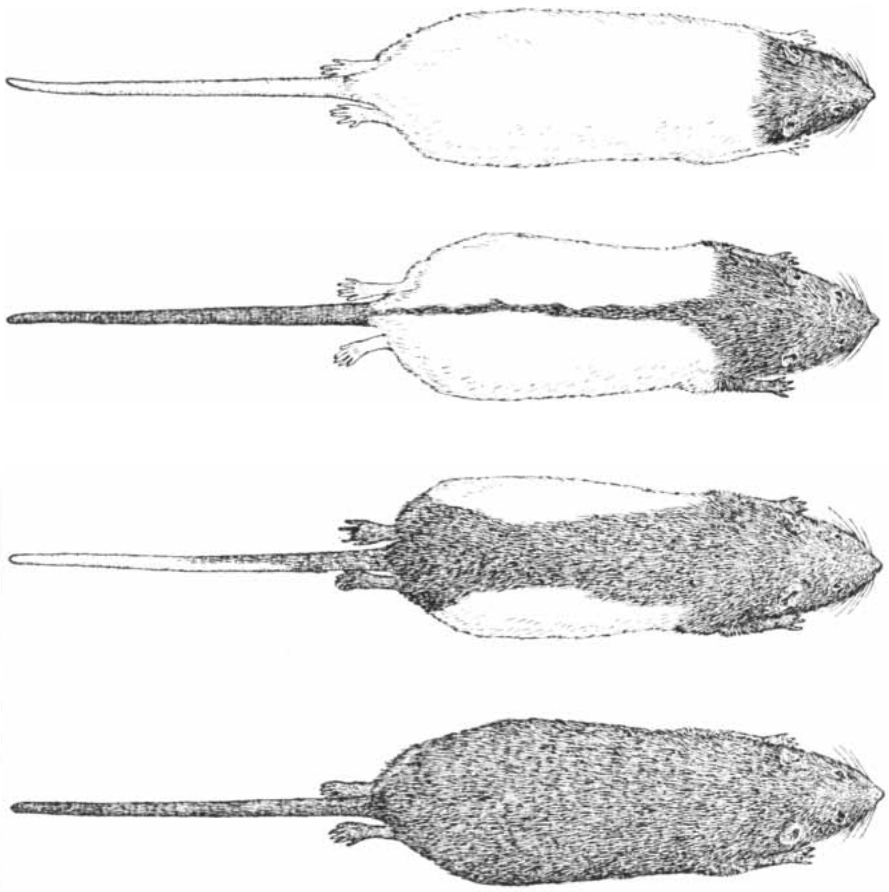
whether or not the chromosome complement of the individual is paired or unpaired, gynandromorphs may arise from a two-nucleus egg by another mechanism. If only one of the two nuclei is fertilized, that nucleus will give rise to tissue cells with paired chromosomes (female), while the other will give rise to tissue cells with unpaired chromosomes (male). A gynandromorph of XX female and XO male constitution can occur in fruit flies when a cell in a developing female embryo loses an X chromosome. A gynandromorph can thus be due to many causes and may arise during any stage of embryonic development.

It was long thought that gynandromorphs would not show up in the higher vertebrates because of the overriding influence of the sex hormones on the expression of secondary sexual characteristics. In vertebrates such as man the sex chromosomes seemed merely to determine whether the embryo is to develop ovaries or testes; once these organs develop, the hormones they secrete take over the task of determining the sexual characteristics of the individual. In fishes, newts, toads and birds simple administration of hormones during development can change genetic males into functional females, or (less often) genetic females into functional males. Intersexes in higher vertebrates are usually found to have an insufficiency or overabundance of certain hormones. Despite the overwhelming evidence in favor of hormonal determination of the secondary sexual characteristics in vertebrates, however, reports of gynandromorphs in birds and mice continually crop up, and various studies have affirmed their genetic basis. The condition has been found to be associated with differences in the number of chromosomes in the two types of tissue in the mosaic, and in some cases the missing or aberrant element has been identified as a sex chromosome. According to another study, differences in the growth of the genetically different tissues indicated that one type was more responsive to the



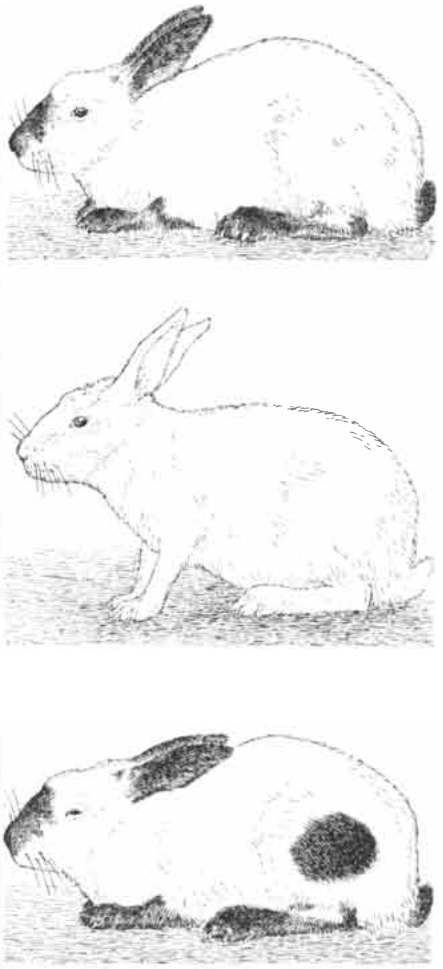
HOODED RATS, so called because of their black heads, inherit the trait through a single recessive gene. The size of the hood, however, depends on other genetic factors. By selective breeding, W. E. Castle succeeded in producing a strain of "hooded" rats that was practically all white (*top*) and another that was black except for its abdomen (*bottom*). The original population had hoods like that of the second rat. One intermediate strain (*third*) is shown.

sex hormone present in the organism. The sex hormones, in any case, have been yielding their monopoly on the determination of secondary sexual characteristics in vertebrates. Coloring in finches is known to be genetically determined and quite independent of the action of the sex hormones. Undoubtedly the same is true of other species of bird.

These observations helped to take some of the surprise out of the report several years ago of a human gynandromorph: an individual described as a mosaic for bearded and beardless areas of skin and for some other secondary sexual characteristics. More recently the new techniques for counting chromosomes in animal tissue cells have been applied to the cells of persons suffering from certain genetic syndromes. Individuals with Turner's syndrome (who were essentially female in appearance) were found to lack one X chromosome, and individuals with Kleinfelter's syndrome (who were nearly normal males) had two X chromosomes in addition to a Y chromosome.

Taken together with recent work on other mammals, these reports have radically revised the prevailing view of sex determination in man. As in the lower animals, the human egg bears an X chromosome, and the sperm carries an X or a Y chromosome; the combination XX gives rise to a female and XY to a male. Once the gonads were determined in accord with the genetic combination, however, it was thought that the hormones took over. Now it appears that genetic factors play a much more pervasive and decisive role in the determination of sex in the human species. The Y chromosome appears to possess factors for "maleness."

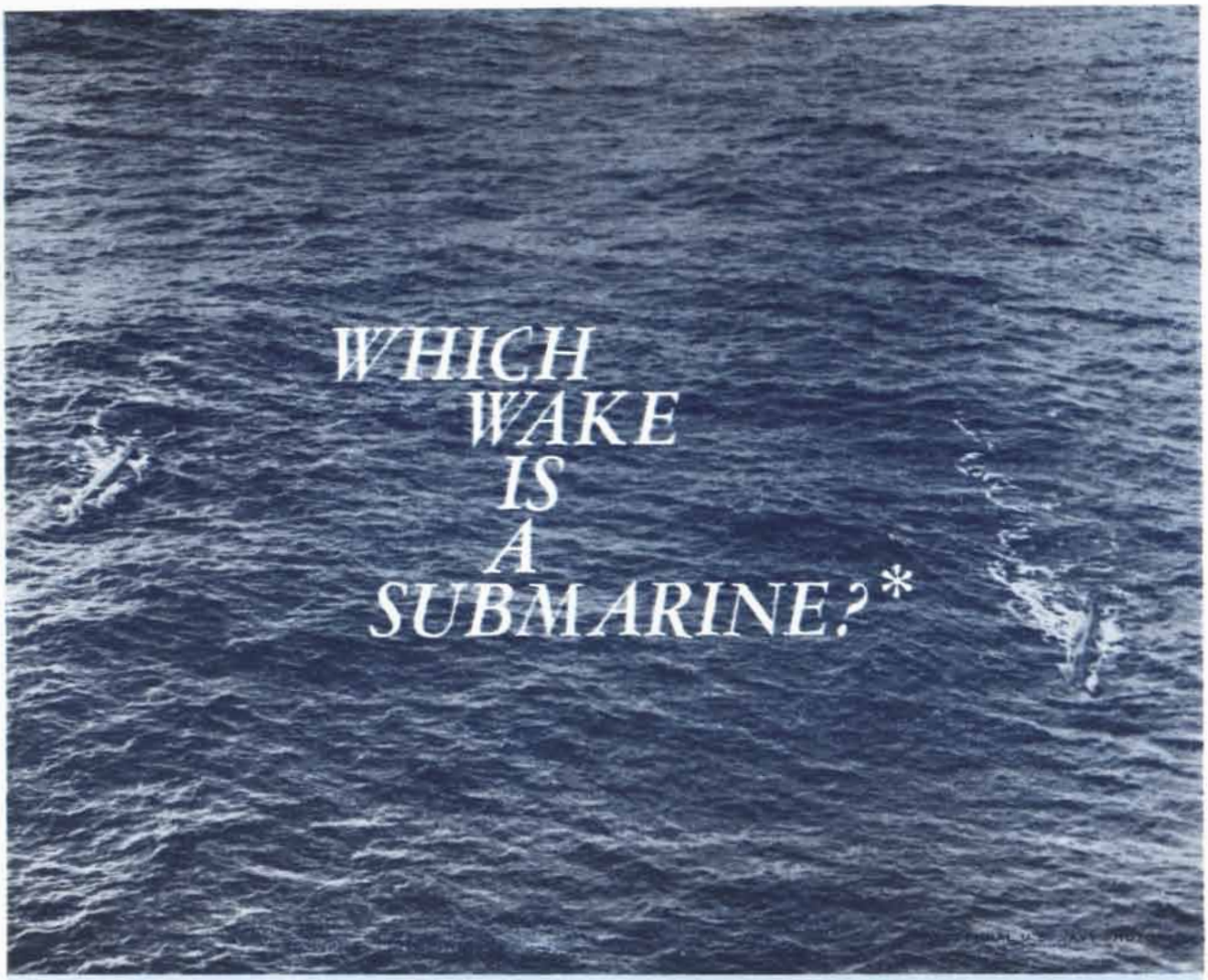
If this is the case, it is the presence or absence of the Y chromosome rather than of the X chromosome that makes the difference. The loss of an X chromosome, which produces an insect gynandromorph, would not produce a sexual mosaic in man; tissues with an XO genetic complement as well as those with the normal XX complement will be female in constitution. An XO-XX mosaic could be detected only by the manifestations of sex-linked recessive genes associated with the single X chromosome in the XO sectors. These might not show up at all if the sectors are small. One such mosaic might be indicated, however, by the occurrence of color blindness in one eye of a woman. Color blindness is a recessive sex-linked trait associated with the X chromosome. The color-blind eye would be derived from XO tissue with



HIMALAYAN RABBIT has a temperature-sensitive color factor. When reared in a cool place, the rabbit has black hair on its extremities, the coolest parts of its body (*top*). When reared in a warm place, it is all white (*center*). If an area of skin is shaved and then cooled artificially, the hair grows in black at that spot on the rabbit (*bottom*).

the color-blindness factor carried by the X chromosome; the normal eye would be derived from XX tissue, with the gene for color blindness being suppressed by its normal partner associated with the second X chromosome.

From the evidence to date one would expect that if chromosomal elimination can produce gynandromorphs in humans at all, such persons would be mosaic for XY male and XO female tissues by the loss of a Y chromosome. Similarly individuals with an extra sex chromosome could be mosaics of XX female and XXY male tissues. Such persons would have some cells with 46 chromosomes (the normal number) and some cells with 47 or 45 chromosomes. Individuals with these counts have been reported recently, but so far none has shown a corresponding mixture of male and female characteristics.



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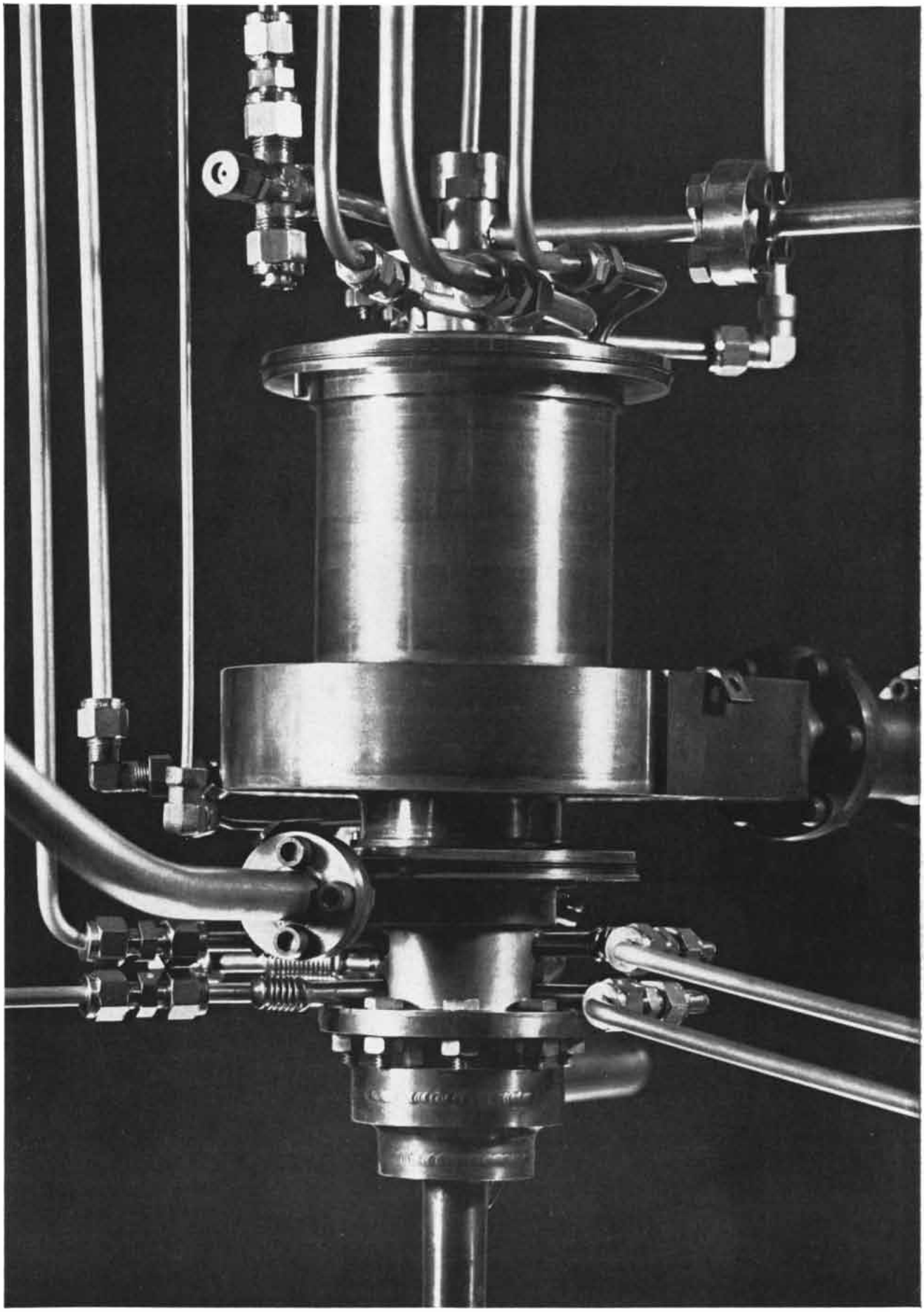

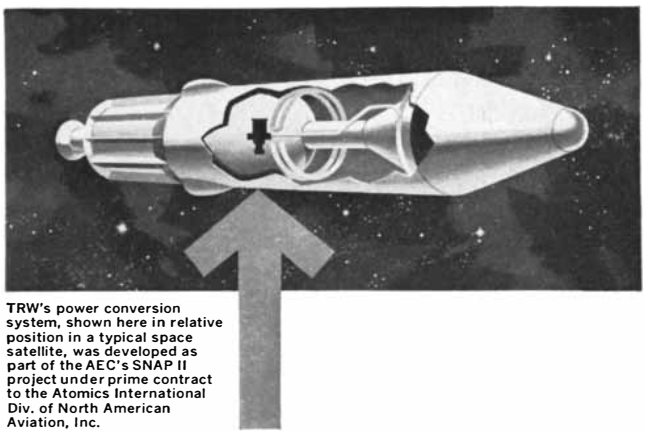

TRW's power conversion system, shown here in relative position in a typical space satellite, was developed as part of the AEC's SNAP II project under prime contract to the Atomics International Div. of North American Aviation, Inc.

from a miniature turbo-generator...

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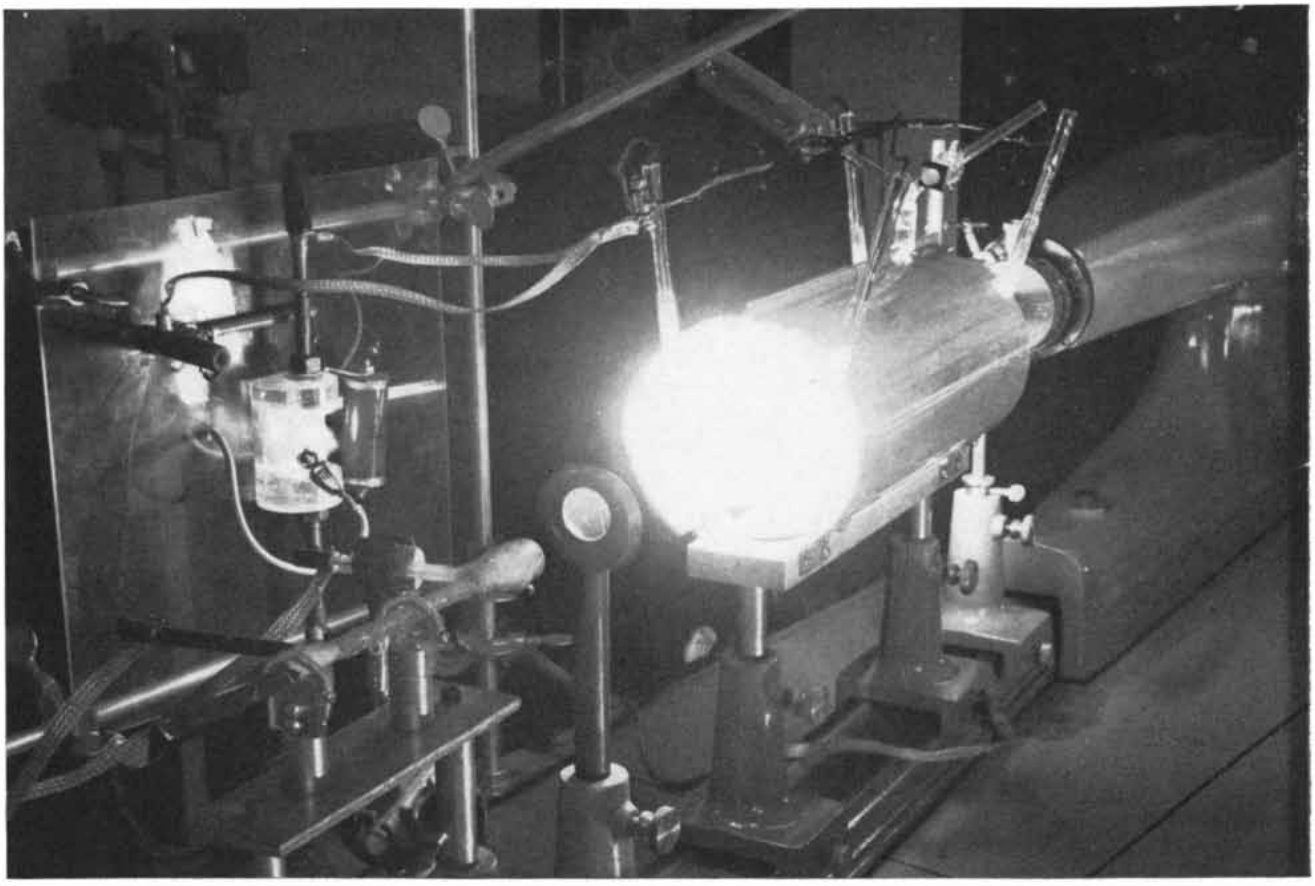
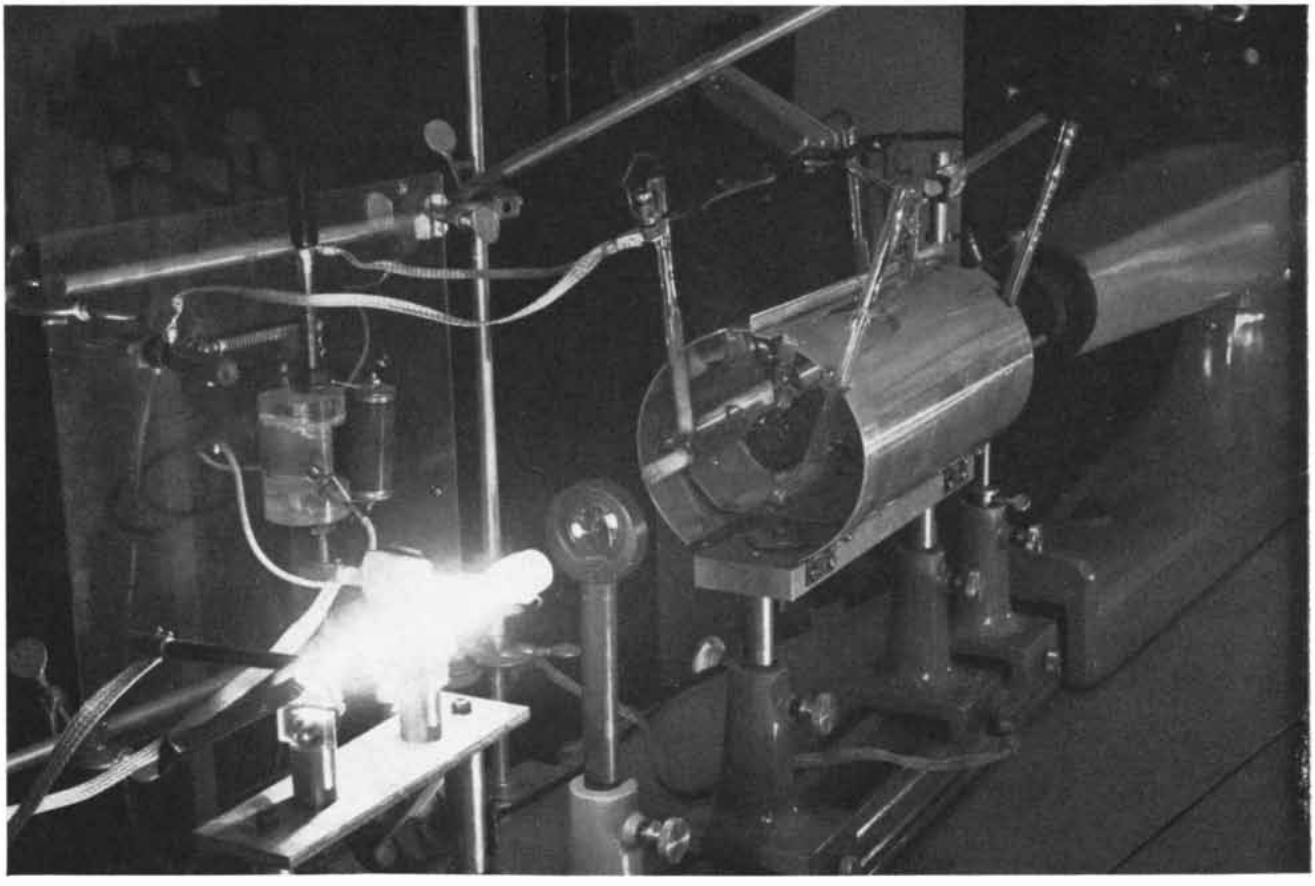




INTENSE FLASH OF LIGHT visible in top photograph sets off photochemical reactions in a quartz irradiation cell. After a brief interval a monitoring flash (*bottom photograph*) directs a beam of light through the cell to the spectrograph at upper right, where the products of the reaction can be identified. Some of these substances have a lifetime of less than a millionth of a second.

FLASH PHOTOLYSIS

With this new method investigators have been able to observe directly many of the short-lived, unstable substances that play a key role in photochemistry and other fast chemical processes

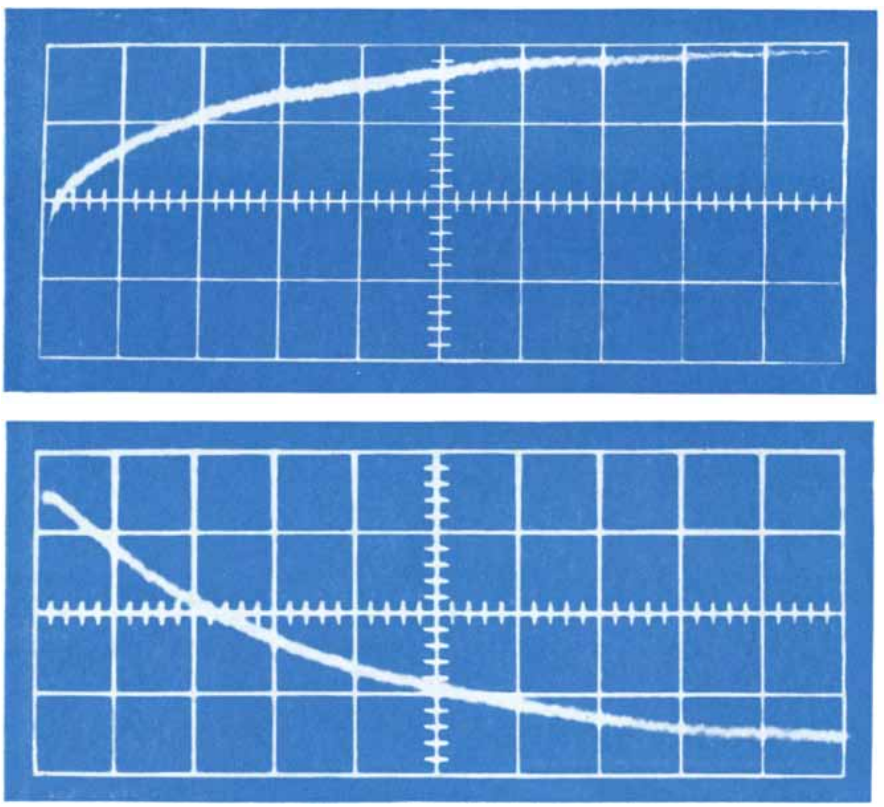
by Leonard I. Grossweiner

Visible light induces a wide variety of chemical changes, from the blackening of photographic film to photosynthesis. In trying to follow the course of such reactions the chemist has been frustrated by their extreme rapidity. Traditionally the experimenter attacked the problem by exposing a photosensitive mixture to a steady source of light and attempting to analyze the intermediate products as they formed. It became clear, however, that he was usually coming late to the show. The first substances he could catch were obviously several steps removed from the initial materials. To fill in these steps it was necessary to resort to theory to postulate a series of fast reactions between intermediates too fleeting to identify by conventional analysis.

Recently a new technique called flash photolysis has begun to fill in the gap. Instead of a steady light source it employs a brief, strong flash to start the reaction. Then, after a very short interval, the mixture is analyzed spectroscopically by a fainter burst of light. In this way intermediate products with a lifetime of only a few millionths of a second have been positively identified. Flash photolysis has already revealed the details of important chemical processes in areas ranging from inorganic chemistry to biology. The technique promises to contribute substantially to many branches of high-speed chemistry.

A photochemical reaction begins with the absorption of energy in the form of discrete packets, or photons, by molecules of the reacting substances. What happens next depends on the strength of the chemical bonds within the molecules and on the energy of the photons. The latter depends in turn on the wavelength of the light; the shorter the wavelength, the higher the energy of the photons. Thus visible light can split an iodine molecule (I_2) into two iodine atoms, but the disruption of an oxygen molecule (O_2) requires the shorter-wavelength ultraviolet radiation.

A normal chemical bond consists of a pair of electrons, one from each of the bonded atoms. Like all electrons, they are spinning and hence are magnetized. In a stable molecule the spins of the two electrons are in opposite directions, thus canceling the magnetic effect. This is the arrangement preferred by nature because it has the minimum of energy. Being unmagnetized, the molecule is unaffected by external magnetic fields, which has led spectroscopists to name it a sing-



OSCILLOSCOPE TRACES show changes in light transmission at a given wavelength which plot the growth and decline of transitory substances produced by photolysis. Transmission increases with downward direction of vertical scale. Each unit on horizontal scale represents .02 second. These traces show the effects of green (*top*) and red (*bottom*) flashes of light on color centers in a crystal of potassium chloride. In both cases a sharp change, which is too fast to leave a trace, is followed by a relatively slow return to the original value.

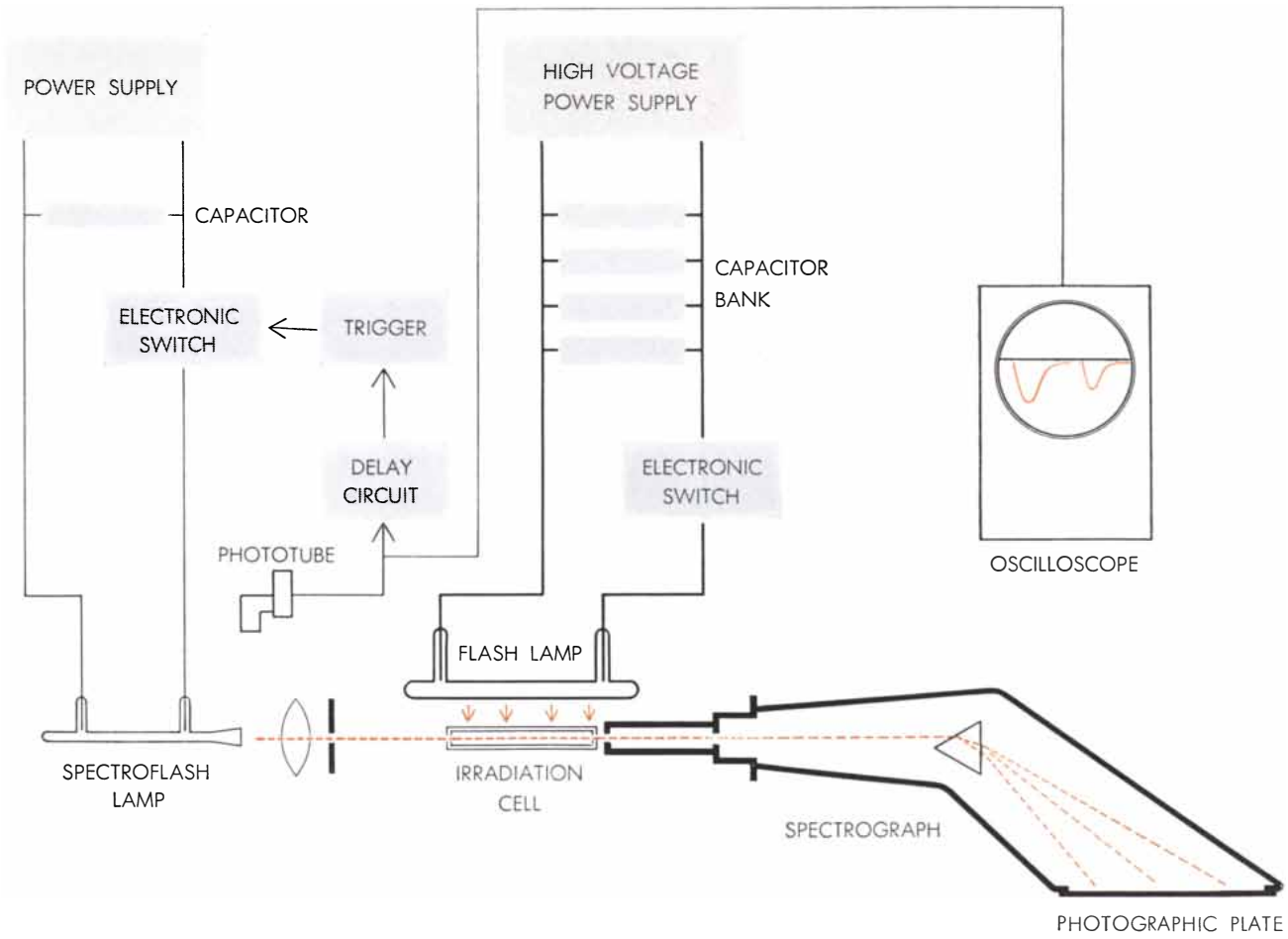
let. (A magnetized atom or molecule can assume different orientations with respect to an external field. These orientations differ in energy and give rise to split lines in the spectrum. An unmagnetized molecule can have only a single energy and therefore only single lines.)

When a chemical bond is disrupted by absorbing a light quantum, the molecule splits into two fragments, each with an unpaired electron. These fragments, known as free radicals, are intensely reactive because of the high energy stored in the odd electron. When they do react, the electron again pairs off with one of opposite spin, and the energy is released. Even in small numbers free radicals can set off large-scale chemical changes through their capacity to initiate chain reactions. A free radical reacts with a stable molecule, liberating another free radical, which reacts with another stable molecule, and so on [see "Free Radicals," by Paul D. Bartlett; SCIENTIFIC AMERICAN, December, 1953].

If the absorbed light-quantum does not have enough energy to break a chemical bond, it raises an electron of the molecule to a higher energy-level, producing an "excited" singlet. In this form the singlet may react with another molecule, but it generally does not have the chance, because it loses its excess energy very quickly—within a hundred millionth of a second—by emitting light or heat. Sometimes, however, it decays in a different way. Part of its excess energy reverses the spin of one of the electrons, so that now two of them are unpaired [*see illustration on opposite page*]. Such a molecular arrangement has three possible orientations with respect to an external magnetic field, and is therefore called a triplet.

The process, known as internal conversion, is fairly common in molecules containing heavy atoms. The resulting triplets, which constitute another species of free radical, still have some extra energy. If left to themselves, they will eventually give it up by radiation, but this happens much more slowly than in the case of singlets; some isolated triplets can endure for a second or more. Therefore they often have time to react with other molecules, losing their energy in this way.

Only by identifying these early products of photochemical reactions can we explain the succeeding steps, which proceed by the thermal, or "dark," reactions of ordinary chemistry. Unfortunately, as has been mentioned, excited molecules and free radicals are present so briefly and in such small quantities that they elude conventional methods of detection. In some cases they can be caught by dissolving the reacting substances in viscous solvents at low temperatures and freezing in the unstable products. But this technique yields little information about normal room-temperature reactions. The same objections apply to a related method in which free radicals



FLASH PHOTOLYSIS APPARATUS shown in the photographs on page 134 is depicted here schematically. The capacitor bank, with a power output of up to 100 million watts, produces a violent burst of light (*colored arrows*) which liberates short-lived products. The spectroflash lamp, triggered by the main flash, sends a beam of light (*broken colored line*) through the irradiation chamber to the spectroscope. In some experiments this lamp is replaced by a continuous light, and the photographic plate by a photocell.

are trapped in solid form on a surface chilled by liquid nitrogen [see "Frozen Free Radicals," by Charles M. Herzfeld and Arnold M. Bass; SCIENTIFIC AMERICAN, March, 1957].

Flash photolysis solves the problem in a different way. By using light of extremely high intensity it produces excitation products in quantities sufficient for detection by ordinary spectroscopy. And by operating with very short flashes it detects them before they disappear.

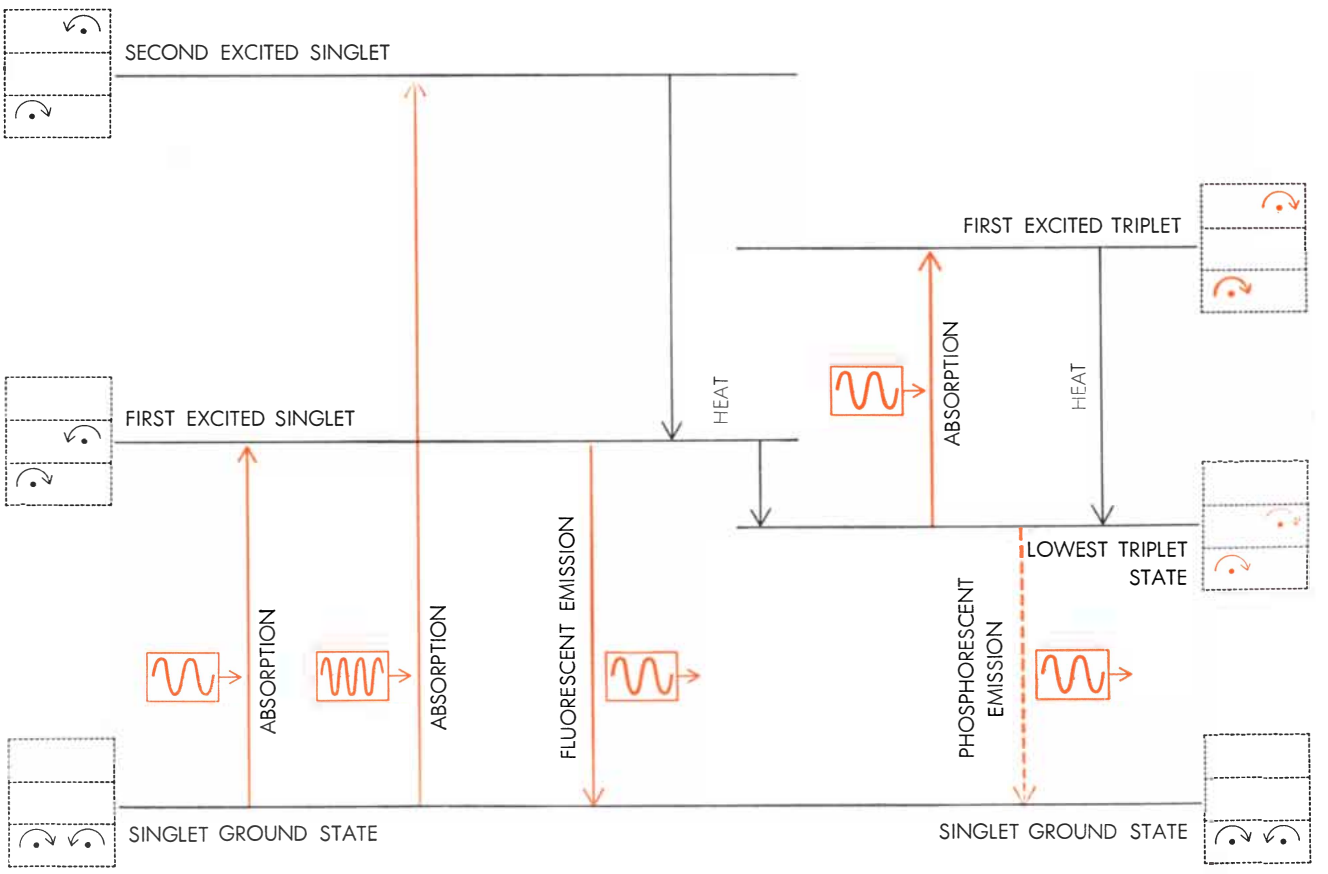
The initial burst of radiation is delivered by lamps that are essentially large-scale models of the familiar photographic stroboscopic-flash lamp. Their heavy metal electrodes, set within a fused quartz jacket filled with xenon or some other inert gas, are excited by a bank of capacitors that delivers an electrical pulse at 5,000 to 25,000 volts. Discharging in a few hundred thousandths of a second, they deliver power at rates as high as a billion watts!

Synchronized with the big lamp, and set to fire after a short predetermined interval, is a much weaker auxiliary flash lamp that sends a light beam through the reaction vessel. The beam then passes into a spectrograph that records the absorption spectrum of the mixture [*see opposite page*].

A series of such snapshots not only identifies the reaction products but also shows the rate at which they appear and disappear. Once the constituents have been determined, each one can be traced more accurately by replacing the second flash lamp with a small continuous lamp, and the photographic plate with a photoelectric tube, set to receive a particular wavelength. In this way the absorption due to one of the constituents is monitored continuously. The signal from the phototube is fed to an oscilloscope, where it produces a graph showing the growth and disappearance of the substance [*see illustration on page 135*]. The method is quite sensitive; it easily detects changes in light transmission as small as one part in 10,000.

Flash photolysis was devised in 1949 by George Porter and R. G. W. Norrish at the University of Cambridge. They and Gerhard Herzberg and D. A. Ramsay at the National Research Council of Canada proceeded to apply it to research on free radicals. They soon identified a number of small ones, such as ClO, SO, NH_2, PH_2 and CH_3, whose existence had previously been suspected from indirect evidence. Now the chemistry of these substances could be worked out in detail.

Porter and his co-workers then went on to investigate a group of more complex free radicals deriving from simple "aromatic" compounds, which consist of the six-carbon benzene ring (C_6H_5) plus an attached side-chain. After flash photolysis all these substances yielded the same transient spectrum, identified as that of the benzyl radical (C_6H_5

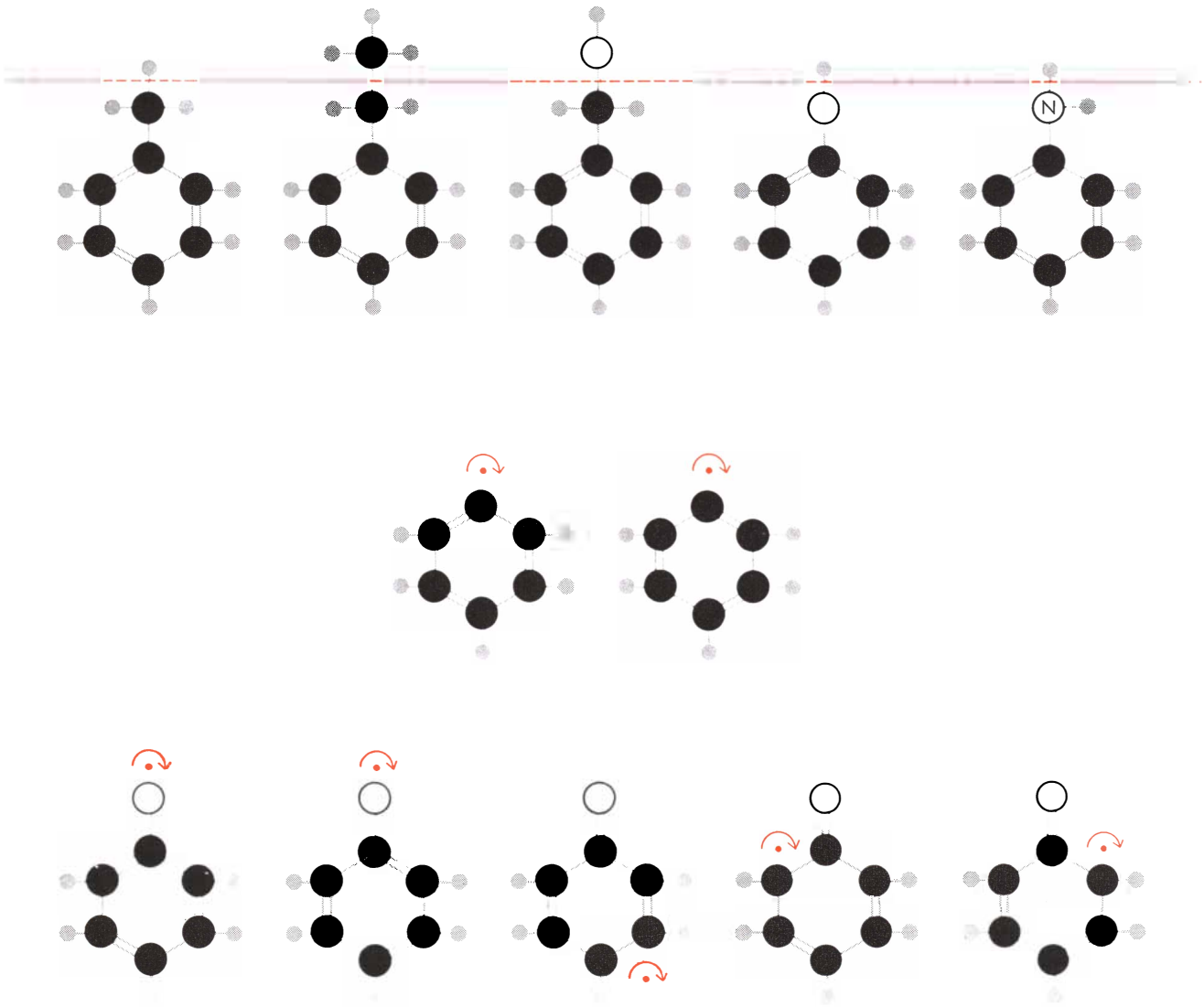


PHOTOEXCITATION PROCESSES shown here are the first steps in many photochemical reactions. Straight colored arrows indicate processes in which photons (*colored waves*) are absorbed or emitted; straight black arrows, those involving heat emission. A singlet molecule, in which electrons of opposite spin (*black curved arrows*) are paired, rapidly returns to the ground state. Sometimes, however, it changes to a triplet molecule with two unpaired electrons (*colored curved arrows*), which then decays more slowly.

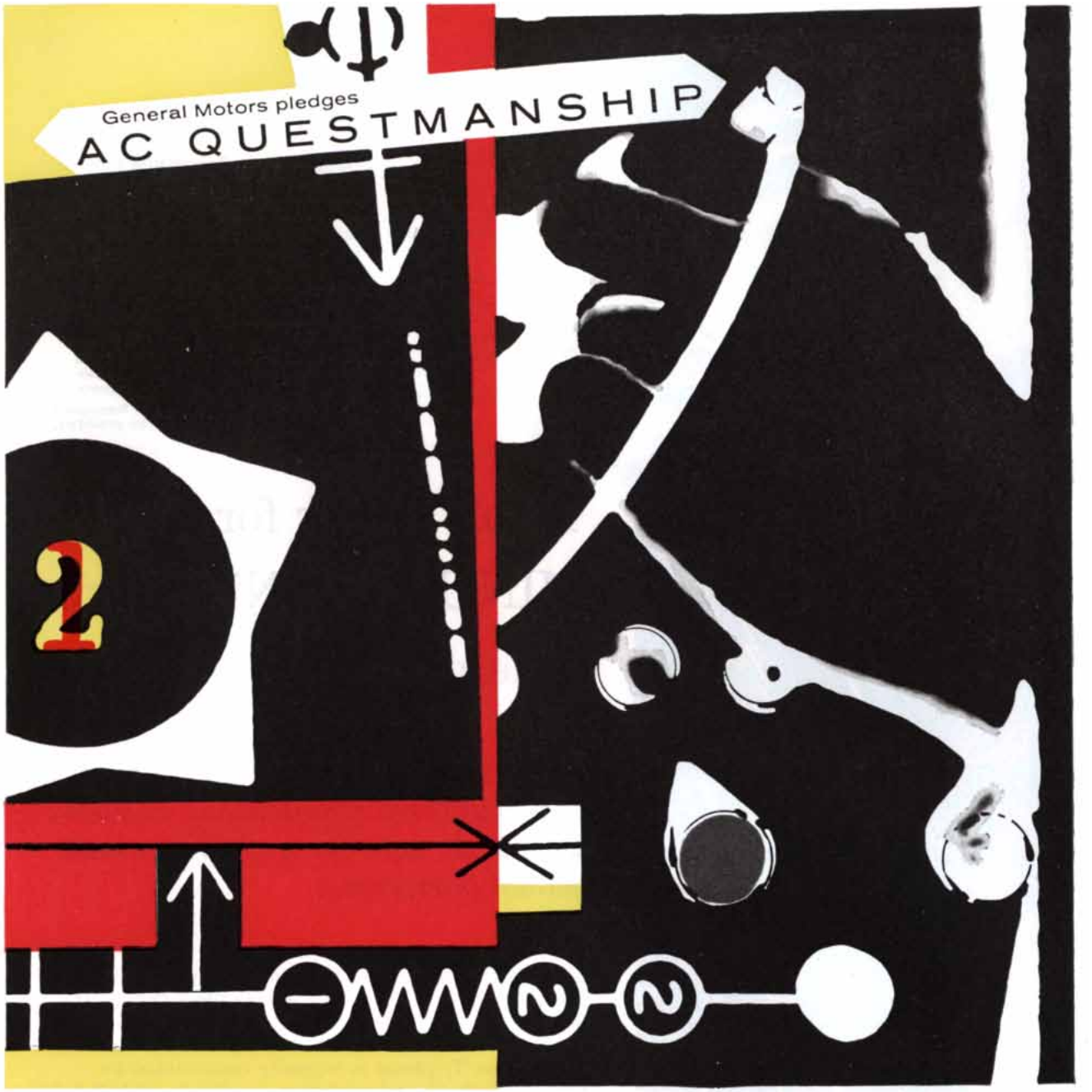
CH_2). In each case the irradiation detached only part of the side chain, leaving a single carbon atom. Similar results were obtained with related compounds. Almost invariably a single atom of carbon, oxygen or nitrogen remained attached to the ring. These results confirm a prediction of the resonance theory of chemical bonds, which says that the single and double bonds of an aromatic compound oscillate between different arrangements of equal energy. By itself the benzene ring has two such patterns, whereas a benzyl or similar free radical has no less than five [*see illustration below*]. Hence it is a more likely product of molecular disruption than is the bare ring.

At the Argonne National Laboratory we extended this work to more complex substances such as proteins. When we irradiated the protein ovalbumin, we found that its transient spectrum was a combination of the spectra of two of its constituents: the aromatic amino acids tyrosine and tryptophan. This suggested that the action of light in decomposing the giant molecule could be understood in terms of its action on the two amino acids.

On further investigation we found that tryptophan, though considerably more complex than the aromatic substances studied by Porter, decomposes in much the same manner: by a break in the side chain. Strangely, however, tyrosine, with a structure much closer to that of the simple aromatics, behaves quite differently. Properly speaking it does not



SIMPLE AROMATIC COMPOUNDS shown at top are decomposed by light (*broken colored line*) into free radicals consisting of the hexagonal phenyl group plus a one-link side chain, rather than the phenyl radical alone. The latter is less "probable" because its bonds can assume only two configurations (*middle*). Addition of the side chain, as in the phenoxy radical (*bottom*), provides another bonding site and thus makes possible five different arrangements of the bonds. The dots in color represent unpaired electrons.



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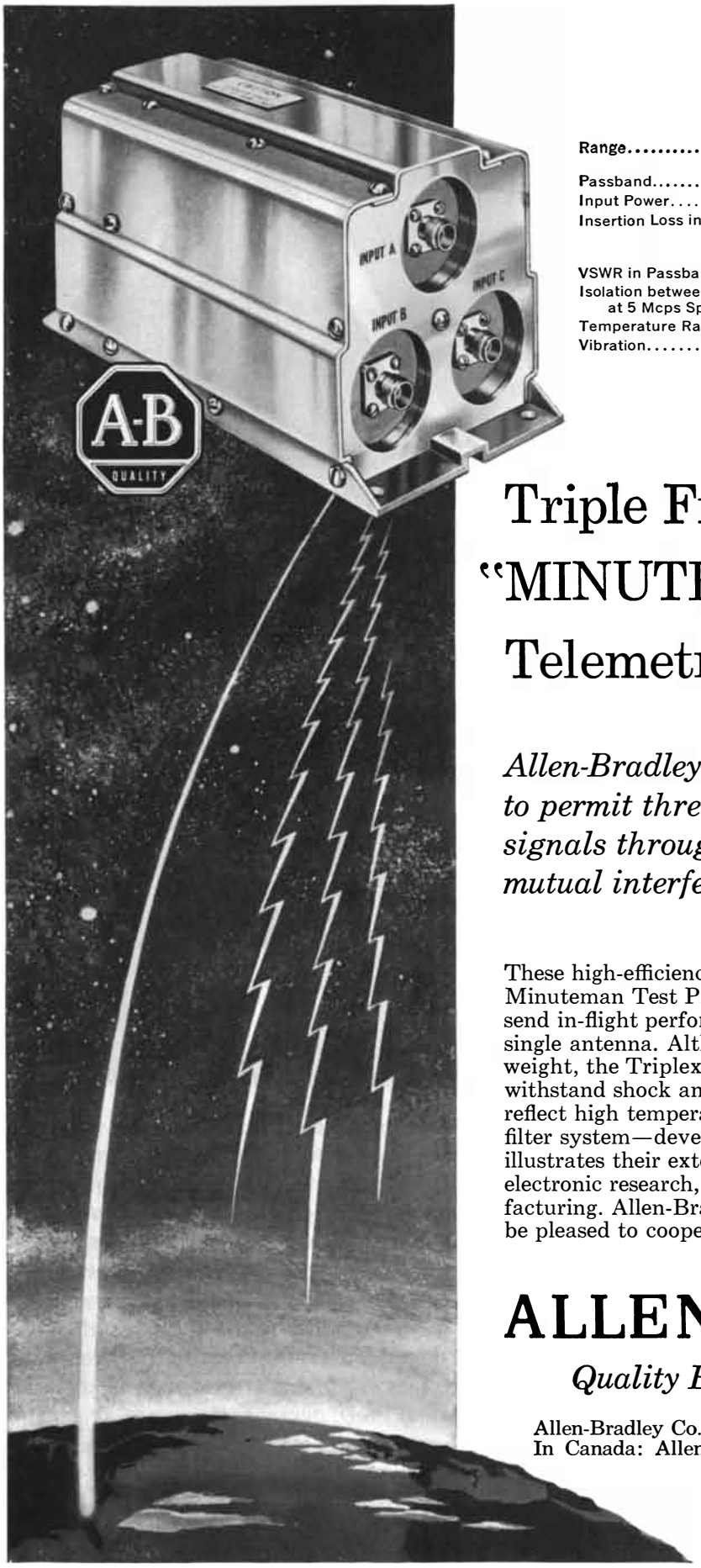

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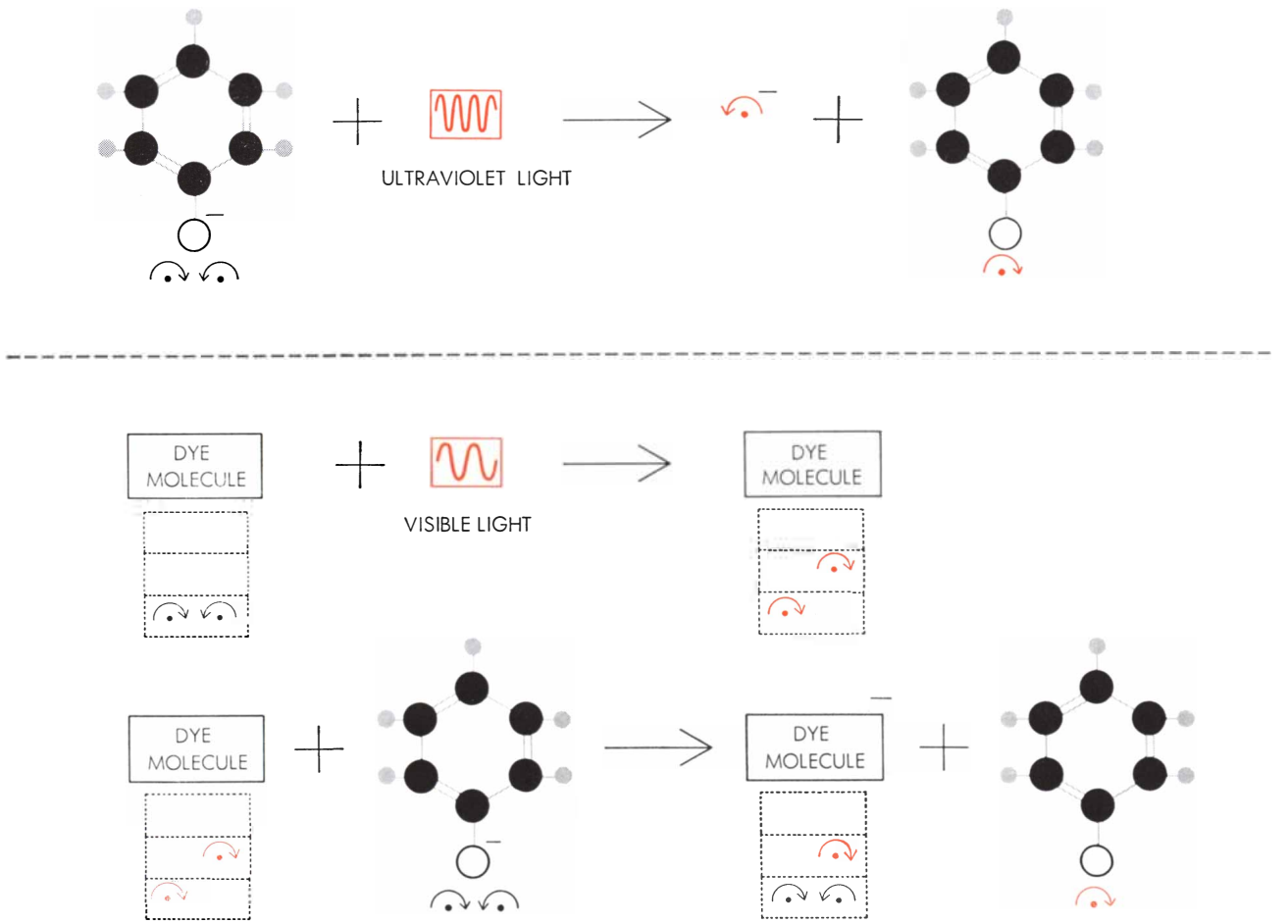
break down at all, but instead ejects an electron to become a positively charged free radical. This process is exceedingly rare in photochemistry, usually requiring energies higher than those provided by light.

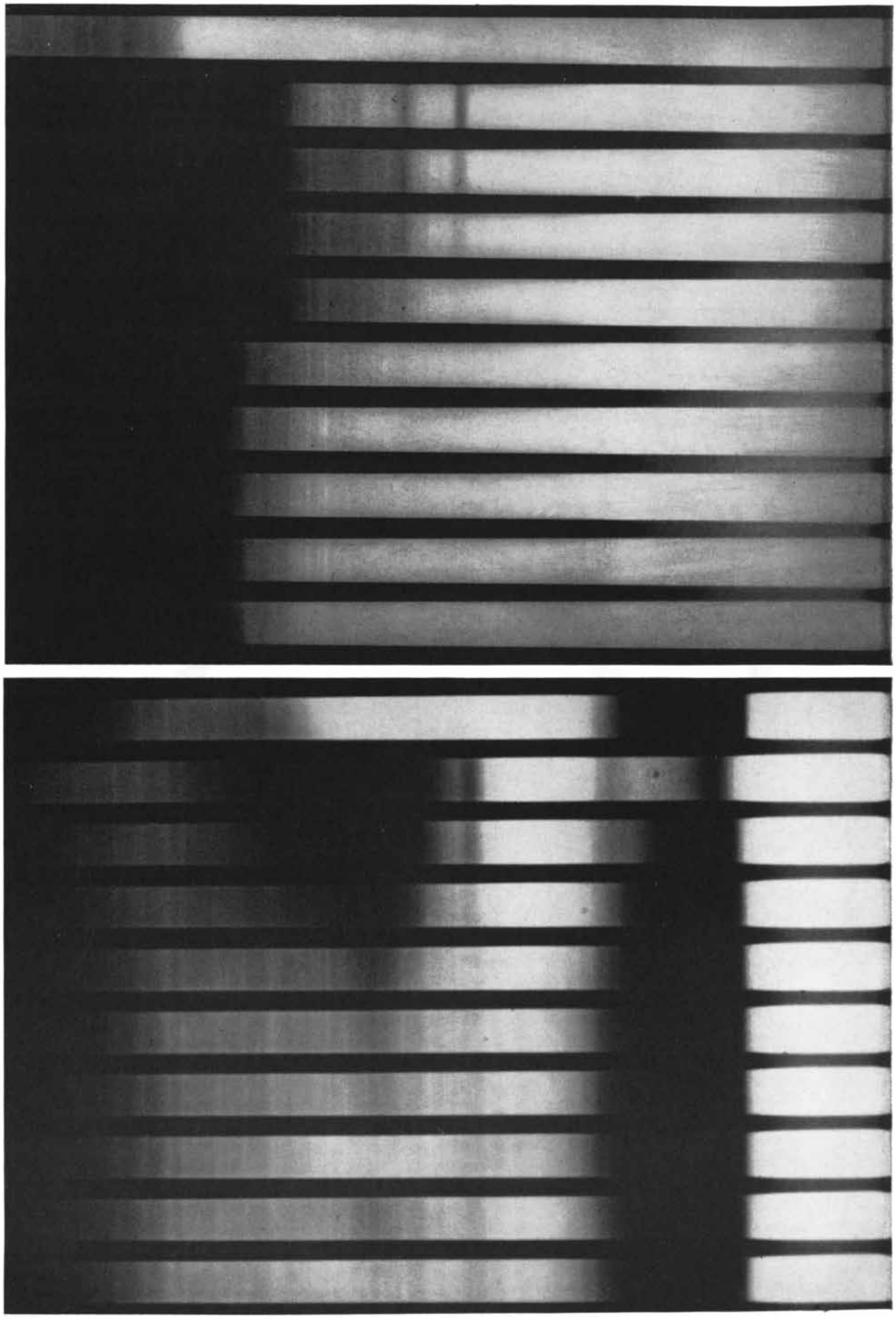
Thus flash photolysis makes it possible to break down complicated reactions into simpler components. It has also demonstrated that some apparently simple reactions are more complicated than they seem. Consider the decomposition of molecular iodine (I_2). Flash irradiation of this brownish substance produces a jump in light transmission due to the formation of colorless iodine atoms (I). After the flash the transmission returns to normal as the atoms recombine. For iodine in solution the rate of recombination agrees well with that calculated on the simple assumption that pairs of iodine atoms react when they collide. For gaseous iodine, however, the rate of recombination is slower. It turns out that two iodine atoms cannot recombine unless a third body is present to carry away the energy released. In a solution the molecules of the solvent are readily available for this purpose, and recombination takes place on almost every collision of two iodine atoms. In gaseous iodine the presence of a third body at the time of collision is a much rarer event, and so the process develops more slowly.

Further measurements indicate that even this three-body model does not tell the whole story, because the rate of recombination accelerates as the concentration of iodine molecules increases. In fact, these molecules are about 1,000 times more efficient than are molecules of other gases in promoting the reaction. Recent experiments by Norman Davidson at the California Institute of Technology indicate that they operate through a succession of two-body collisions rather than through the rarer three-body events. An I_2 molecule collides with an I atom and forms a fairly stable molecule of I_3. This in turn hits another I atom, forming a pair of I_2 molecules. The existence of the I_3 form was predicted nearly 30 years ago, but has only now been confirmed.

The chemical behavior of excited molecules parallels that of free radicals in many respects. Flash photolysis enables us to distinguish the two species spectroscopically. Excited singlets usually disappear too quickly to be detected; the excited molecules thus far observed are assumed to be in the longer-lived triplet state. Early work at the University of Cambridge showed that complex aromatic molecules containing two or more rings are particularly likely to form triplets. The first direct measurements of triplet lifetimes were made on anthracene, a three-benzene-ring coal-tar derivative. In very pure solutions the triplets disappear relatively slowly by emitting light or heat. Even small amounts of impurities drastically shorten



"PHOTOSENSITIZATION" BY DYES is typified by the processes diagrammed here. Ultraviolet light, but not visible light, converts phenol ion into the phenoxy free radical plus an electron (*top*). The addition of certain dyes sensitizes the mixture to visible light, which can then produce the phenoxy radical by a two-step process (*bottom*). The light converts the dye molecule to the triplet state; the triplet thereupon reacts with the phenol ion by taking up an electron from it and thus converting it into a phenoxy radical.



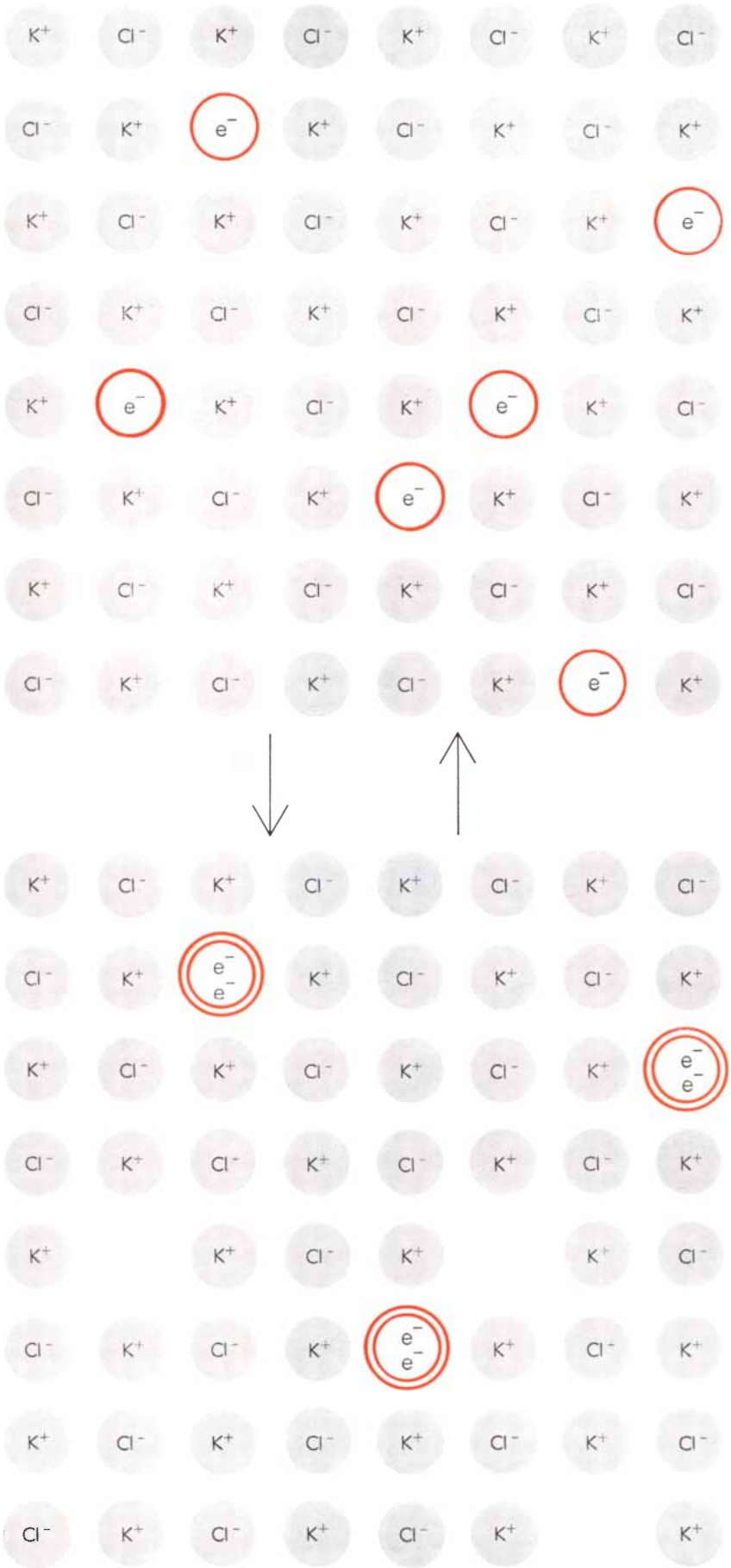
their lifetimes by reacting with them.

Sometimes triplets transfer their excess energy to other molecules without combining with them. These energized materials then proceed to react with still other molecules. Here the triplet acts as a catalyst, and the reaction that finally takes place is said to be photosensitized. Such processes are useful in a number of technological applications. For example, the emulsion of black-and-white photographic film responds chiefly to the blue and green light that strikes it. By adding dyes which absorb red and yellow light, and which then transfer the light's energy to the emulsion, the response of the film can be extended over the entire visible spectrum.

The most important of all photochemical reactions is photosynthesis, in which the green pigment chlorophyll absorbs light energy and catalyzes the transformation of water and carbon dioxide into carbohydrate. This transformation requires about three times as much energy as is provided by each light quantum absorbed. One of the major unsolved problems of photosynthesis is how and where energy is stored up until it accumulates in sufficient quantity to activate the synthesis. Flash photolysis has not yet succeeded in answering the question, but it has given a glimpse of the first step. Robert Livingston of the University of Minnesota has discovered that when chlorophyll absorbs light, it is converted to a triplet state that lasts for about a thousandth of a second. Where the triplet then deposits its energy is still unknown.

Another problem, less fundamental but of considerable commercial impor-

SPECTROGRAMS show the decomposition of ionic phenol by ultraviolet and by visible light. Phenol alone (*top spectrum of top group*) absorbs only ultraviolet light. The next spectrum shows the narrow absorption bands of a phenol radical measured a hundred thousandth of a second after irradiation. Successive spectra show its gradual disappearance. The broad dark band at the far left indicates some permanent decomposition. With the addition of the dye eosin the solution absorbs a broad region of visible light (*top spectrum of bottom group*). The next spectrum, made after a hundred thousandth of a second, shows simultaneously a bleaching of the dye, the bands of the phenol radiation and a broad absorption band due to the bleached dye. Later spectra show a return to the original condition. Both processes are diagrammed on page 141.



tance, that is being studied by flash photolysis is the light-fading of dyes. N. K. Bridge and his associates at the British Rayon Research Association have studied this complex process in the widely used anthraquinone dyes. In their first experiments they examined a more elementary system consisting of simple quinones in organic solvents. Flash photolysis bleaches the solutions temporarily, forming free radicals.

These workers next discovered that the quinones that yield large amounts of relatively stable free radicals act as photosensitizers in such reactions as the oxidation of ethyl alcohol. The anthraquinone dyes with the poorest resistance to light also catalyze the oxidation reaction; on photolysis they yield free radicals resembling those of the simple quinones. These results are beginning to show what type of molecule is most sensitive to fading, and to suggest the changes that can produce light-fast colors.

An interesting solid-state phenomenon that my colleagues and I have recently looked into is the "color centers" in crystals. When a crystal of potassium chloride, for example, is subjected to X-rays, it turns a deep purple. The color comes from so-called F-centers—sites in the crystal where a negative ion has been replaced by an electron [*see illustration at left*]. Exposing a colored crystal to a flash of visible light bleaches the crystal by emptying some of the F-centers and transferring their electrons to others, which contain two electrons and are known as F′-centers. The material now slowly returns to its former equilibrium state. Our experiments have clarified some of the details of these electronic shifts.

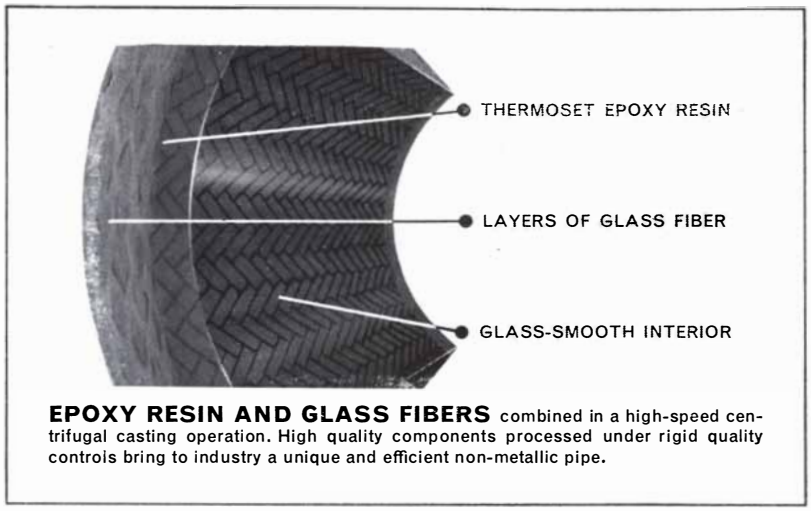
Examples could be multiplied almost indefinitely, but we shall consider just one more: the investigation of an old discovery that has been exploited for years without being understood. This is the action of tetraethyl lead in preventing gasoline-engine knock. At the Uni-

"COLOR CENTERS" in a crystal of potassium chloride are altered by light of different colors. A crystal irradiated with X-rays turns purple because of the formation of "F-centers," where electrons occupy positions in the crystal lattice normally filled by chloride ions (*top*). A flash of green light converts these centers to F′-centers, containing two electrons (*bottom*); a flash of red light reverses the process.

versity of Cambridge, Norrish and K. H. L. Ehard used acetylene as a simple model of the complex collection of hydrocarbons in gasoline. They mixed it with oxygen and added a small amount of the compound pentyl nitrite as a photosensitizer. A bright flash ignited the mixture, which, after 20 millionths of a second, gave out a series of intense bursts of light. These were caused by the impact of shock waves on the walls of the container. The waves demonstrated that the fuel was not burning evenly but was undergoing the explosive detonations responsible for knock. Adding tetraethyl lead lengthened the interval between flash and detonation and weakened the detonation itself. Examining the mixture spectroscopically, the investigators found that tetraethyl lead delays the appearance of the hydroxyl (OH) free radical, one of the chief initiators of the explosive chain reaction. It does so by capturing the oxygen that would otherwise form OH. As lead oxide it then reacts with other radicals, slowing combustion still further.

The basic techniques of flash photolysis are also finding related applications. L. S. Nelson and his associates at Bell Telephone Laboratories have decomposed solid materials by irradiating them with especially intense flashes. A clear piece of polyethylene plastic thus treated explodes with a loud report. The effect is due to small particles of impurities which the flash rapidly heats to about 2,000 degrees centigrade. In other experiments light flashes have vaporized tungsten lamp filaments and carbonized mineral oil. This technique is a promising means of studying thermal decomposition, since it requires only about a thousandth of a second to achieve high temperatures, as compared to several seconds with ordinary methods.

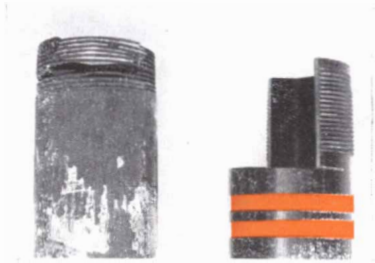
Perhaps the most serious limitation of flash photolysis is that the initial flash lasts longer than the lifetime of the excited singlet state, and therefore blots it out. It now appears that the difficulty is only temporary. Eugene Rabinowitch and S. Steven Brody at the University of Illinois have developed a lamp whose flash lasts only a billionth of a second. With it they have measured excited singlet lifetimes in chlorophyll and in several dyes. In its present version the lamp is too weak for most photochemical experiments, but it will no doubt be improved. We can safely predict that this and other developments will make possible the study of the very fastest chemical reactions.



EPOXY RESIN AND GLASS FIBERS combined in a high-speed centrifugal casting operation. High quality components processed under rigid quality controls bring to industry a unique and efficient non-metallic pipe.

"Impossible" corrosion, temperature and pressure problems solved by Fibercast® epoxy pipe

- Operating temperature range wider than any non-metallic pipe (–65° to 300° F.)
- Operating pressure range extends to 1000 psi.
- Effectively combats corrosion, contamination, abrasion, scaling, electrolytic action.



Fibercast Tubing (right) used to suspend a 1,200 lb. pump for 3 years in a salt water supply well. *There was no loss in strength.* The damaged plastic-coated steel nipple (left) was used in the same installation, failed after 3 months' service.

WHAT is Fibercast?

It is a centrifugally cast, thermoset, epoxy resin reinforced pipe that handles temperature and pressure problems where no other non-metallic pipe will do.

Its body of woven glass fibers provides resistance to high tension forces. These fibers, combined by adhesion, are imbedded and bonded by heat in epoxy resin. The result is a strong, long-lasting pipe with remarkable ability to withstand high pressure and temperature in corrosive environments.

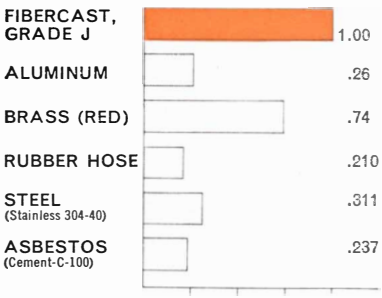
WHY use Fibercast?

For a multitude of reasons. Because its advantages range from superior resistance to heat, pressure and corrosion, to its ease of handling, light weight, dielectric properties and structural stability. Because Fibercast's long service life alone would justify choosing it over other materials. Because even more expensive metal pipe or pipe with thermo-plastic interior coatings cannot match Fibercast's proven durability. Case histories and accurate testing have proved over and over that Fibercast performs better, lasts longer, costs less. Out of 338 common corrosive solutions, Fibercast competently handles 320. And naturally, Fibercast's unique and lasting qualities under such conditions mean that it drastically reduces maintenance and replacement costs, too.

Although Fibercast's light weight makes it correspondingly easy to work with (it is less than 25% the weight of steel), it has the same basic linear coefficient of expansion as steel (7.06 x 10^{-6} to 8.25 x 10^{-6} in./in./°F.). Fibercast's strength permits installation on pipe racks with span lengths generally used for metal pipe.

The pipe has a smooth interior, with a Hazen-Williams C Flow Factor of 147. This cuts friction losses, aids flow and tends to resist build-up. It is a non-conductor (accepted by the electrical industry as a superior insulator), and is not subject to cold flow. A low coefficient of heat transfer (3.0 x 10-3 Cal/CM² /sec/CM°C.),

COMPARATIVE LIFE DATA*



**Basing Fibercast as unit life of 1 and others as comparative percentages thereof.*

minimizes heat loss and may even eliminate heat tracing.

All three major systems of joining all pipe are used with equal success on Fibercast. They are: standard flanged, cemented, and threaded and coupled with a complete selection of Fibercast fittings (the world's largest line of corrosion-resistant epoxy pipe fittings).

Safety, too, is an important reason for using Fibercast Pipe in transporting dangerous chemicals, particularly in areas where the pipe is adjacent to personnel. Most piping materials corrode undetectably from inside-to-out and can suddenly burst without warning, inflicting injury to personnel. Because of Fibercast's woven glass fiber construction, such occurrences, if they ever occur, *are* detectable in minute, repairable leaks.

WHO uses Fibercast?

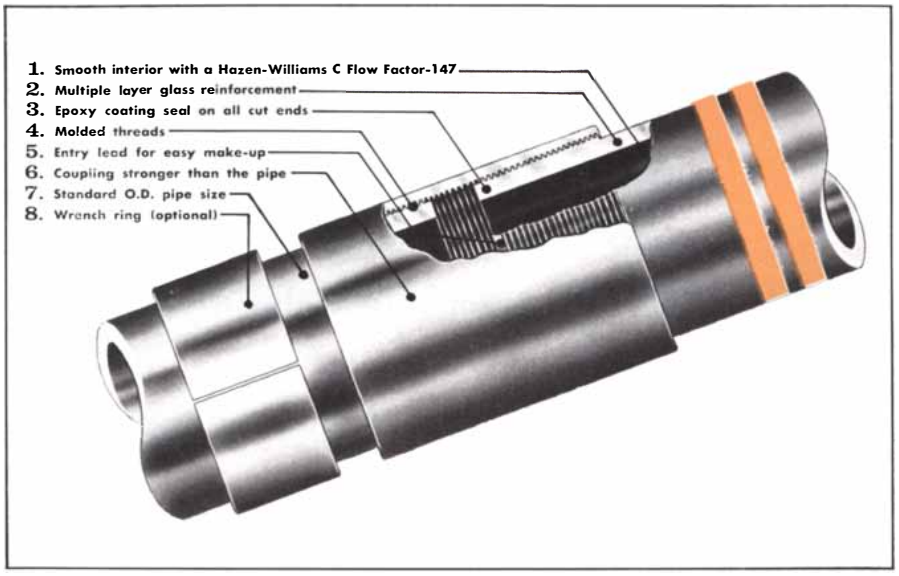
The petroleum industry . . . chemical . . . petro-chemical . . . nuclear energy . . . textile . . . paper . . . and food-processing industries . . . countless operations handling acids, alkalies, salt water and other corrosive liquids under pressure can all use Fibercast profitably.

In oil country, Fibercast is already

Workman is painting a section of Fibercast Pipe bearing 32% HCl at Shell's Texas Chemical plant. Note that Fibercast has sufficient strength for installation on span racks with the spacing normally used for metal pipes.

widely acclaimed for superior performance in rugged, abusive and even high pressure installations like salt water disposal wells and horizontal lines. In cases where other pipe and tubing required replacement after just a few weeks of service, Fibercast is still performing efficiently after many years.

In petro-chemical and chemical-processing plants, Fibercast is valued



8 Points of Fibercast Superiority

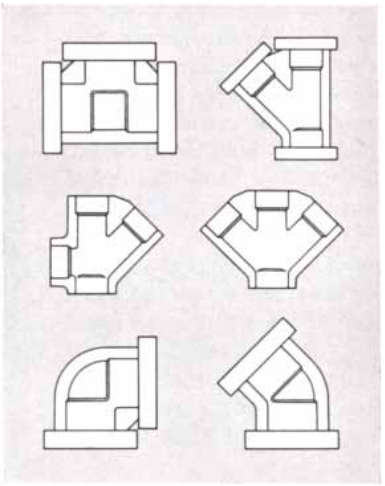
not only for high heat and corrosion resistance, but also for its remarkable maintenance of the purity of the solutions it is required to carry. Such installations range from Fibercast pipes which carry 37% hydrochloric acid at ambient temperatures to lines carrying solutions containing brine, alum, and other sulphates, sulphuric and phosphoric acids, and other damaging chemicals.

Food-processing industries, among the most demanding of all industries in purity, corrosion and heat standards of operation, know the long-term benefits of using Fibercast. Fibercast is especially effective in the processing of foods requiring use of sulphuric and phosphoric acids (such as corn syrup, starches, gelatins), as well as brines and other highly corrosive acids and solutions.

The operating conditions peculiar to the man-made textile and paper processing plants are also improved by the use of Fibercast Pipe and Fittings. The ever-growing demands of all industry . . . the rigid quality controls imposed by governmental and other agencies. . . the unique and often unsolved needs of new processes and methods . . . all of these factors help to create "impossible" problems that can be solved by the use of Fibercast.

Complete Line of Fittings

Fibercast provides fittings to solve any fitting problem. Besides a vast stock of standard sizes and types, Fibercast also designs and makes special fittings to meet individual requirements. All, of course, have the same corrosion, pressure and heat resistance properties of Fibercast Pipe and Tubing. A few of the regularly stocked types are shown in the line drawings below



If *you* have an "impossible" corrosion, temperature, or pressure problem, consider the advantages of using Fibercast. To receive a free sample of Fibercast, and to get specific information about how Fibercast can help *you*, mail the coupon below.

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HOW ANIMALS RUN

Many animals, both predators and prey, have evolved the ability to run two or three times faster than a man can. What are the adaptations that make these impressive performances possible?

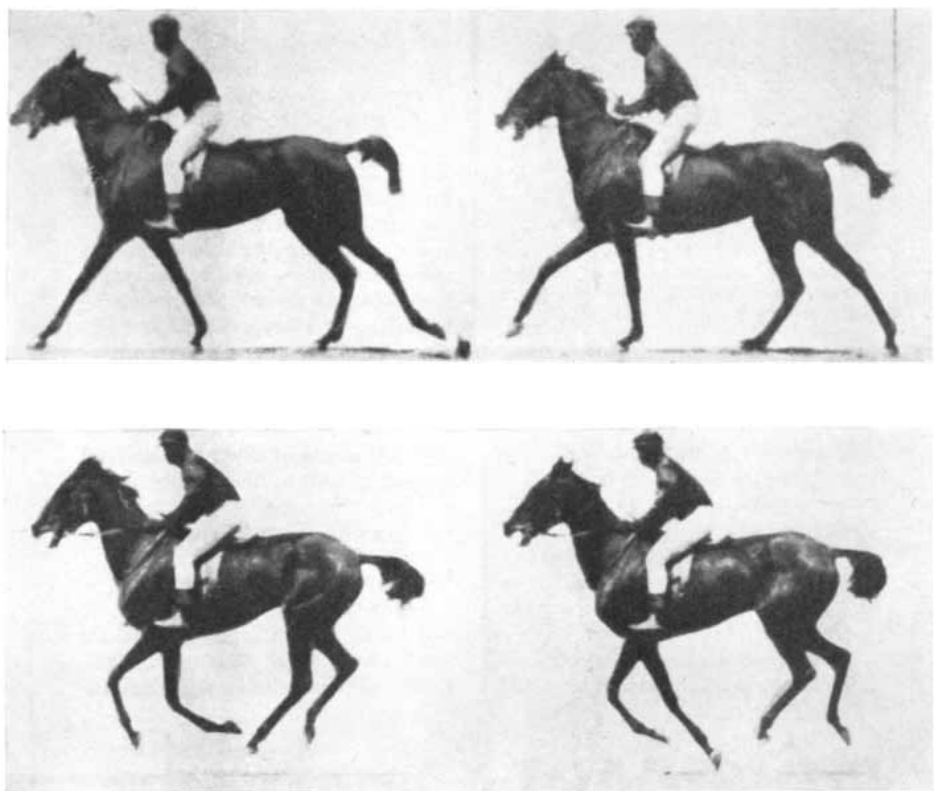
by Milton Hildebrand

A man (but not necessarily you or I!) can run 220 yards at the rate of 22.3 miles per hour, and a mile at 15.1 miles per hour. The cheetah, however, can sprint at an estimated 70 miles per hour. And the horse has been known to maintain a speed of 15 miles per hour not just for one mile but for 35 miles.

Other animals are capable of spectacular demonstrations of speed and endurance. Jack rabbits have been clocked at 40 miles per hour. The Mongolian ass is reported to have run 16 miles at the impressive rate of 30 miles per hour. Antelopes apparently enjoy running beside a moving vehicle; they have been reliably timed at 60 miles per hour. The camel has been known to travel 115 miles in 12 hours. Nearly all carnivorous mammals are good runners: the whippet can run 34 miles per hour; the coyote, 43 miles per hour; the red fox, 45 miles per hour. One red fox, running before hounds, covered 150 miles in a day and a half. A fox terrier rewarded with candy turned a treadmill at the rate of 5,000 feet per hour for 17 hours.

I have been attracted by such performances as these to undertake an investigation of how the living running-machine works. The subject has not been thoroughly explored. One study was undertaken by the American photographer Eadweard Muybridge in 1872. Working before the motion-picture camera was invented, Muybridge set up a battery of still cameras to make photographs in rapid sequence. His pictures are still standard references. A. Brazier Howell's work on speed in mammals and Sir James Gray's studies on posture and movement are well known to zoologists. Many investigators have added to our knowledge of the anatomy of running vertebrates, but the analysis of function has for the most part been limited to deductions from skeletons and muscles. The movements of the running animal are so fast and so complex that they cannot be analyzed by the unaided eye.

In my study I have related comparative anatomy to the analysis of motion pictures of animals in action. The method is simple: Successive frames of the motion picture are projected onto tracing paper, where the movements of the parts of the body with respect to one another and to the ground can be analyzed. The main problem is to get pictures from the side of animals running at top speed over open ground. With an electric camera that exposes 200 frames per second I have succeeded in photographing the movements of a cheetah that had been trained by John Hamlet of Ocala, Fla., to chase a paper bag in an enclosure 65 yards long. However, the animal never demonstrated its top speed, but merely loped along at about 35 miles per hour. I have used the same



STRIDE OF A CANTERING HORSE is shown in these photographs from Eadweard Muybridge's *The Horse in Motion*, published in 1878. The sequence runs right to left across the

camera to make pictures of horses running on race tracks, and I am presently collecting motion-picture sequences of other running animals from commercial and private sources.

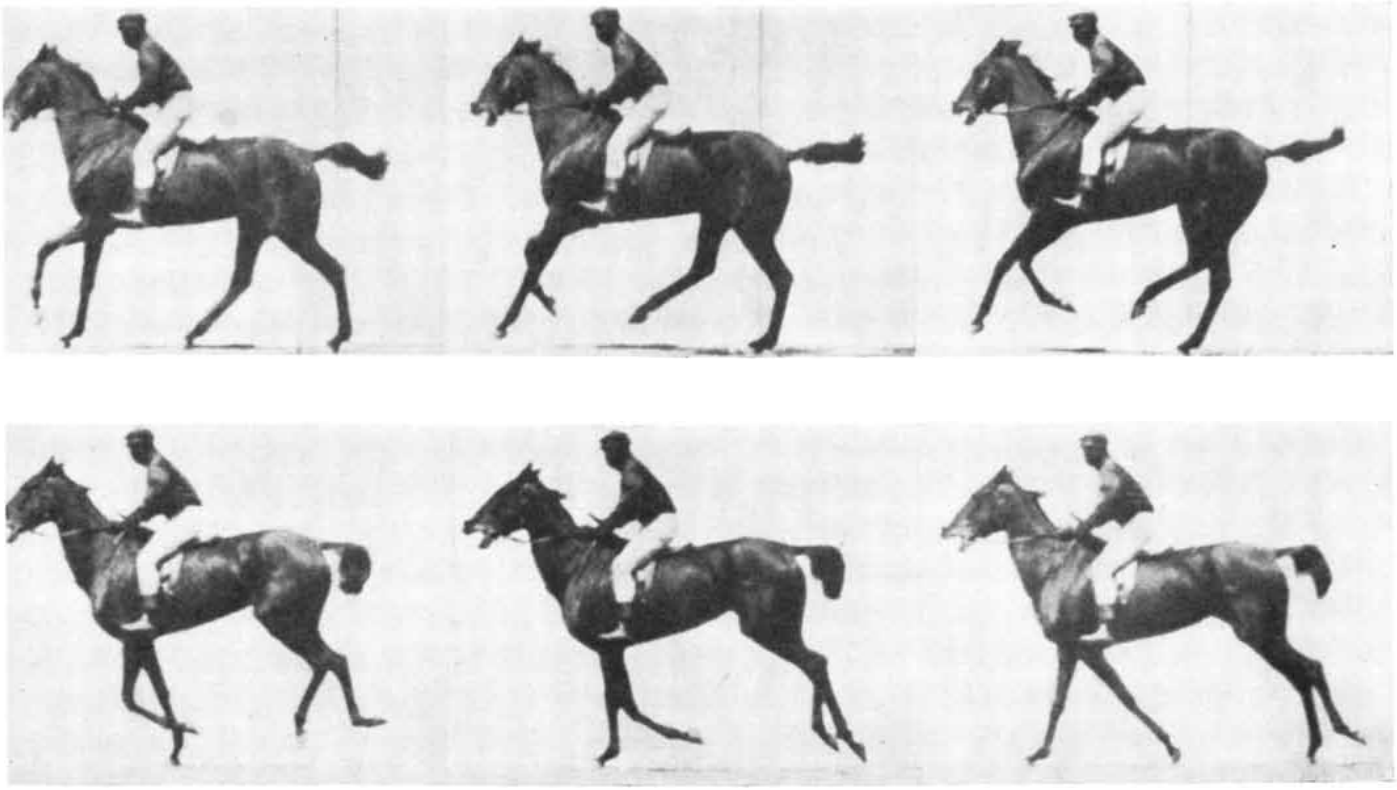
All cursorial animals (those that can run far, fast and easily) have evolved from good walkers, and in doing so have gained important selective advantages. They are able to forage over wide areas. A pack of African hunting dogs, for example, can range over 1,500 square miles; the American mountain lion works a circuit some 100 miles long; individual arctic foxes have on occasion wandered 800 miles. Cursorial animals can seek new sources of food and water when their usual supplies fail. The camel moves from oasis to oasis, and in years of drought the big-game animals of Africa travel impressive distances. The mobility of cursorial animals enables them to overcome seasonal variations in climate or in food supply. Some herds of caribou migrate 1,600 miles each year. According to their habit, the predators among the cursorial animals exploit superior speed, relay tactics, relentless endurance or surprise to overtake their prey. The prey species are commonly as swift as their pursuers, but sometimes they have superior endurance or agility.

Speed and endurance are the capacities that characterize all cursorial vertebrates. But one could not make a definitive list of the cursorial species without deciding quite arbitrarily how fast is fast and how far is far. Even then the list would be incomplete, because there are reliable data on speed for only a few animals; in most cases authors quote authors who cite the guesses of laymen. Many cursors are extinct. On the basis of fossils, however, we can surmise that many dinosaurs were excellent runners; that some extinct rhinoceroses, having had long and slender legs, were very fast; and that certain extinct South American grazing animals, having evolved a horselike form, probably had horselike speed.

In order to run, an animal must overcome the inertia of its body and set it into motion; it must overcome the inertia of its legs with every reversal in the direction of their travel; it must compensate for forces of deceleration, including the action of the ground against its descending feet. A full cycle of motion is called a stride. Speed is the product of length of stride times rate of stride. The giraffe achieves a moderate speed with a long stride and a slow rate of stride; the wart hog matches this speed with a short stride and a rapid rate. High speed requires that long strides be taken at a rapid rate, and endurance requires that speed be sustained with economy of effort.

Although longer legs take longer strides, speed is not increased simply by the enlargement of the animal. A larger animal is likely to have a lower rate of stride. Natural selection produced fast runners by making their legs long in relation to other parts of the body. In cursorial animals the effective length of the leg—the part that contributes to length of stride—is especially enhanced. The segments of the leg that are away from the body (the foot, shank and forearm) are elongated with respect to the segments close to the body (the thigh and upper arm). In this evolutionary lengthening process the bones equivalent to the human palm and instep have become the most elongated.

Man's foot does not contribute to the length of his leg, except when he rises on his toes. The bear, the opossum, the raccoon and most other vertebrates that walk but seldom run have similar plantigrade ("sole-walking") feet. Carnivo-



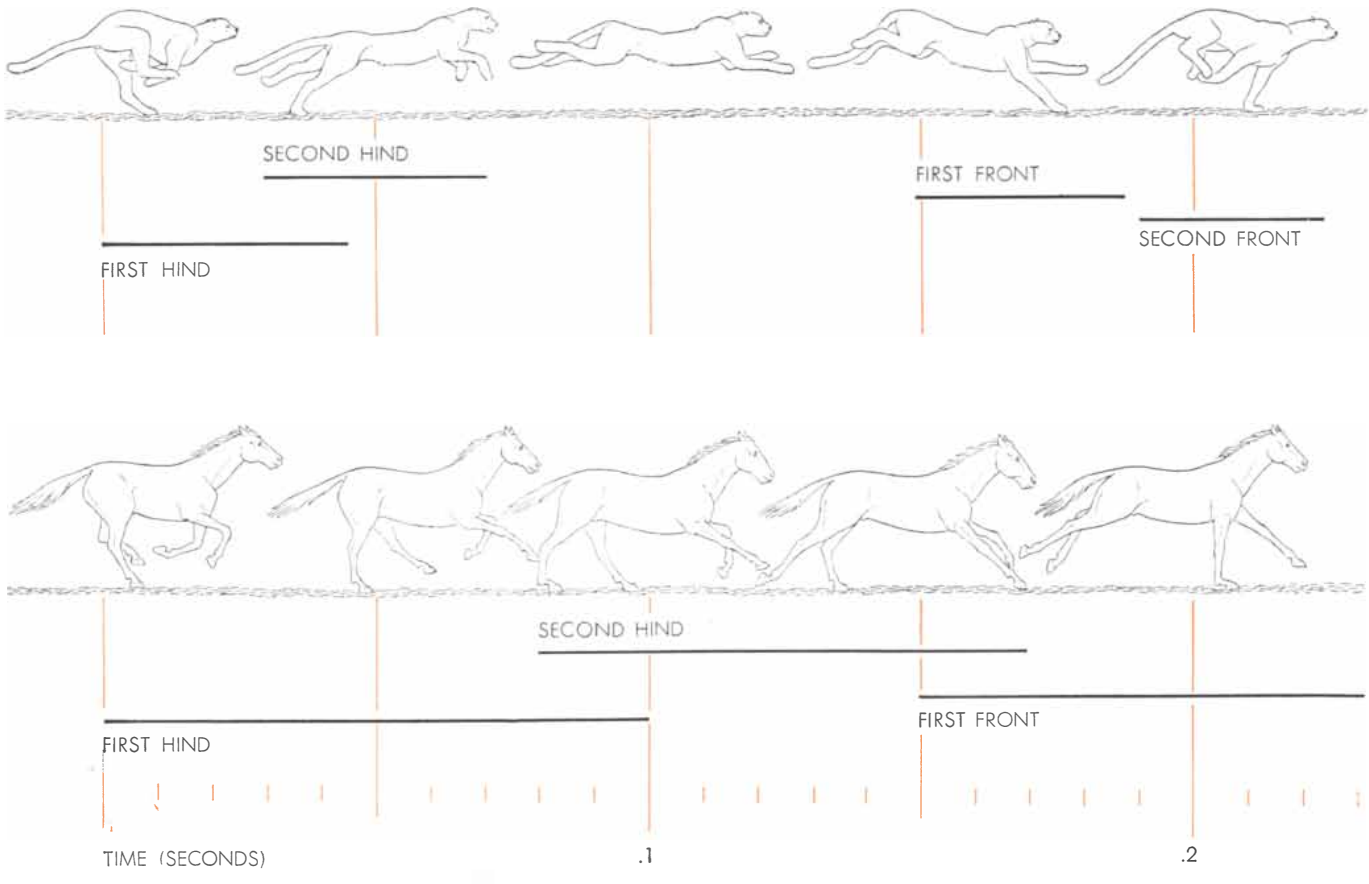
top row and continues across the bottom row. With these and similar photographs Muybridge settled the controversy of whether or not a horse "even at the height of his speed [has] all four of his feet . . . simultaneously free from contact with the ground."

rous mammals, birds, running dinosaurs and some extinct hoofed mammals, on the other hand, stand on what corresponds to the ball of the human foot; these animals have digitigrade ("finger-walking") feet. Other hoofed mammals owe an even further increase in the effective length of their legs to their unguligrade ("hoof-walking") posture, resembling that of a ballet dancer standing on the tips of her toes. Where foot posture and limb proportions have been modified for the cursorial habit, the increased length and slenderness of the leg is striking [*see illustration on page 155*].

The effective length of the front limb of many runners is also increased by the modification of the structure and function of the shoulder. The shoulder joint of amphibians, reptiles and birds is virtually immobilized by the collarbone, which runs from the breast bone to each shoulder blade, and by a second bone, the coracoid bone. Because mammals do not have a coracoid bone their shoulder blade has some freedom of movement. In the carnivores this freedom is increased by the reduction of the collarbone to a vestige; in the ungulates the collarbone is eliminated. In both carnivores and ungulates the shoulder blade is oriented so that it lies against the side of a narrow but deep chest rather than against the back of a broad but shallow chest, as it does in man. Thus mounted, the shoulder blade pivots from a point about midway in its length, and the shoulder joint at its lower end is free to move forward and backward with the swing of the leg. The exact motion is exceedingly difficult to ascertain in a running animal, but I have found that it adds about 4.5 inches to the stride of the walking cheetah.

The supple spine of the cat and the dog increases the length of stride of these animals still further. The body of such an animal is several inches longer when the back is extended than when it is flexed. By extending and flexing its back as its legs swing back and forth the animal adds the increase in its body length to its stride. Timing is important in this maneuver. If the animal were to extend its back while its body was in mid-air, its hindquarters would move backward as its forequarters moved forward, with no net addition to the forward motion of the center of mass of its body. In actuality the running animal extends its back only when its hind feet are pushing against the ground. The cheetah executes this maneuver so adeptly that it could run about six miles per hour without any legs.

With the extra rotation of its hip and shoulder girdles and the measuring-worm action of its back, the legs of the running cursor swing through longer arcs, reaching out farther forward and backward and striking and leaving the ground at a more acute angle than they would if the back were rigid. This clear-



STRIDES OF THE CHEETAH AND THE HORSE in full gallop are contrasted in these illustrations. The sequence and duration of their footfalls, indicated by the horizontal lines under each animal, relate to the time-scale at bottom, which is calibrated in 10ths of a second. The cheetah has two unsupported periods, which account for about half its stride; the horse has one unsupported period,

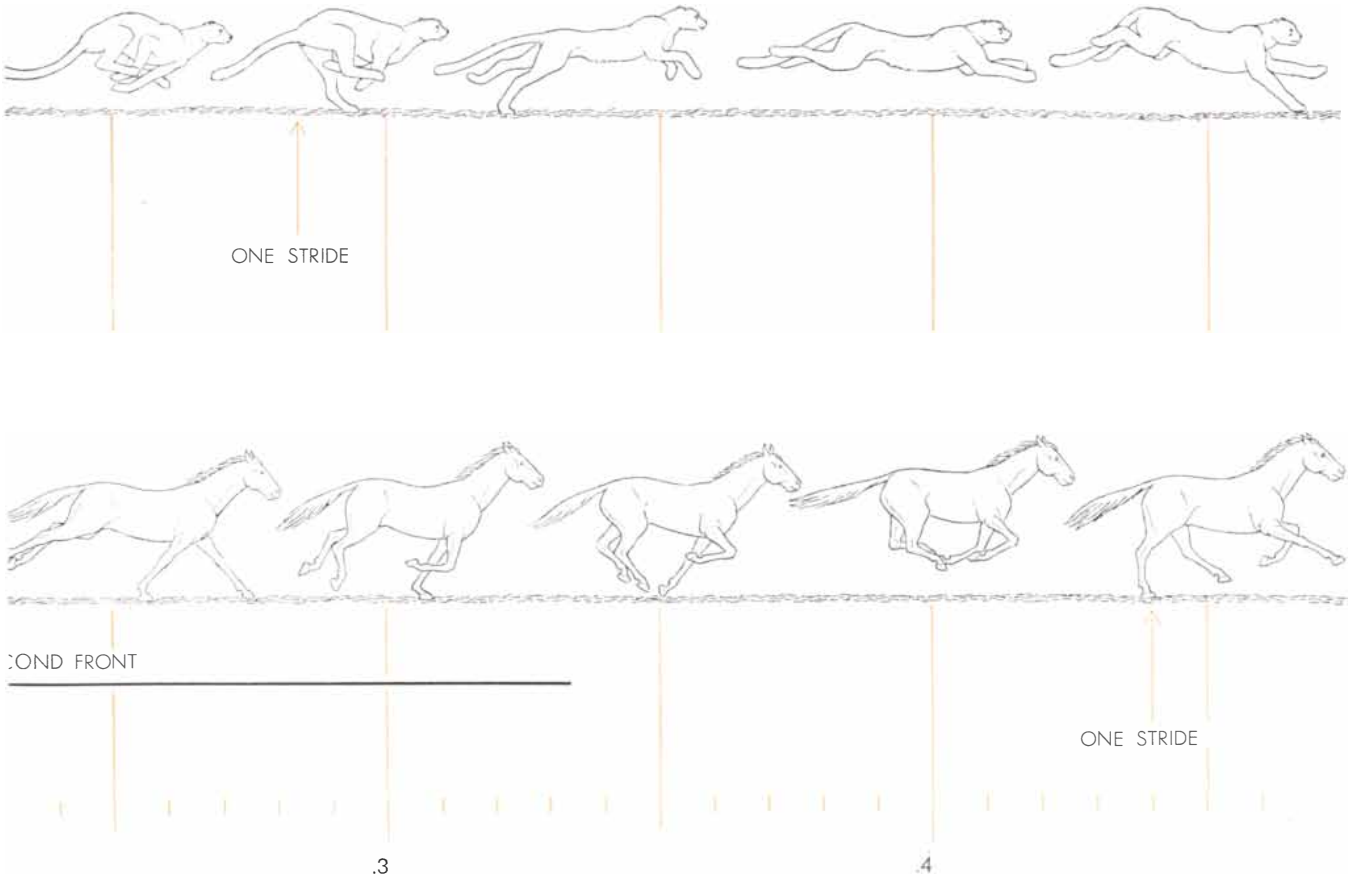
ly increases stride length, but it also aggravates a problem. The body of the animal tends to rise when its shoulders and hips pass over its feet, and tends to fall when its feet extend to the front or rear. Carnivores offset this bobbing motion by flexing their ankles and wrists, thus shortening their legs. Ungulates do the same by sharply flexing the fetlock joint at the moment that the body passes over the vertical leg. The cheetah, a long-striding back-flexer, supplements its wrist-flexing by slipping its shoulder blade up its ribs about an inch, and thus achieves a smooth forward motion.

Since running is in actuality a series of jumps, the length of the jump must be reckoned as another important increment in the length of the stride. Hoofed runners have one major unsupported period, or jump, in each stride: when the legs are gathered beneath the body. The galloping carnivore has two major unsupported periods: when the back is flexed, and again when it is extended. In the horse all of these anatomical and functional adaptations combine to produce a 23-foot stride. The cheetah, although smaller, has a stride of the same length.

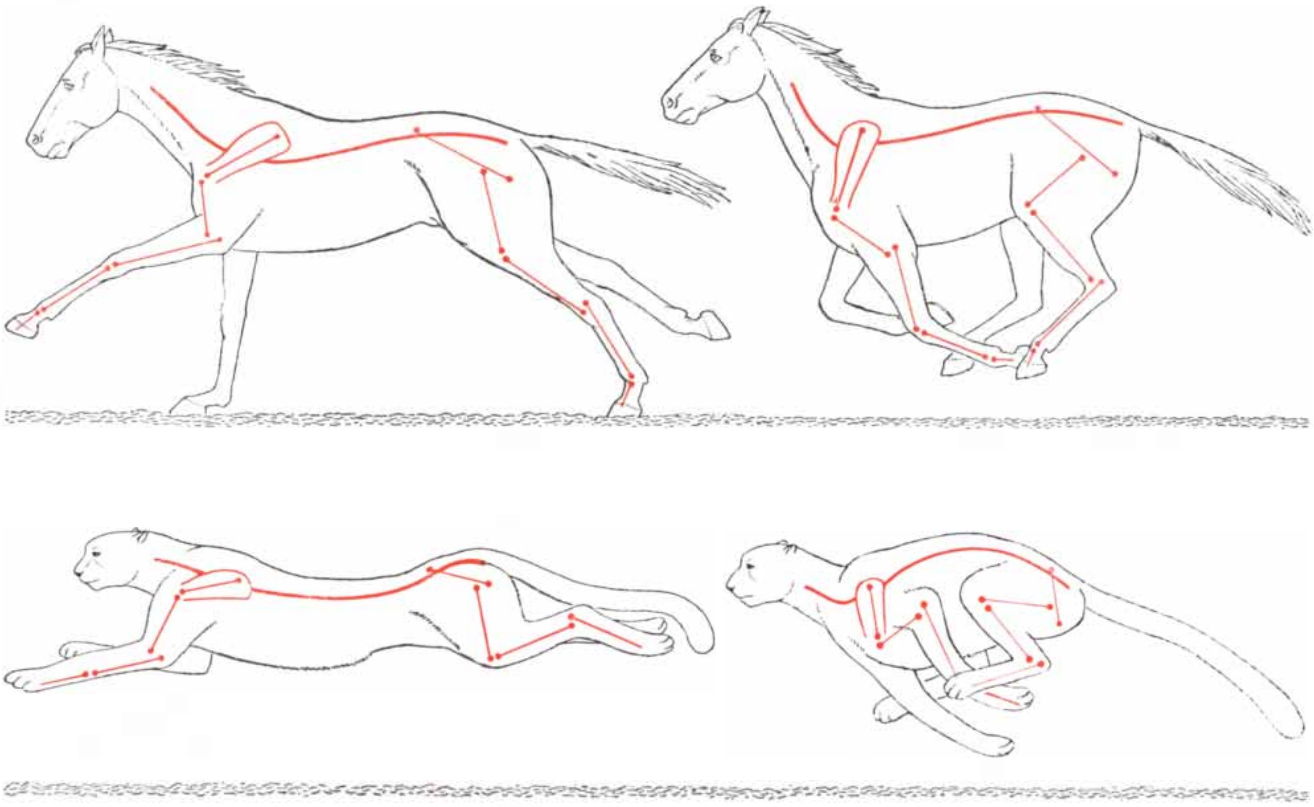
Fast runners must take their long strides rapidly. The race horse completes about 2.5 strides per second and the cheetah at least 3.5. It is plain that the higher the rate of stride, the faster the runner must contract its muscles. One might infer that cursorial animals as a group would have evolved the ability to contract their muscles faster than other animals. Within limits that is true, but there is a general principle limiting the rate at which a muscle can contract. Assuming a constant load on the muscle fibers, the rate of contraction varies inversely with any of the muscle's linear dimensions; the larger muscle therefore contracts more slowly. That is why an animal with a larger body has a slower rate of stride and so loses the advantage of its longer length of stride.

The familiar mechanical principle of gear ratio underlies the fast runner's more effective use of its trim musculature. In the linkage of muscle and bone the gear ratio is equal to the distance between the pivot of the motion (the shoulder joint, for example) and the point at which the motion is applied (the foot) divided by the perpendicular distance between the pivot and the point at which the muscle is attached to the bone. Cursorial animals not only have longer legs; their actuating muscles are also attached to the bone closer to the pivot of motion. Their high-gear muscles, in other words, have short lever-arms, and this increases the gear ratio still further. In comparison, the anatomy of walking animals gives them considerably lower gear-ratios; digging and swimming animals have still lower gear ratios.

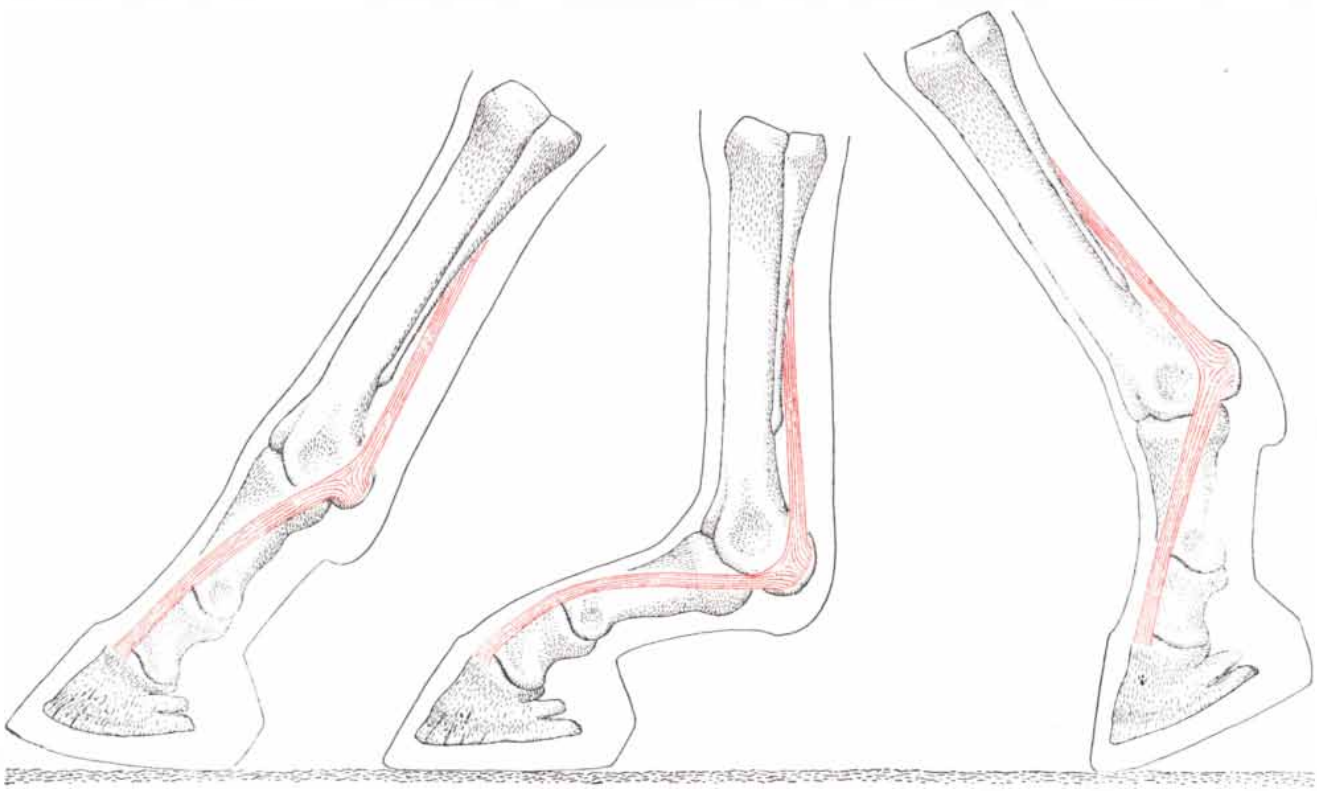
But while high gears enable an automobile to reach higher speed, they do



which accounts for about a quarter of its stride. Although both the cheetah and the horse cover about 23 feet per stride, the cheetah attains speeds on the order of 70 miles per hour, to the horse's 43, because it takes about 3.5 strides to the horse's 2.5. The size of the horse has been reduced disproportionately in these drawings for the sake of uniformity in the stride-lines and time-scale.



SWIVELING SHOULDER BLADES of the horse and the cheetah add several inches to their stride length. The faster cheetah gains a further advantage from the flexibility of the spine, which in addition to adding the length of its extension to the animal's stride, adds the speed of its extension to the velocity of its travel. Horse's relatively longer leg partially compensates for its rigid spine.



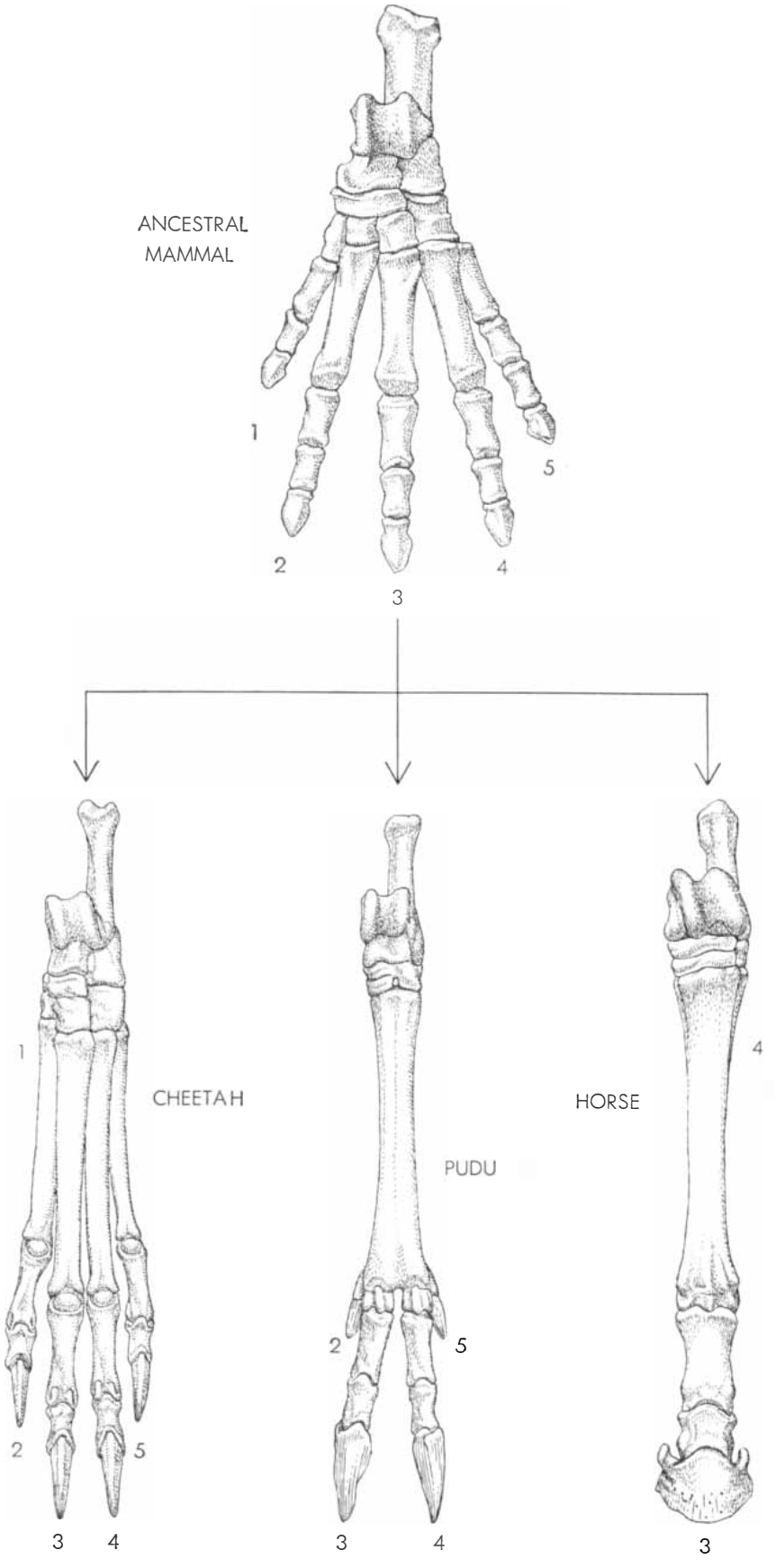
SPRINGING LIGAMENTS in the legs of horses, shown here, and other hoofed runners reduce the need for heavy muscles. Impact of the foot against the ground (*left*) bends the fetlock joint (*middle*) and stretches an elastic ligament (*shown in color*) that snaps back when the foot leaves the ground (*right*). The springing action at once straightens the foot and gives the leg an upward impetus.

so at the expense of power. The cursorial animal pays a similar price, but the exchange is a good one for several reasons. Running animals do not need great power: air does not offer much resistance even when they are moving at top speed. Moreover, as the English investigators J. M. Smith and R. J. G. Savage have noted, the animal retains some relatively low-gear muscles. Probably the runner uses its low-gear muscles for slow motions, and then shifts to its high-gear muscles to increase speed.

Since the speed at which a muscle can contract is limited, the velocity of the action it controls must be correspondingly limited, even though the muscle speed is amplified by an optimum gear-ratio. A larger muscle, or additional muscles, applied to action around the same joint can produce increased power but not greater speed. Several men together can lift a greater weight than one can lift alone, but several equally skilled sprinters cannot run faster together than one of them alone. The speed of a leg can be increased, however, if different muscles simultaneously move different joints of the leg in the same direction. The total motion they produce, which is represented by the motion of the foot, will then be greater than the motion produced by any one muscle working alone. Just as the total speed of a man walking up an escalator is the sum of his own speed plus that of the escalator, so the independent velocities of each segment of the leg combine additively to produce a higher total velocity.

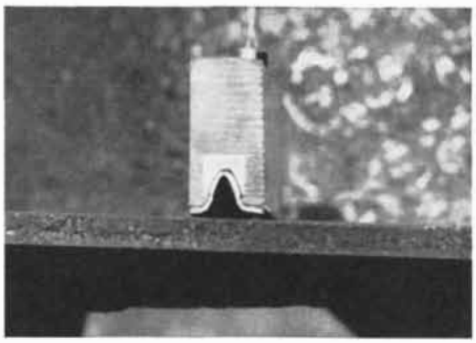
The trick is to move as many joints as possible in the same direction at the same time. The evolution of the cursorial body has produced just this effect. By abandoning the flat-footed plantigrade posture in favor of a digitigrade or unguligrade one, the cursorial leg acquired an extra limb-joint. In effect it gained still another through the altered functioning of the shoulder blade. The flexible back of the cursorial carnivore adds yet another motion to the compound motion of its legs; the back flexes in such a way that the chest and pelvis are always rotating in the direction of the swinging limbs.

The supple spine of the carnivore contributes to stride rate by speeding up the motion of its body as well as of its legs. The spine is flexed when the runner's first hind foot strikes the ground, and by the time its second hind foot leaves the ground the animal has extended its spine and thus lengthened its body. In the brief interval when its hind

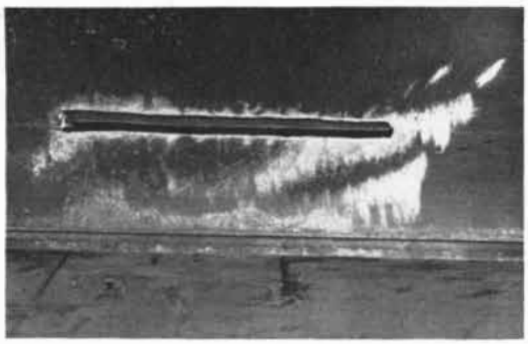


MODERN CURSORIAL FOOT EVOLVED from the broad, five-digited foot of an ancestral mammal (*top*). Lateral digits were lost and metatarsal bones, the longest in the foot, were further elongated. Resultant foot is lighter and longer. Pudu is a deer of the Andes.

A plastic that blasts holes



1. Explosive charge is set in urethane casting.

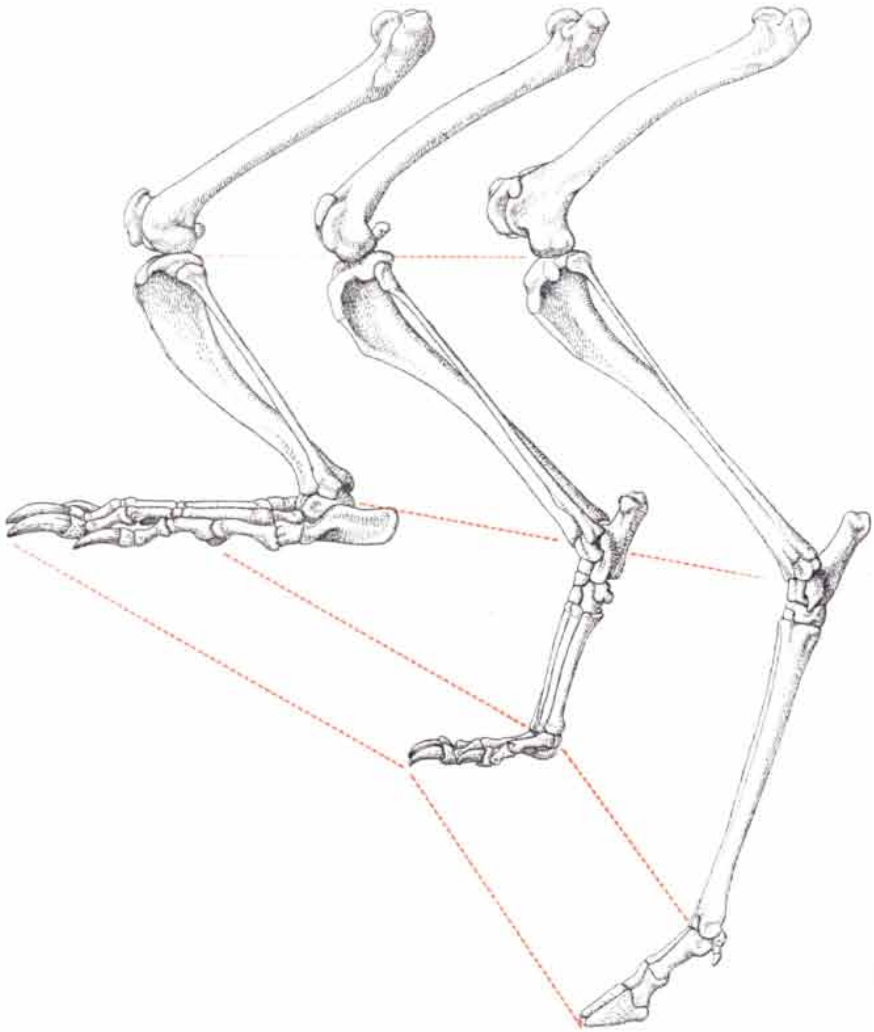


3. "Line" of fire cuts right through metal plate.

2. Casting directs force of explosion along a sharp line.

feet are planted, the forequarters, riding on the extending spine, move farther and faster than the hindquarters. Similarly when the front feet are on the ground, the hindquarters move faster than the forequarters. So although the speed that the driving legs can impart to the forequarters or hindquarters is limited by their rate of oscillation, the body as a whole is able to exceed that limit. In a sense the animal moves faster than it runs. For the cheetah the advantage amounts to about two miles per hour—enough to add the margin of success in a close chase.

In addition to the obvious tasks of propelling the animal's body and supporting its weight, the locomotor muscles must raise the body to compensate for the falling that occurs during the unsupported phases of the stride. The load they must raise is proportional to the mass of the body, which is in turn proportional to the cube of any of its linear dimensions. A twofold increase in body length thus increases weight eightfold. The force that a muscle can exert, on the other hand, increases only as the square of its cross section. Thus against an eightfold increase of load, bigger muscles can bring only a fourfold increase of force. As body size increases, the capacity of the muscles to put the body in forward motion and to cause its legs to oscillate cannot quite keep up with the demands placed upon them. These fac-

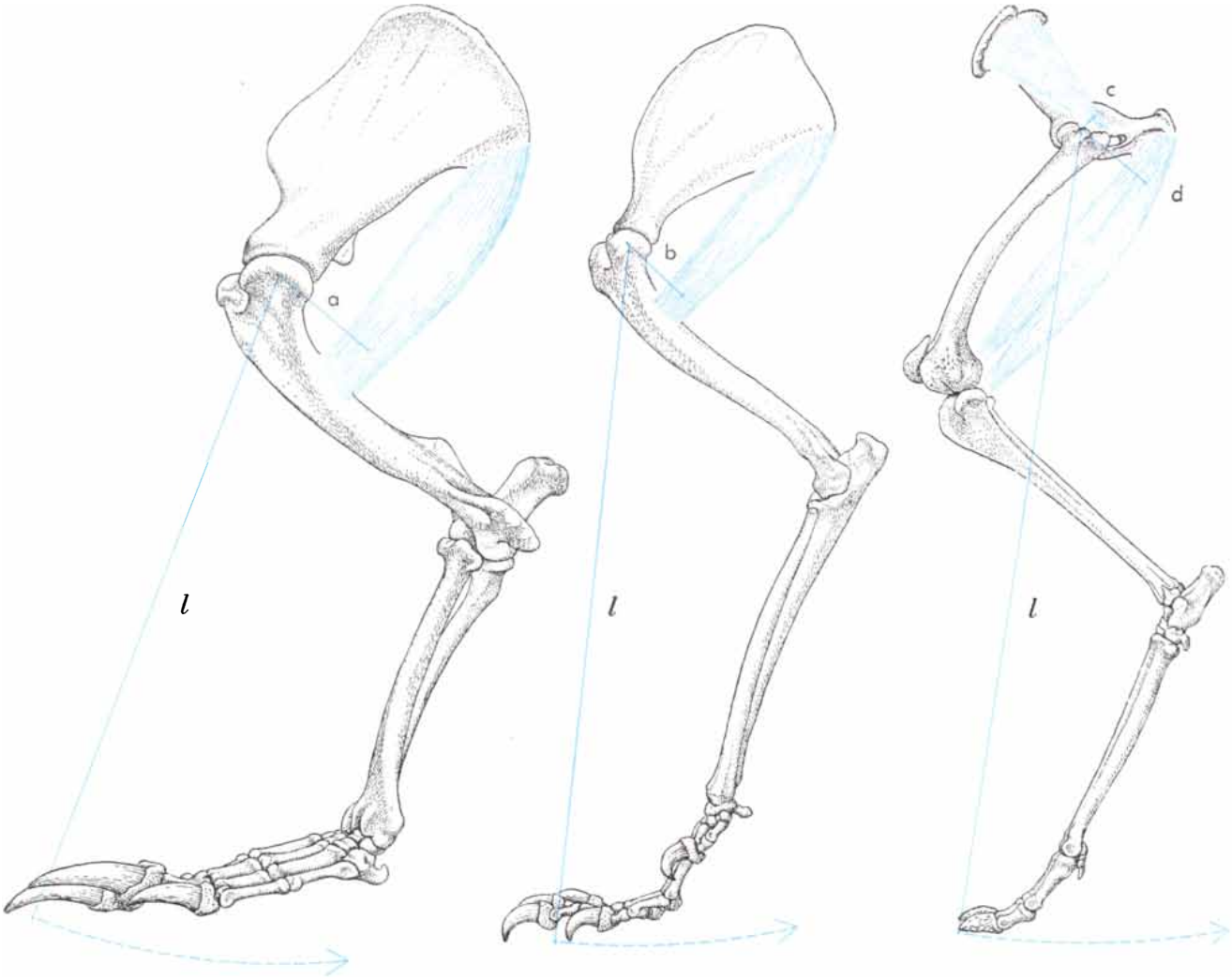


ADAPTATION OF THE LEG FOR SPEED is illustrated by the hind-leg bone of the slow badger (*left*), moderately fast dog (*middle*) and highly adapted deer (*right*). The lengthened metatarsus of the latter two has yielded a longer foot and an altered ankle posture that is better suited to running. The thigh bones of all three animals have been drawn to the same scale to show that the leg segments farthest from the body have elongated the most.

tors in the nature of muscle explain why the largest animals can neither gallop nor jump, why small runners such as rabbits and foxes can travel as fast as race horses without having marked structural adaptations for speed and why the larger cursorial animals must be highly adapted in order to run at all.

If the bigger runners are to have endurance as well as speed, they must have not only those adaptations that increase the length and rate of their stride, but also adaptations that reduce the load on their locomotor structures and economize the effort of motion. In satisfying this requirement natural selection produced a number of large and fast runners that are able to travel for long distances at somewhat less than their maximum speed. In these animals the mass of the limbs is minimized. The muscles that in other animals draw the limbs toward or away from the midline of the body (the "hand-clapping" muscles in man) are smaller or adapted to moving the legs in the direction of travel, and the muscles that manipulate the digits or rotate the forearm have disappeared. The ulna in the forearm and the fibula in the shank —bones involved in these former motions—are reduced in size. The ulna is retained at the point where it completes the elbow joint, but elsewhere becomes a sliver fused to its neighbor; the fibula is sometimes represented only by a nubbin of bone at the ankle.

The shape of the cursorial limb embodies another load-reducing principle.



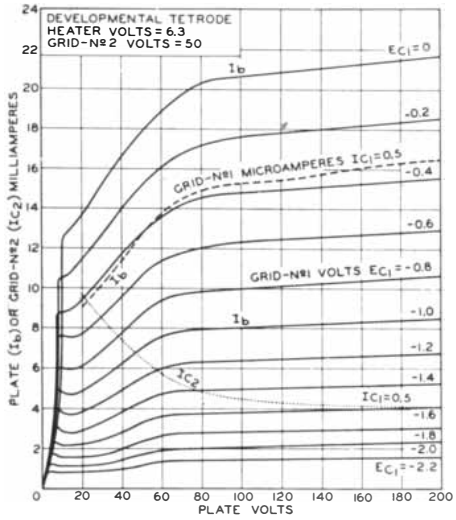
POWER AND SPEED are alternatively achieved in the badger (*left*) and the cheetah (*middle*) by placement of the teres major muscle. In the cheetah the small distance (b) between the muscle insertion and the joint it moves yields a higher rate of oscillation than in the badger, in which the distance (a) is greater. The higher oscillation rate, coupled with a longer leg (*l*), yields a faster stride. In the vicuña (*right*) the gluteus muscle (c) develops about five times the velocity but only a fifth the force of the larger semimembranosus muscle (d). The animal may use the latter to overcome inertia; the former, for high speed. Legs are not in same scale.

Since the kinetic energy that must be alternately developed and overcome in oscillating the limb is equal to half the mass times the square of its velocity, the load on muscles causing such motions can be reduced not only by reducing the mass of the faster-moving parts of the limb but also by reducing the velocity of the more massive parts. Accordingly the fleshy parts of the limb are those close to the body, where they do not move so far, and hence not so fast, as the more distant segments. The lower segments, having lost the muscles and bones involved in rotation and in digit manipulation, are relatively light.

The rigor of design imposed by natural selection is especially evident in the feet of cursorial animals. The feet of other animals tend to be broad and pliable; the bones corresponding to those of the human palm and instep are rounded in cross section and well separated. In the foot of the cursorial carnivore, on the other hand, these bones are crowded into a compact unit, each bone having a somewhat square cross section. In the ungulates the ratio of strength to weight has been improved still further by reduction of the number of bones in the foot. The ungulates have tended to lose their lateral toes; sometimes the basal elements of the other toes are fused into a single bone. This process gave rise to the cannon bone: the shank of the hoofed mammals [*see illustration on page 153*]. In compensation for the bracing lost as the bones and muscles of their lower limbs were reduced or eliminated, these animals evolved joints that are modified to function as hinges and allow motion only in the line of travel.

The burden on the muscles of hoofed animals is relieved by an especially elegant mechanism built into the foot. When the hoof of the running animal strikes the ground, the impact bends the fetlock joint and stretches certain long ligaments called the suspensory or springing ligaments [*see bottom illustration on page 152*]. Because the ligaments are elastic, they snap back as the foot leaves the ground, thereby straightening the joint and giving the leg an upward push. Charles L. Camp of the University of California has found that these built-in pogo-sticks evolved from foot muscles at the time that the animals forsook river valleys for the open plains. The exchange was advantageous, for by means of this and the other adaptations, nature has reconciled the limitations of muscle mechanics with the exacting requirements of speed.

Following RCA's announcement of the nuvistor concept and subsequent announcement of the first commercial nuvistor type—the 7586 general-purpose industrial triode—comes news that a nuvistor tetrode is now available to equipment manufacturers on a limited sampling basis. This developmental small-signal tetrode—RCA Dev. No. A-2654—promises to extend the horizons of the nuvistor concept far into the entertainment, industrial, and military electronic fields.



Incorporating all the advantages of nuvistor design, this small-signal general-purpose tetrode is Step 2 of a daring electron-tube-improvement program by RCA. Our developmental work indicates that the nuvistor tetrode will establish new high standards of tube performance for the electronics industry.

Dynamic in Concept

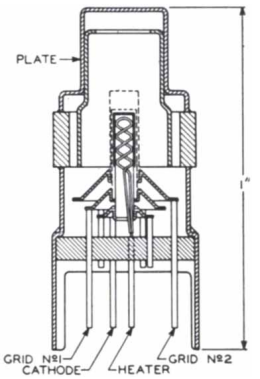
RCA had as its objective in the design of the nuvistor tetrode superior performance in many amplifier applications, particularly at the higher radio frequencies. The new tube is ⅓ the size of conventional rf-amplifier tetrodes, and consumes approximately ½ the heater power.

The nuvistor method of construction eliminates or minimizes many of the known causes of tube failure. Use of only ceramics and strong metals provides a structure of extreme ruggedness. Brazing of all connections in a hydrogen atmosphere at extremely high temperatures eliminates structural strain and element distortion. Exhaust and seal-off at very high temperatures minimizes gases and impurities from metal parts.

Opening a New Era: "Nuvistorization"

The nuvistor tetrode shows great promise for mixer, oscillator-mixer, if-amplifier and low-level video-amplifier service.

Application tests in laboratory circuits show that the nuvistor tetrode will give top performance in industrial and military equipment. Outstanding performance has been obtained in the mixer and if-amplifier stages of such equipment.



Nuvistor Developmental Small Signal Tetrode A-2654

TYPICAL DATA

ELECTRICAL:		
Heater, for Unipotential Cathode:		
Voltage (AC or DC)	6.3±10%	volts
Current	0.165	amp
DIRECT INTERELECTRODE CAPACITANCES (approx.):		
Grid No. 1 to plate	0.01	μμf
Grid No. 1 to cathode heater, grid No. 2, metal shell and internal shield	6.0	μμf
Plate to cathode, heater, grid No. 2, metal shell and internal shield	1.4	μμf
Heater to cathode	1.4	μμf
CHARACTERISTICS, CLASS A_1 AMPLIFIER:		
Plate Supply Voltage	125	volts
Grid No. 2 (Screen-Grid) Voltage	50	volts
Cathode Resistor	68	ohms
Plate Resistance (approx.)	0.2	megohm
Transconductance	10,400	μmhos
Plate Current	9.6	ma
Grid—No. 2 Current	2.9	ma
Grid—No. 1 Voltage (approx.) for plate current of 10 μa	—5	volts
MAXIMUM RATINGS, ABSOLUTE-MAXIMUM VALUES:		
PLATE VOLTAGE	250 max.	volts
GRID—NO. 2 VOLTAGE	110 max.	volts
GRID—NO. 1 VOLTAGE:		
Negative bias value	55 max.	volts
Positive bias value	2 max.	volts
GRID—NO. 2 INPUT	0.2 max.	watt
PLATE DISSIPATION	2.2 max.	watts
GRID—NO. 1 CURRENT	2 max.	ma
CATHODE CURRENT	20 max.	ma
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	100 max.	volts
Heater positive with respect to cathode	100 max.	volts
MAXIMUM CIRCUIT VALUES:		
Grid—No. 1 Circuit Resistance:		
For cathode-bias operation	1.0 max.	megohm

DESIGN ENGINEERS: You will want to evaluate this tetrode for possible use in your equipment designs. For more details on nuvistors and information on how you may obtain samples of the tetrode call your RCA Field Representative at the Field Office nearest you.

Among other nuvistor types in development at RCA is a beam power tube for military, industrial, and entertainment applications. Half the size of its present-day counterpart, the nuvistor beam power tube will have a maximum plate-dissipation rating of 30 watts, and an output of several watts with less than 75 volts on the plate.

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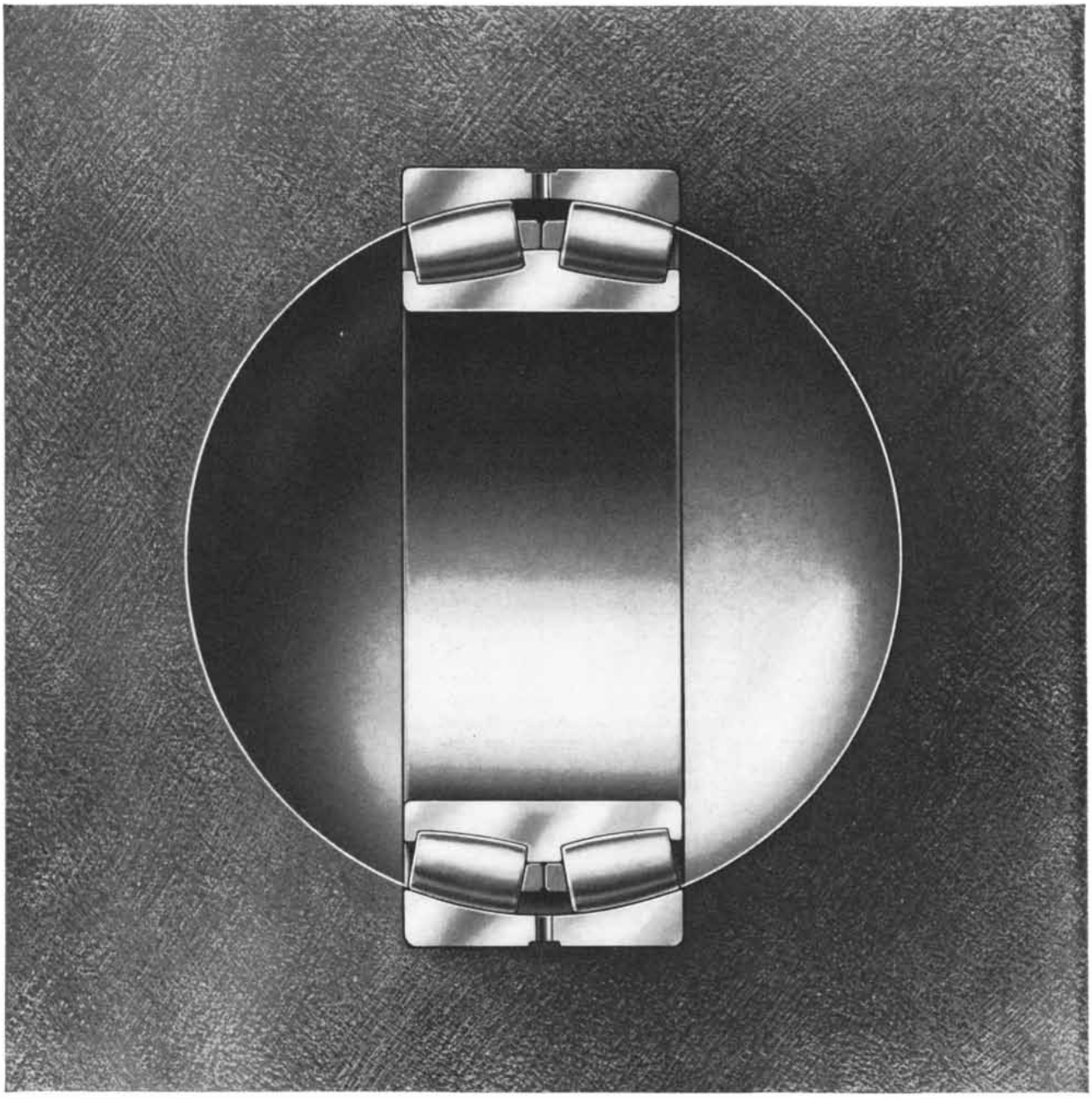

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PROGRESS THROUGH PRECISION—IN BEARING DESIGN AND PERFORMANCE

Animal Infections and Human Disease

During most of man's history his worst diseases were carried by animals and transmitted by insects and other arthropods. These "zoonoses" are still a threat over much of the world

by Meir Yoeli

The word "plague" stirs an ancient fear in most of us. Then we quickly shrug it off, remembering that we have moved out of reach of this scourge of our ancestors. But to a substantial majority of the earth's peoples, plague and other "zoonoses"—animal infections that may be transmitted to man—remain a daily threat. They are still one of the chief causes of disease over most of the earth.

In a shrinking world these diseases are not so far from our urban civilization as we like to think. An airline pilot lands in New York after a long flight from central Africa and is rushed to the hospital suffering from cerebral malaria. Oil-well drillers are invalided home from the Persian Gulf suffering from ague and the enlarged spleen typical of many tropical fevers. People in New Jersey die of equine encephalitis contracted not in some remote and primitive place, but in their own backyards.

Men have been observing infectious diseases since earliest times. Even while they regarded these pestilences with superstitious awe, helplessly attributing them to the wrath of the gods, the ancients made some acute observations. In some of the oldest chronicles—Babylonian laments, Homeric songs, Chinese annals, the Old Testament—are records of pestilence and its connection with factors in the environment. Thus in the book of Samuel we read how the Philistines, having defeated the Israelites and stolen the sacred ark, felt "the hand of the Lord . . . heavy upon them." The God of Israel "destroyed them and smote them with emerods" (the swollen lymph glands of bubonic plague).

In the light of modern knowledge we can interpret what happened. An infection of field mice was transferred to human beings by biting fleas. Once in the new host, the bacterium discarded its natural mode of propagation by insect "vector." In the cities of the Philistines the infection took on its explosive form of pneumonic plague, passing directly

MEDIEVAL "PLAGUE POSTER" displays this woodcut over an announcement of a Mass in Paris, commemorating the death of Saint Roch, who was especially invoked against plague. The saint is pointing to the plague spot on his leg. At his feet is the dog reputed to have brought him bread when, infected with plague, he was expelled from an Italian town and left to starve in a forest.

from person to person by means of exhaled droplets of fluid. "There was a deadly destruction . . . and the men that died not were smitten with emerods." The terrified inhabitants could know nothing of this complicated epidemiology, but they did understand that the mice were in some way responsible for their trouble. Deciding to return the ark, they were directed by their priests to send with it a "trespass offering" of "five golden emerods and five golden mice, according to the number of the lords of the Philistines: for one plague was on you all and on your lords. Wherefore ye shall make images of your emerods and images of your mice that mar the land."

The passing millennia have added considerably to our sophistication. We now know that each zoonosis is an exceedingly complex biological system. It comprises not only the actors—the infective agent, human host, animal reservoir and insect vector—but also the setting of terrain, climate, plant life and so on in which they play their interconnected roles. But to recognize the elements in the system is by no means to understand all the details of its workings. There are still serious gaps in our knowledge.

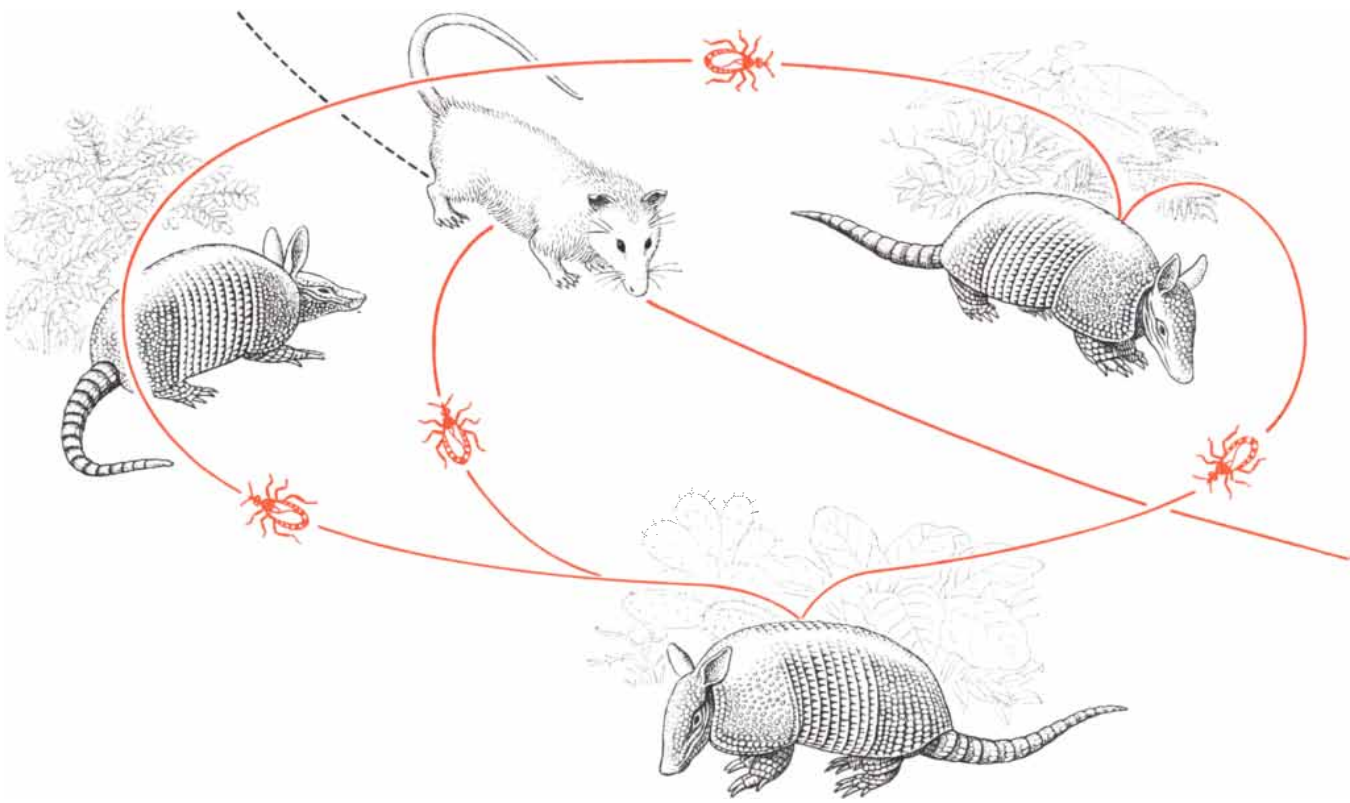
As a classic example of the ecology of a zoonosis let us consider Chagas' disease, an often fatal infection that occurs in South and Central America. The infecting organism is a protozoon known as *Trypanosoma cruzi*, a first cousin to the germ of African sleeping sickness. There are natural foci of this trypanosome as far north as Texas, where it infects wood rats. Blood-sucking "kissing bugs" prey on an infected animal, picking up the organism and eventually transferring it to another rat. Thus the trypanosome circulates quietly in its wild cycle. The human population of Texas, living in well-built houses, hardly ever comes into contact with the bugs, and so it does not become infected.

Farther south, in British Honduras, there are plenty of wood rats and other suitable animal hosts; the people live in huts infested with vermin, but the climate is too wet for the kissing bug, and so the disease does not spread. In Costa Rica the animal reservoir is the vampire bat, which does not usually come near human beings, and the native bug is an inefficient vector. Cases of human infection occur, but only sporadically.

In South America the disease finds a much more hospitable environment. The wild host is the armadillo, and the wild vector a species of kissing bug that transfers the organism efficiently. This natural cycle, however, occurs in the deep jungle, where man rarely intrudes. Enter now the opossum, ranging through the jungle, bitten by an infected kissing bug and picking up the organism. Unlike the armadillo, the opossum is not shy of human beings. Under cover of night it steals into native huts looking for scraps of food. A domestic strain of kissing bug takes a blood meal from the opossum and then later from a dog, cat or human being. Thus is set up a second cycle, and the disease spreads through a village.

The process does not end here. Pregnant women can transfer the trypanosome via the bloodstream to their unborn children. Now the disease can progress within a family, without the intervention of wild or domestic animals or even of the kissing bug.

There are a number of points to be noted about these patterns. The first is that they *are* patterns: the significance of each part can be understood only in its relation to the whole. In the cycle of



ECOLOGY OF CHAGAS' DISEASE is illustrated diagrammatically. The left-hand section of the drawing shows the wild cycle, where the infecting organism, *Trypanosoma cruzi*, circulates among armadillos, carried by the kissing bug. Through this "nest" comes an

armadillo, kissing bug and trypanosome the disease is slumbering, as it were, at its natural hearth. (The concept of a hearth, or "nest," of a zoonosis is due to Evgeny N. Pavlovsky of the U.S.S.R., a world leader in the study of animal-borne infections.) As the earlier examples show, the existence of such a hearth does not necessarily mean that the disease will "awaken" and attack human beings. In Texas the disease has thus far lain dormant.

In fact, in the wild state the trypanosome infection does not even deserve the term disease. As with many other such biological associations, the microorganism follows its life cycle with the help, but not at the expense, of the animals. Neither the insect nor the mammalian host is made sick, but both are essential to the normal propagation of the organism. During its stay in the insect it undergoes a number of striking metamorphoses, returning to the typical infective form as it re-enters the circulation of a warm-blooded animal.

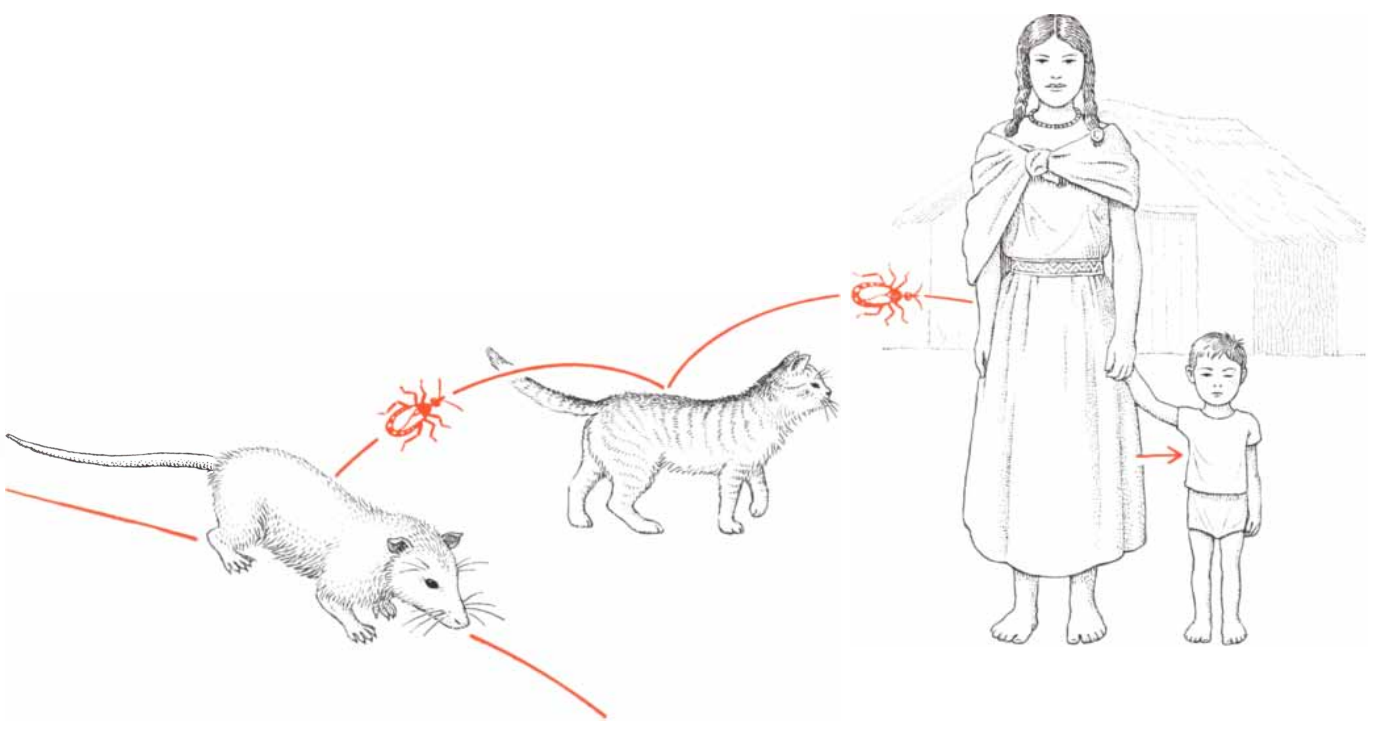
The disease agents of zoonoses range from viruses through bacteria and protozoa to worms. Not all of them have so complex a life cycle as that of *Trypanosoma cruzi*. However, dependence on an insect or another arthropod vector and on a mammalian "maintenance host" or reservoir is not the exception but the rule. African trypanosomes, for example, can be cultured in the laboratory, but they lose their power of infection. The infectivity can be restored by culturing the organisms in a medium containing some cells from the salivary gland of the tsetse fly, the natural vector, as William L. Trager of the Rockefeller Institute has recently demonstrated. Again, a rodent malaria parasite that naturally infects tree rats loses its ability to pass through the sexual part of its normal reproductive cycle when transferred to an abnormal host, the white mouse. When the exhausted strain is reinoculated in tree rats, it regains its vigor.

On the other hand, parasites may break away from their normal pattern. We have already seen, both in Chagas' disease and in the pneumonic form of plague, examples of organisms that can propagate in more than one way. We shall find others.

Knowing the nest—the natural setting—of a zoonosis, we can assess the possibilities of its emergence as a human disease and undertake rational measures to prevent or eradicate it. Chagas' disease is an unusual case, involving a remote nest and an additional mammal to make liaison with human beings. Most infections do not spread to man unless he blunders into them.

In Israel some years ago we witnessed a striking instance of a nest of endemic infection that had slumbered quietly for about 1,000 years between invasions by men. On a hill in the northern Galilee stand the ruins of a castle built by the crusaders. Like many such fortresses it is located on a commanding site along an ancient road and over natural caves that served as shelter and storerooms. It is said that the castle was abandoned by its builders after they fell ill of a severe recurrent fever.

The story is quite plausible. Endemic relapsing fever, a spirochete infection transmitted by ticks, resides in cave-dwelling rodents. These animals must have infested the cave under the Galilean castle during the occupation of the crusaders. They were still there in 1947, when a group of 65 young people came to the strategically situated fortress to guard its approaches and establish a settlement. Within a few weeks 45 of them



opossum which picks up the infection and brings it to an inhabited region (*right*). There the kissing bug transfers it to domestic animals and to people. Pregnant women can transfer the trypanosome to unborn children without any further intervention of the vector.

were hospitalized with relapsing fever.

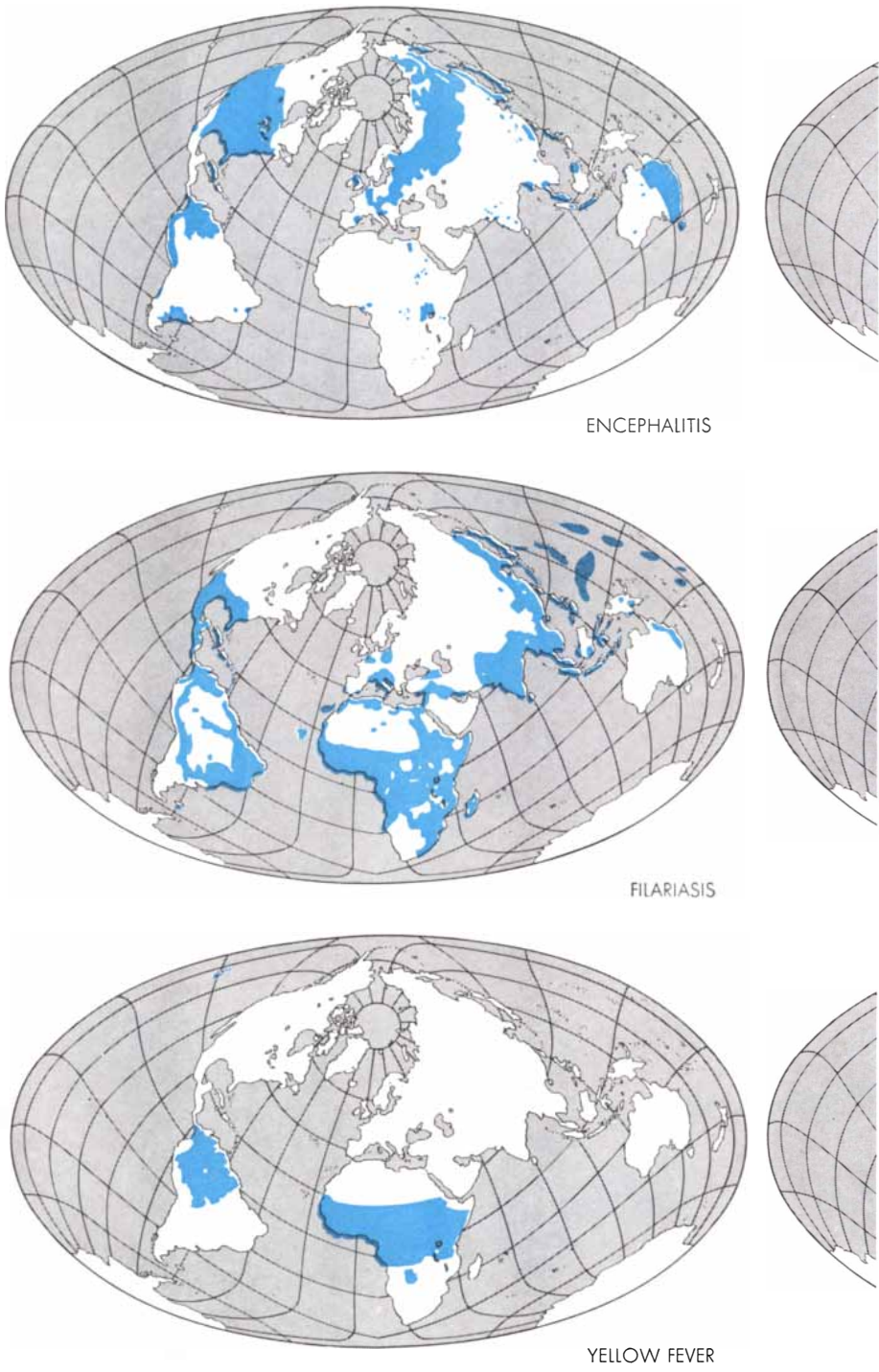
While some zoonoses nest in small, isolated pockets, others spread widely, holding enormous areas in their grip. Sleeping sickness, the African form of trypanosomiasis, stretches over an area as vast as the U. S., denying it to man for agriculture and animal husbandry. The trypanosome, carried by wild game in which it causes no sickness, is transferred by the tsetse fly, and transmitted by the same vector to men and cattle within its domain.

Still more pervasive are the typhus fevers. Not confined to the tropics or warm climates, they reach as far as the northern tundras of Siberia, and have broken out as epidemics in many parts of the globe. The microorganisms of typhus fever are rickettsiae, minute "inclusion bodies" that have characteristics of both viruses and bacteria and that live only inside cells. They infect a variety of rodent and other mammalian hosts, and are carried by mites, ticks, fleas and lice. A special adaptation by which they grow in the yolk cells of their arthropod carriers makes it possible for typhus rickettsiae to perpetuate themselves through generations of vectors without recourse to the mammalian reservoir. When the infection spreads to man, the organisms invade the cells lining the blood vessels, causing fever, hemorrhages and other severe symptoms. Although all the rickettsial diseases have a common pattern of development, each in its turn shows its own dark countenance. Like beasts of prey that belong to a common family but live and hunt in different regions, these typhus infections are each bound by their environment and by different ecological and biological factors.

Under the name of Rocky Mountain spotted fever, typhus has become all too familiar to U. S. residents. Now another zoonosis, this time a virus infection, is acquiring equal notoriety. Virus encephalitis has struck in several sections of the U. S. Considering the variety of its mammalian reservoirs and vectors, the wonder is that it is not more prevalent than it is. Encephalitis virus is to be found in horses, in various wild animals and in migratory birds. Numerous species of tick and of mosquito can carry it.

Perhaps the most interesting, as it is surely the most threatening, aspect of the zoonoses is the ability of the infective agents to adapt themselves to different modes of existence. The sudden conversion of *Pasteurella pestis* from the flea-borne agent of bubonic plague to the droplet-carried germ of pneumonic plague has been noted earlier. It is still not fully understood.

Let us consider another example or two. Relapsing fever, as we have said, normally travels to man from underground rodents via ticks. In the vector the spirochete enters the salivary glands, the most favorable location for transmission when the tick bites another animal. One type of spirochete found in central Africa has abandoned the rodent reservoir and propagates directly from man to tick, from tick to its offspring and again to man. In North Africa and southern Spain there is a closely related spirochete that can go a step farther from its normal cycle and adapt itself to a new vector: the body louse. The switch causes a sharp change in virulence, and

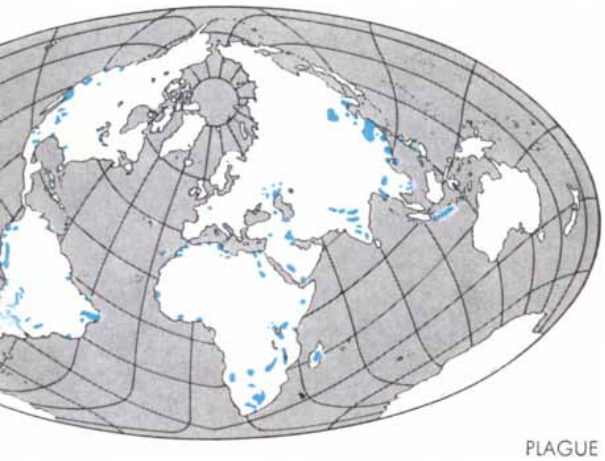


WORLD DISTRIBUTION of some of the major diseases discussed in the text is shown in color on these global maps. In most cases the colored areas are regions where the human

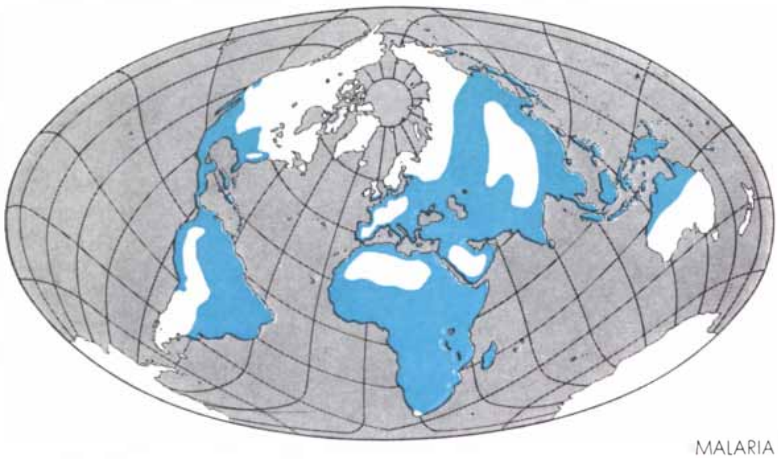
the former endemic disease can explode into an epidemic, especially in overcrowded and undernourished populations. Such epidemics are only too well remembered in eastern Europe from the years of World War I and immediately afterward.

Despite its devastating efficiency, the body louse is not a true biological vector. Its relationship with the spirochete has not evolved to the point where the latter takes up a favorable station for transmission. Infected lice have spirochetes in their body fluids, but cannot excrete them while biting. To pick up the infection the human host must crush the bug on his skin and then scratch the body fluids into the irritated area around the bite. However, this unlikely mode of transfer works all too well.

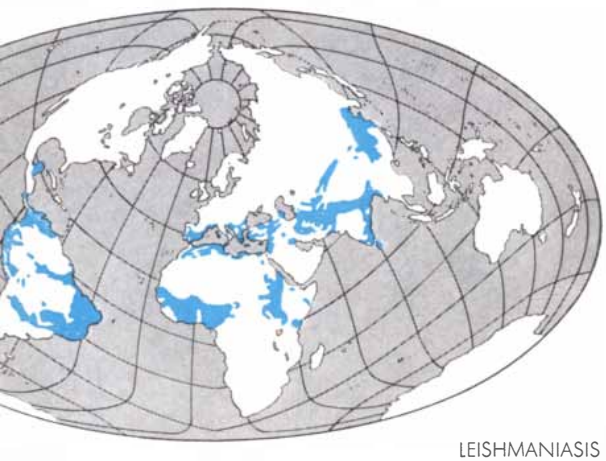
As in any other biological system, the older a disease, the more highly specialized adaptations we expect to find. Consider the group of infections known as leishmaniasis, after their infecting agents, the protozoa *Leishmania*. These organisms are probably among the most ancient parasites of man. There are now four quite distinct strains of leishmania infecting human beings. They attack dif-



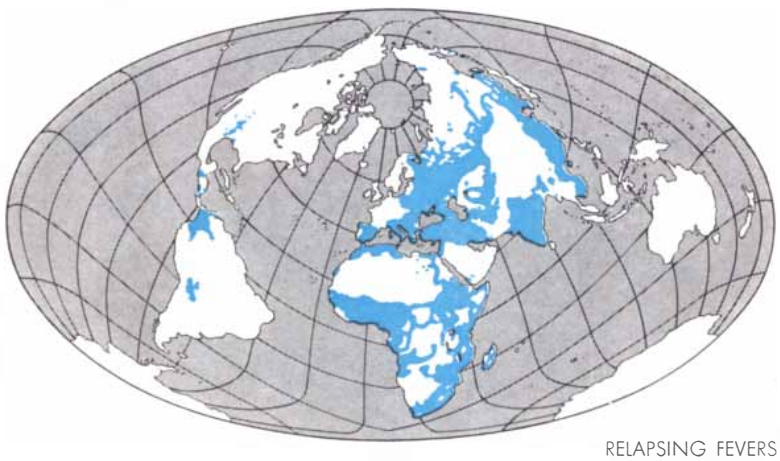
PLAGUE



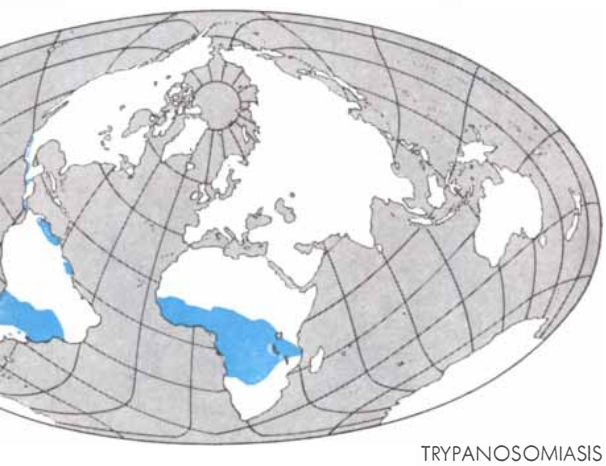
MALARIA



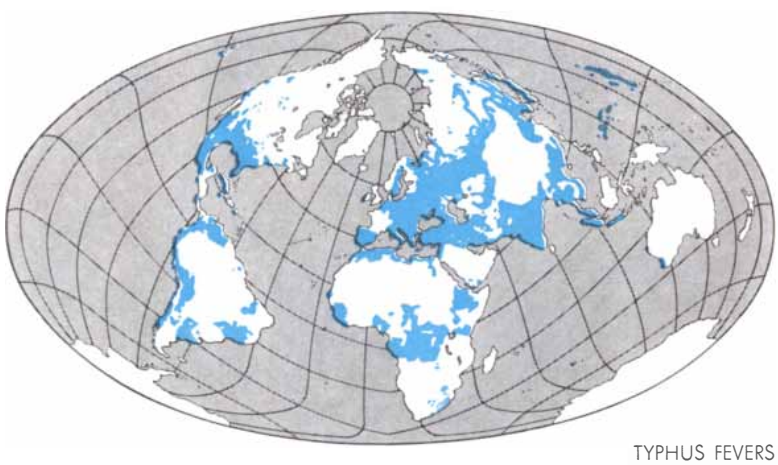
LEISHMANIASIS



RELAPSING FEVERS



TRYPANOSOMIASIS



TYPHUS FEVERS

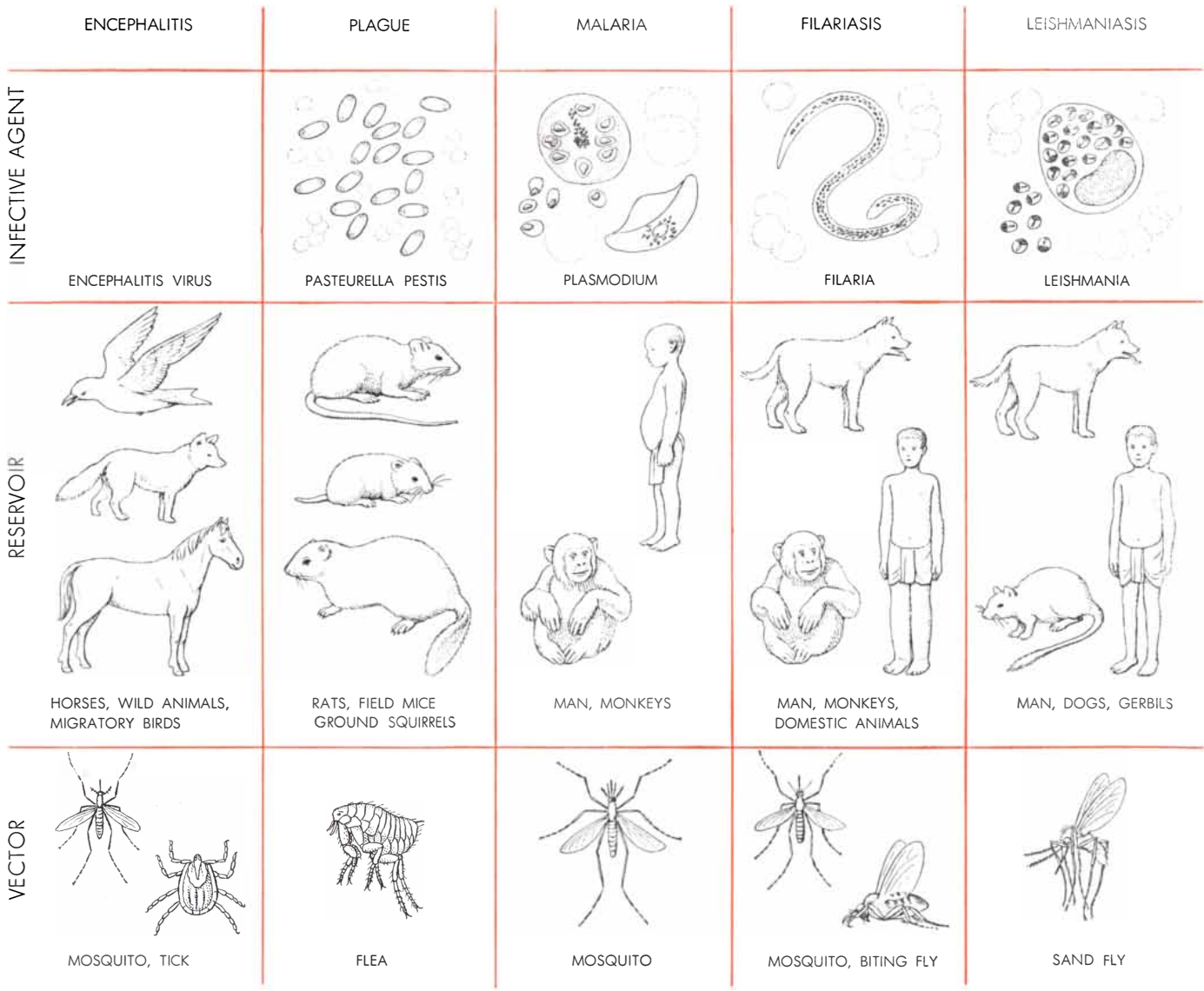
infection regularly occurs. In the case of yellow fever, however, the areas are those where the mosquito vectors are found. The information for these maps was taken from an atlas of diseases that is published by the American Geographical Society of New York.

ferent tissues, cause different symptoms and are transmitted by different species of sand fly. Yet they obviously derive from a common ancestral form. In fact, the different organisms cannot be distinguished under the microscope or even by serological (blood-test) reactions. Only by the symptoms they cause in human hosts can they be told apart.

In one form leishmania cause kala-azar, an often fatal infection of the reticulo-endothelial system (an intricate cellular defense system in the body). Kala-azar is endemic in parts of India and China and appears sporadically in Africa and South America. A second type of leishmaniasis produces a variant called infantile Mediterranean kala-azar, which primarily affects infants and small children in the Mediterranean basin. In Central and South America the organism shows up in espundia, an ulcerative condition of the nasal and oral membranes. And in many parts of the Near and Middle East as well as in central Asia it is responsible for Oriental sore, an ulcerous infection of the skin. The geographical distribution of the leishmania is parallel to that of their vectors and of the natural mammalian reservoir, chiefly dogs.

It seems that leishmania parasites are still going through a process of adaptation. In every country but India kala-azar is an infection limited to the reticulo-endothelial system; it very seldom appears in the blood of its victims. A sand fly, therefore, cannot pick up the organism from a sick human being, but only from a dog that does have leishmania in its skin. In India the dog population is not infected, however, and there the parasite does circulate in white cells of the blood of kala-azar patients, where it is accessible to flies. It has adapted itself to survive and spread in the absence of an extra-human source.

In other diseases this process has long since been completed, and we think of them as purely human afflictions. Often, however, their source is betrayed by the existence of closely similar organisms that infect man and other animals, invading the same tissues and evoking the same serological reactions. In some cases the identical organism can still infect both man and beast. Such parasites, descended from a single ancestor, have evidently retained all their original characteristics and invasive powers despite



ZOONOSES constitute an ecological complex that embraces the infective microorganism (*top*), the animal "reservoir" (*center*) in which this organism perpetuates itself, often without producing any disease, and the insect or other arthropod vector (*bottom*) that

millions of years of development in different hosts.

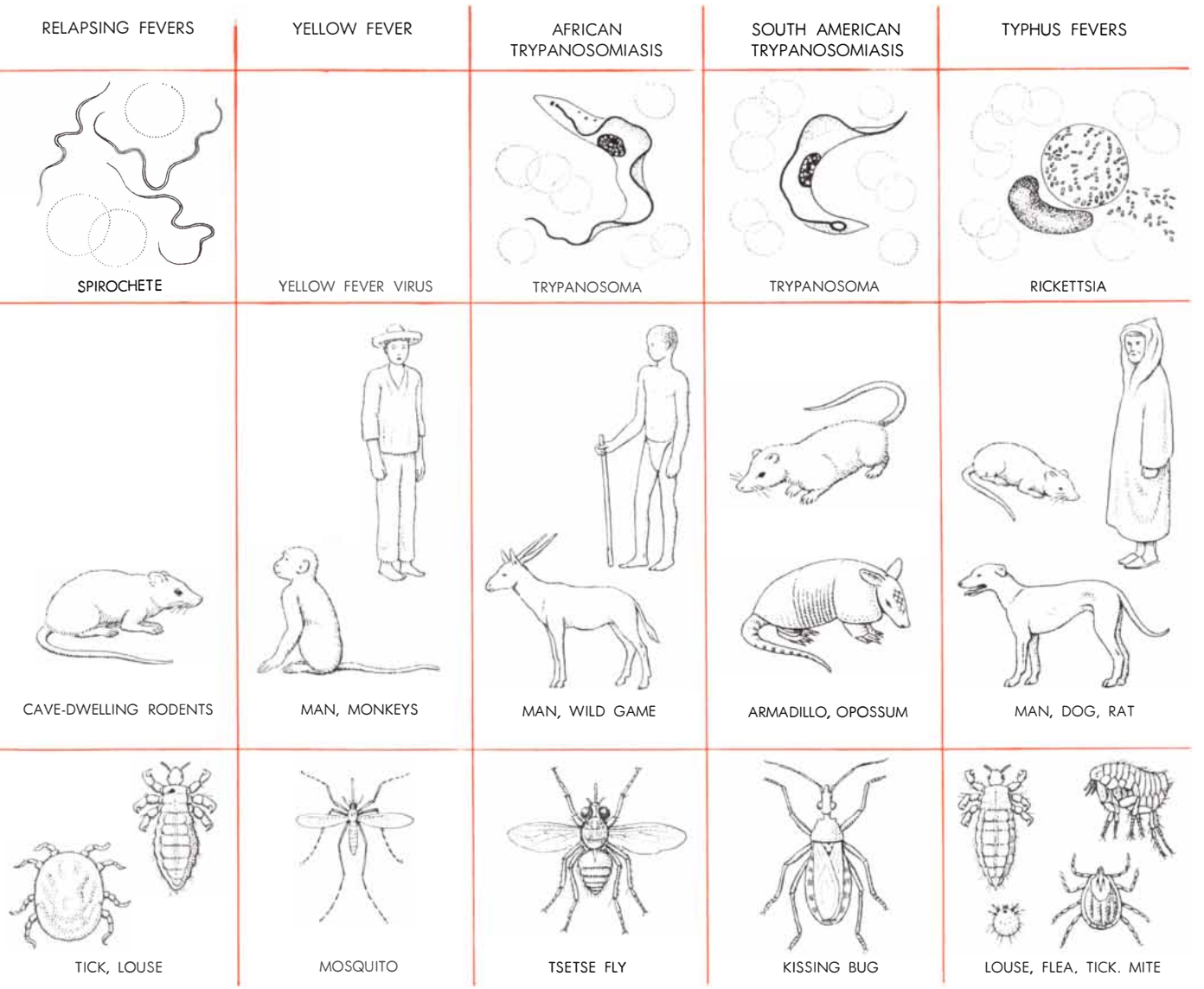
One such family are the plasmodia, the blood protozoa that cause malaria. Widely distributed in the animal kingdom among reptiles, birds, rodents and mammals, four species can develop in human beings. Identical malaria parasites are found in both men and chimpanzees. Man can easily be infected with *Plasmodium knowlesi*, a chimpanzee plasmodium; chimpanzees inoculated with a supposedly strictly human form, *P. malariae*, will develop the typical quartan fever produced by this parasite.

Another example is provided by some of the filarial infections of man, which in their chronic form cause elephantiasis or blindness. The filariae (nematode worms) are transmitted from infected to healthy persons by mosquitoes and biting flies; it had long been believed that they were limited to this insect-human cycle. Recently, however, it has been found that monkeys are a reservoir of one of the African species of filaria, and that an Asian type infects dogs, cats, monkeys and other animals.

Finally we come to yellow fever. Its history in the New World is a tale of fear, of hope, of shattered illusions. It amply demonstrates the dangers of a human disease that has a strong foothold in nature, an infection that has two aspects: an endemic-epidemic disease of man and a zoonosis among wild animals.

Yellow fever is nowadays confined to parts of Central and South America and Africa. But there is no guarantee that it will stay within these limits. It represents an enormous menace to the crowded populations of tropical India, Indonesia, Thailand, China and other parts of the Far East, where for reasons unknown to us it has not taken a foothold, although all the necessary ecological conditions exist there.

In its classical urban form yellow fever is an acute, usually fatal virus infection, carried between human hosts by mosquitoes of the Aëdes family, especially *Aëdes aegypti*. Virus appears in the blood of infected individuals in the last days of the incubation, before they show signs of the clinical disease, and persists into the first few days of the acute infection. During this period a female mosquito that bites an infected person absorbs the virus with the blood meal. The organism multiplies in her



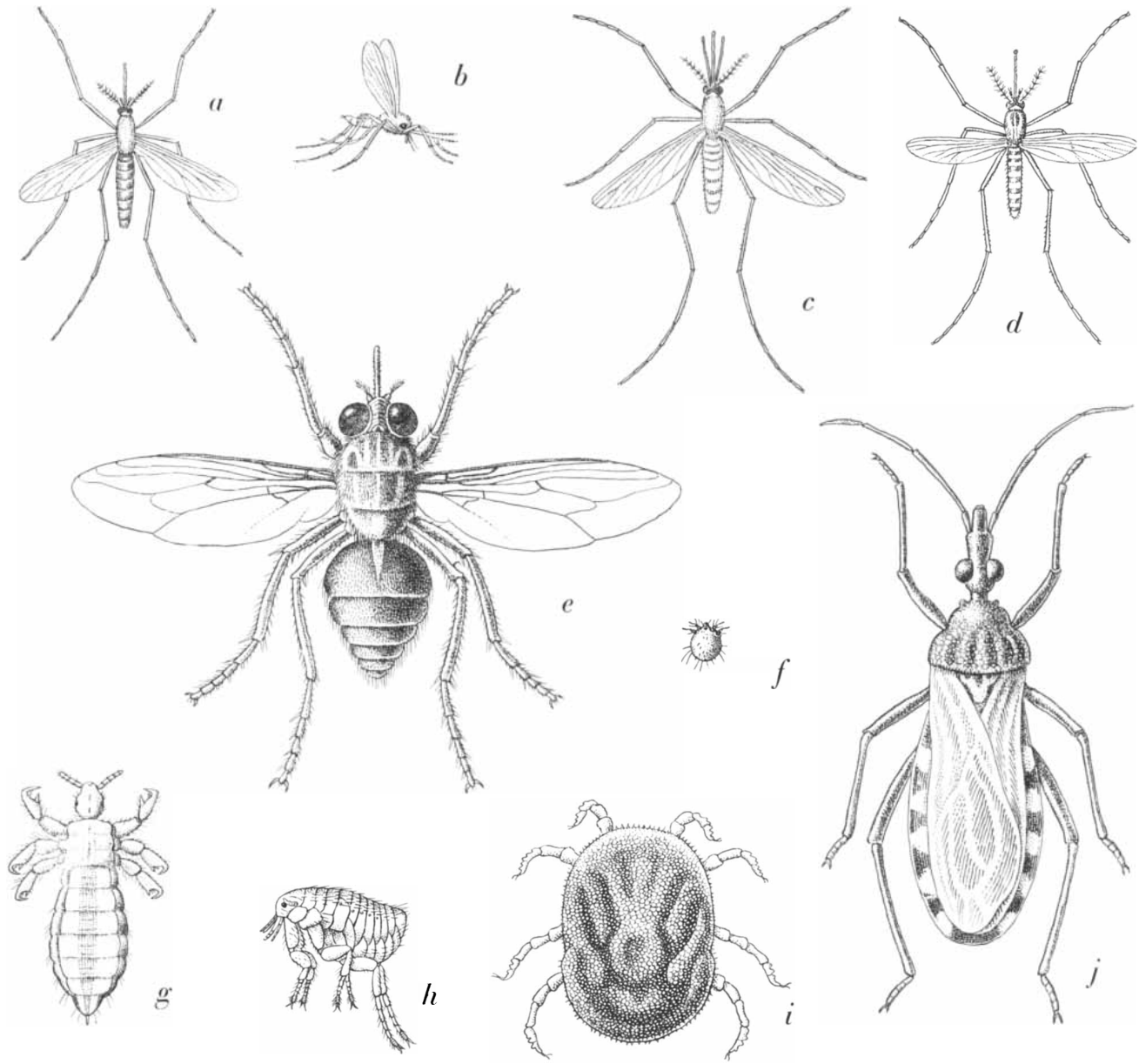
carries the infection among the animal hosts and may also transfer it to human beings. In some cases the reservoirs are wild animals that do not ordinarily intrude on territory occupied by man. In other cases the animals live in direct contact with human beings.

body and persists for the rest of her life.

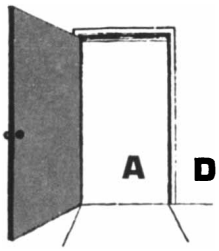
These facts were elucidated in the early days of this century by the investigations of the American Yellow Fever Commission. Control measures against Aëdes mosquitoes in Central and South America had by the 1920's succeeded in greatly reducing yellow fever. There seemed reason to hope that the disease might be totally eliminated. But then was discovered "jungle" yellow fever, a zoonosis of monkeys that is transmitted by a different kind of mosquito, *Haemagogus capricorni*, which lives in treetops. The virus of this wild fever is apparently the same as that of the human form of the disease, and men going into the jungle are occasionally infected. If they return to a town during their incubation period and in turn infect the local Aëdes, the single case of chance infection may snowball into a grave urban epidemic. To wipe out the jungle mosquitoes would be a Herculean task, perhaps impossible at the present time. So this entrenched zoonosis remains a hazard that may bar man's penetration into its strongholds, and is always a threat to break out into inhabited areas.

This discussion of animal-borne disease could include many more examples, but they would merely be further variations on the central theme. We might mention some infections that travel to man from other mammals without requiring an intermediate vector. Bovine tuberculosis, brucellosis, rabies and tularemia are instances of this. The only essential difference is a somewhat simpler ecological pattern.

What is the significance of the zoonoses in our industrial age? We have noted that all of them are bound by certain ecological systems in nature, mostly in rural environments. Modern ways of life are disrupting these old systems in various ways. For example, new



VECTORS that carry zoonoses are insects or other arthropods. Shown here are: (*a*) the Culex mosquito, which carries filariasis, (*b*) sand fly, which carries leishmaniasis, (*c*) Anopheles mosquito, which carries malaria, (*d*) Aëdes mosquito, which carries yellow fever, (*e*) tsetse fly, which carries African trypanosomiasis, (*f*) mite and (*g*) louse, both of which carry typhus, (*h*) rat flea, which carries plague, (*i*) tick, which carries relapsing fever, and (*j*) kissing bug, which carries South American trypanosomiasis.



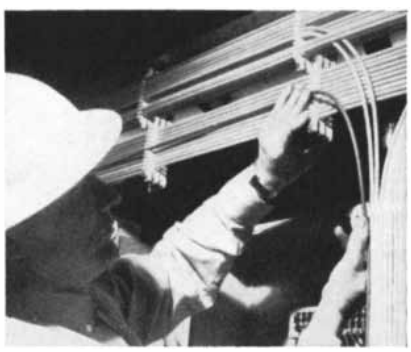
A DOOR IS OPENED... TO COST SAVINGS IN INSTRUMENT-AIR CONTROL

Some wit has said, "Air is free; it's *breathing* that costs money." The same can be said about instrument-air control systems. Miles of expensive tubing are needed to convey air impulses between control panels and field instruments. Until lately, copper was king in this area—particularly in chemical processing, petroleum refining, and in school and office heating and conditioning.

Now, however, a new plastic offers to do the job cheaper—and often better. It's extrudable PLASKON® Nylon, a special form of polycaprolactam (nylon-6) marketed by our Plastics and Coal Chemicals Division. Available in a flexible grade (without sacrifice of tensile strength), it is ideally suited for instrumentation tubing.

Supplants copper

Very logical reasons account for the fact that nylon tubing is supplanting copper. It costs less as a material—averages *half* as much in sizes under ¾ of an inch. Its flexibility reduces installation time by eliminating costly bending and drawing—achieves complex bends where copper might kink. It comes in continuous lengths, avoids the joining of short sections. Connections, when needed, can be made with conventional fittings. It's adaptable to many installation methods, including factory- and job-made bundles. It's light—⅛ the weight of copper. It's color-codable. And nylon, of all the common flexible plastics, is the strongest, toughest and most heat-resistant, with unique surface hardness and resistance to abrasion.



Flexibility of PLASKON *Nylon tubing makes even right-angle bends easy.*

Installing PLASKON *Nylon instrumentation tubing at Allied Chemical's Hopewell, Virginia plant. Note the 1000-foot, continuous, light-weight coils held by workman.*

Proved by use

About now, some cynic is sure to ask, "If the stuff's so darn good, why don't you use it yourself?" We do. We do indeed. In our Edgewater, N. J., plant it has given us nearly two years of trouble-free service. More than 125,000 feet of PLASKON Nylon tubing are installed in our Hopewell, Virginia, plant. Besides saving us more than a few coppers in installation costs (30%, in fact), it serves both as a test and demonstration of nylon instrumentation tubing. You can't help but learn a lot about tubing when you put in nearly 25 miles of it. We'd like to pass on our findings to you.

Allied Chemical

BASIC TO AMERICA'S PROGRESS

Limitations? Some, to be sure, but more than offset by the advantages. A few chemicals attack nylon, and where these are present, it should be protected. The melting point is 420 F. And nylon can burn—but with reluctance, and it tends to be self-extinguishing.

Wide applications

You'll find many other uses for nylon tubing besides instrument-air control: high-pressure hydraulic and air, lubricating and gasoline, hot water, paint spraying and solvent conveying. And, of course, pipe, tape and complex shapes can be extruded from PLASKON Nylon for a multitude of applications.

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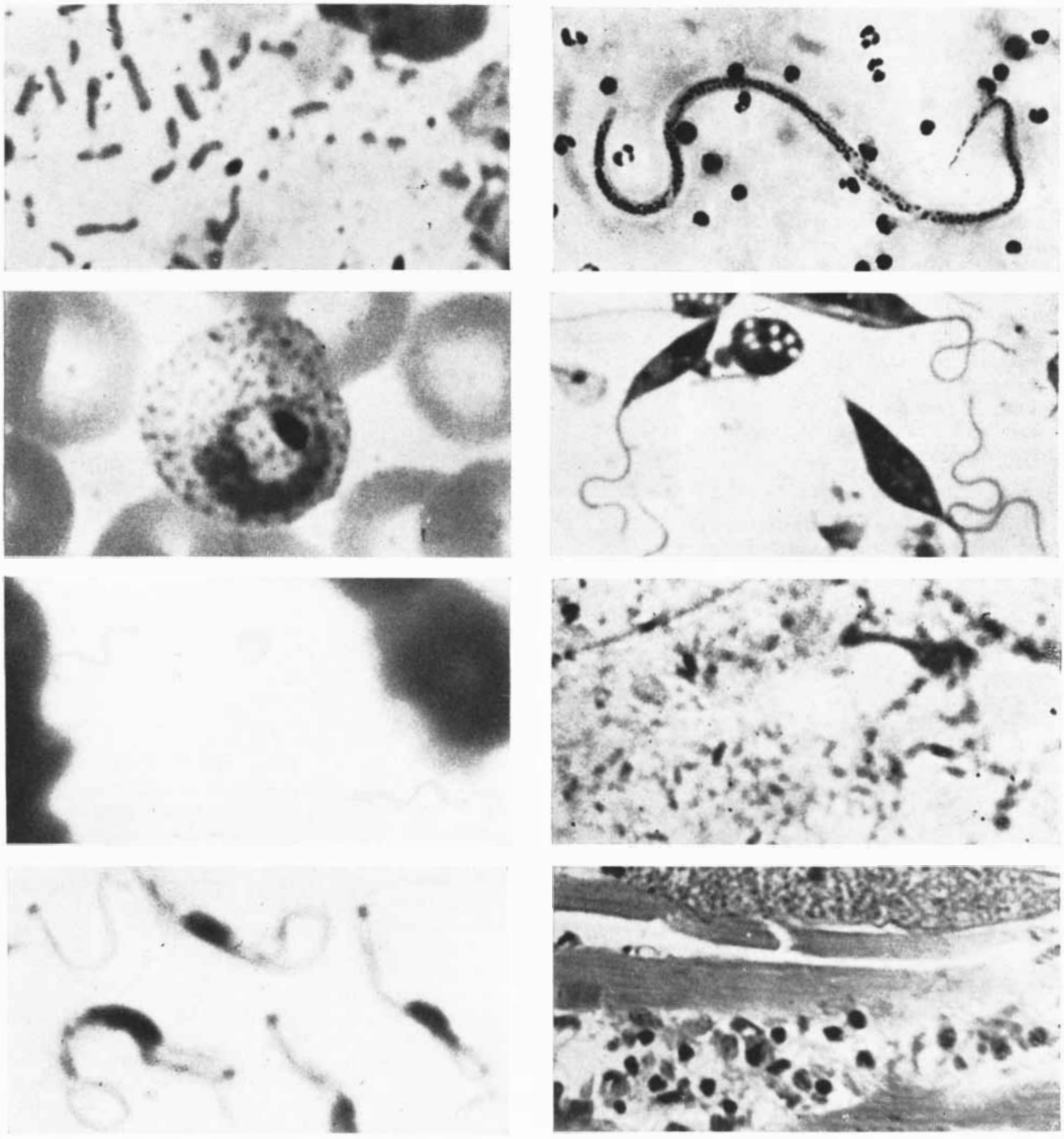
To bring you the whole story of PLASKON Nylon tubing, we have prepared a booklet describing both the advantages and installation methods. Included is a detailed cost analysis of our Hopewell installation, showing in actual figures how it can save money. For a copy, just write, on company letterhead, to Allied Chemical Corporation, Dept. 56-S, 61 Broadway, New York 6, New York, or phone HAnover 2-7300.

insecticides may succeed in wiping out certain of the diseases. On the other hand, it is well to remember that over half of the world's population still live poor peasants' lives, walk barefoot and sleep on mud floors. The automobile and airplane have shortened the distance between these exposed environments and the "safer" parts of the world.

However, the chief danger does not lie here, but in the mutable character of some pathogens, in their powers of adaptation to new surroundings and their ability to develop new modes of spreading. Chance transfers, or the pressure of purposeful campaigns of eradication, may push disease organisms into new environments and biological cycles. The results of such shifts cannot be foreseen.

In many parts of the world man still faces a wild frontier. Before his tractors push farther into the tundra and his electric saws fell the giant trees of the jungle he will do well to reconnoiter the unknown terrain, mapping and studying the nests of wild infection, to be ready for the disease that may be lying in wait.



MICROORGANISMS of some zoonoses are shown in these photomicrographs of stained specimens at various magnifications. From top to bottom at left they are: plague bacilli (*rod shapes*); *Plasmodium* (*dark crescent in red blood cell*); spirochetes (*faint wavy lines*); the trypanosomes of African sleeping sickness (*curled shapes*). From top to bottom at right the organisms are: microfilaria, the prelarval form of the filariasis parasite (*curved thread*); *Leishmania*, in the flagellate form which they assume in the vector (*pointed ovals with thin tails*); *Rickettsiae* (*small dots*); the trypanosomes of Chagas' disease (*dots within a section of heart muscle*).

SILICON NEWS from Dow Corning

Watchword: Reliability

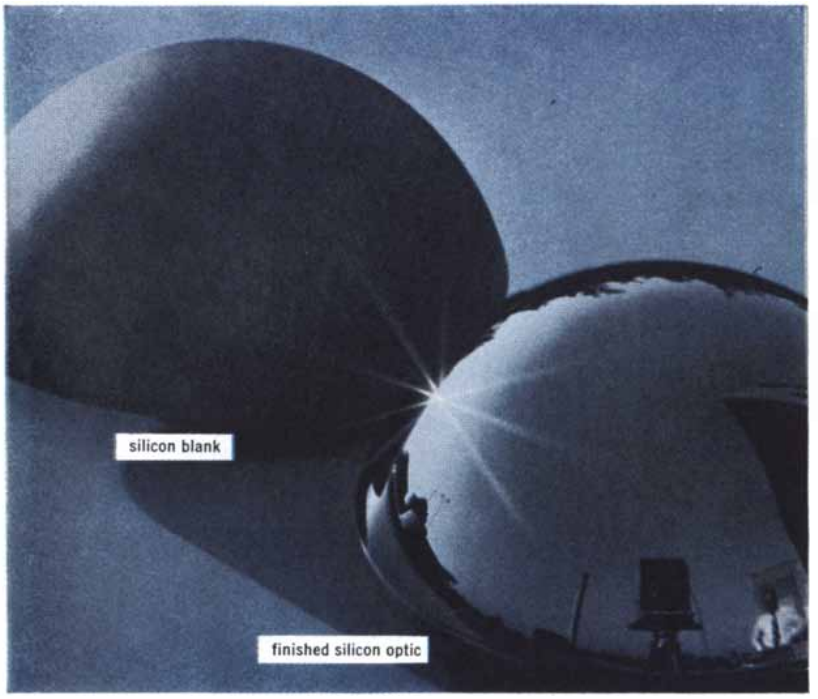


PHOTO COURTESY ACF ELECTRONICS DIVISION
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Avion engineer "reflects" on Dow Corning silicon dome during test of infrared transmission characteristics. Avion's capability in infrared technology dates back to early research and development on the famous "Sidewinder" missile. Present interests and projects include airborne detection and tracking devices.

Silicon Optics Enhance Reliability and Versatility of Infrared Detection Systems

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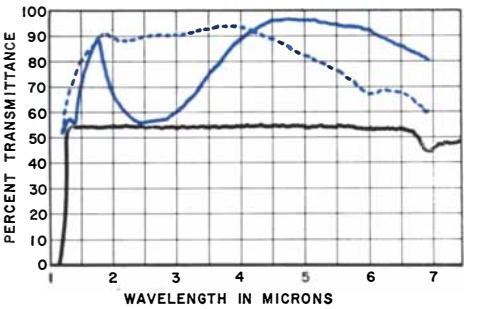
Free Brochure Available — plus latest data on optical silicon for infrared detection. Write today . . . your name will be kept on a special mailing list to receive all new bulletins on this subject. Please address your inquiry to Dept. 9805.



TRANSMISSION DATA COURTESY OPTICAL COATING LABORATORY, INC., SANTA ROSA, CALIFORNIA.

The black line indicates the percent of transmittance for silicon is relatively constant from 1.3 to 6.7 microns. Blue lines show how transmission is increased by coating. Single coating provides maximum transmission on a narrow band; several coatings, dotted blue line, give maximum transmission on a broad band.

Properties of Dow Corning Optical Silicon

Specific gravity	2.329 at 25 C
Melting point	1420 C
Hardness	7 Moh
	1150 Knoop
Thermal conductivity	0.39 cal (cm sec. C°)
Thermal expansion	4.15×10^{-6}/C°
Specific heat	0.168 at 25°C
Dielectric constant	13 at 9.37×10^9 cps
Elastic modulus (Youngs)	19×10^6 psi
Flexural strength	20,000 psi

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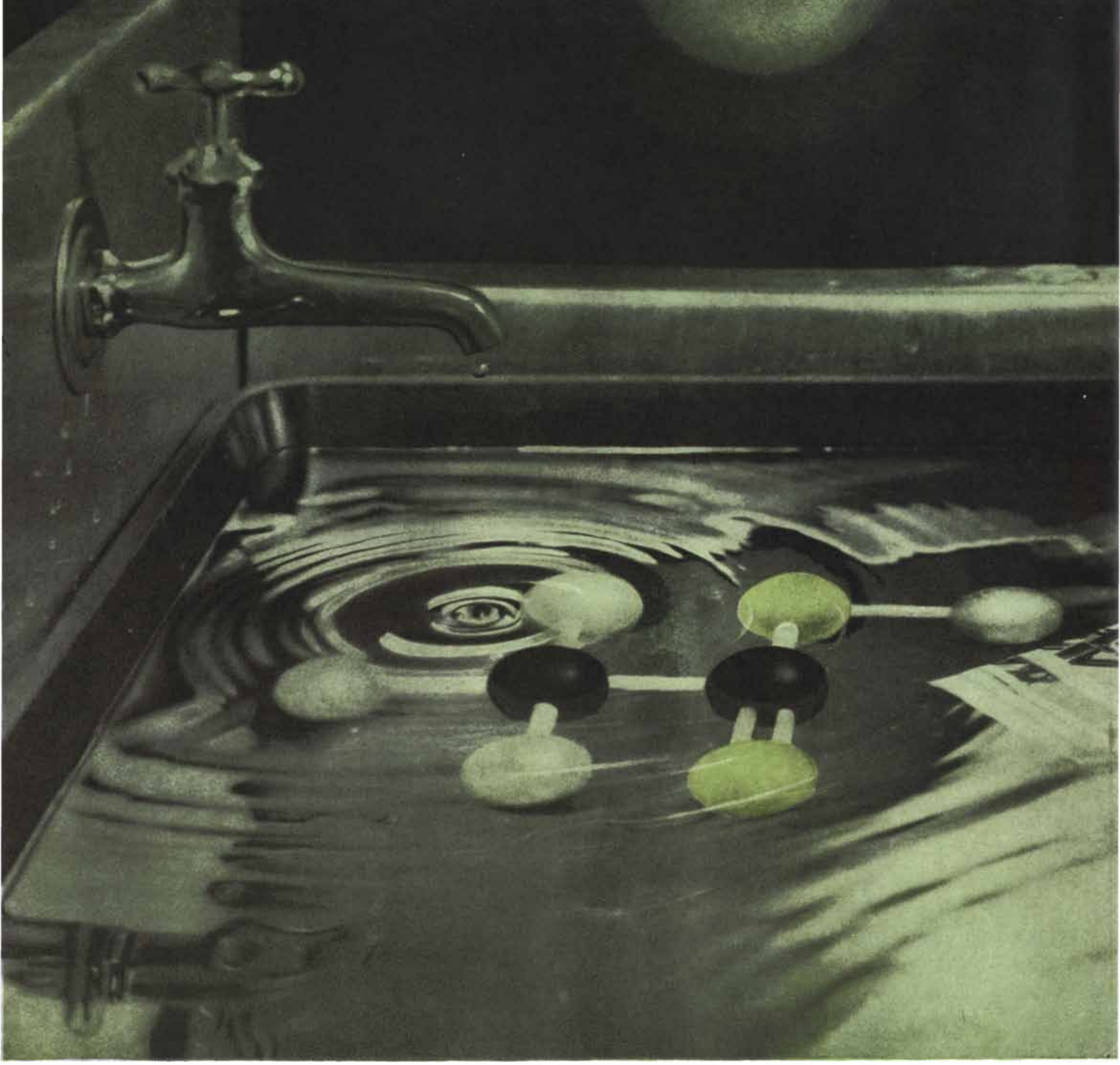

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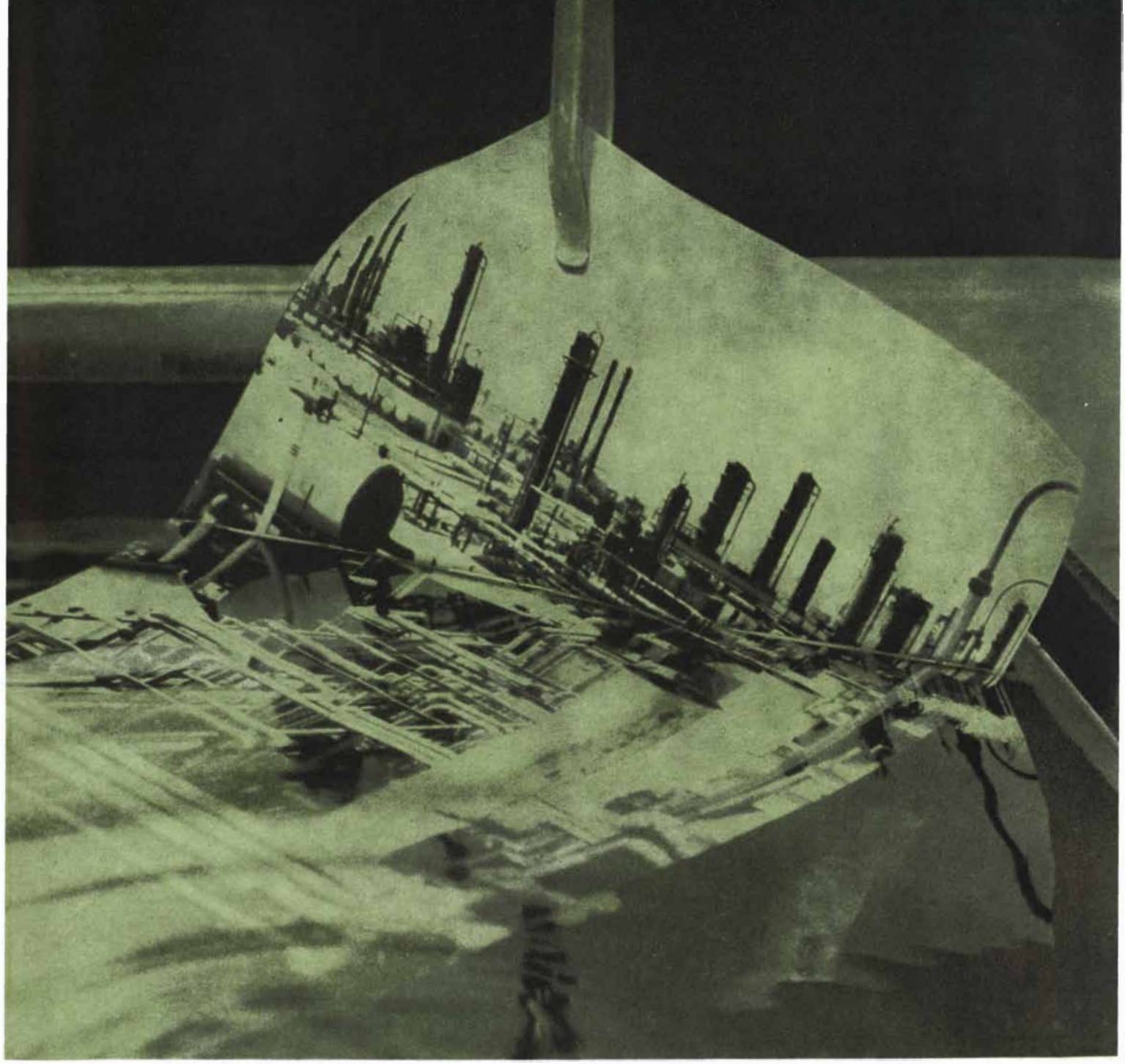

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MATHEMATICAL GAMES

Reflections on the packing of spheres

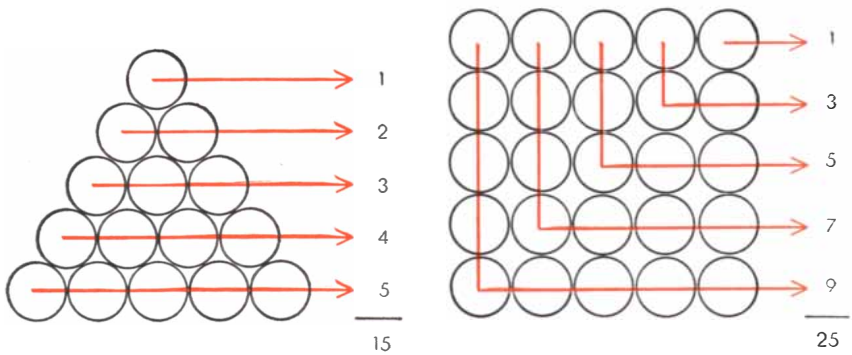
by Martin Gardner

Spheres of identical size can be piled and packed together in many different ways, some of which have fascinating recreational features. These features can be understood without models, but if the reader can obtain a supply of 30 or more spheres, he will find them an excellent aid to understanding. Table-tennis balls are perhaps the best for this purpose. They can be coated with rubber cement, allowed to dry, then stuck together to make rigid models.

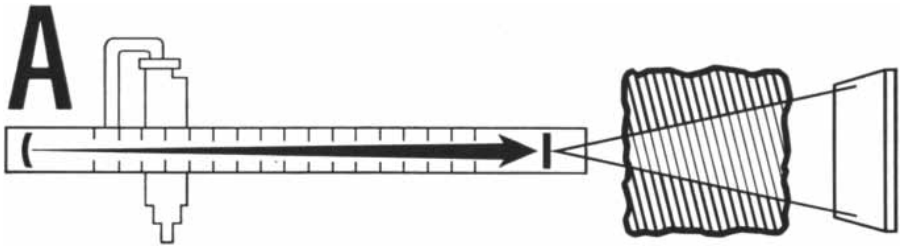
First let us make a brief two-dimensional foray. If we arrange spheres in square formation [*see illustration at right below*], the number of balls involved will of course be a square number. If we form a triangle [*see illustration at left*], the number of balls is a triangular number. These are the simplest examples of what the ancients called "figurate numbers." They were intensively studied by early mathematicians (a famous treatise on them was written by Blaise Pascal), and although little attention is paid them today, they still provide intuitive insights into many aspects of elementary number theory.

For example, it takes only a glance at the illustration at left to see that the sum of any number of consecutive positive integers, beginning with 1, is a triangular number. A glance at the illustration at right shows that square numbers are formed by the addition of consecutive *odd* integers, beginning with 1. The top illustration on page 177 makes immediately evident an interesting theorem known to the ancient Pythagoreans: Every square number is the sum of two consecutive triangular numbers. The algebraic proof is simple. A triangular number with n units to a side is the sum of $1 + 2 + 3 + \ldots n$, and can be expressed by the formula $\frac{1}{2}n(n + 1)$. The preceding triangular number has the formula $\frac{1}{2}n(n - 1)$. If we add the two formulas and simplify, the result is n^2. Are there numbers that are simultaneously square and triangular? Yes, there is an infinite number of them. The smallest (not counting 1, which belongs to any figurate series) is 36; then the series continues: 1225, 41616, 1413721, 48024900 . . . It is not so easy to devise a formula for this series.

Three-dimensional analogies of the plane-figurate numbers are obtained by piling spheres in pyramids. Three-sided pyramids, the base and sides of which are equilateral triangles, are models of what are called the tetrahedral numbers. They form the series 1, 4, 10, 20, 35, 56, 84 . . . and can be represented by the formula $\frac{1}{6}n(n + 1)(n + 2)$, where n is the number of balls along an edge. Four-sided pyramids, with square bases and equilateral triangles for sides (*i.e.*, half of a regular octahedron), represent the square pyramidal numbers 1, 5, 14, 30, 55, 91, 140 . . . They have the for-



The basis of triangular numbers (left) *and of square numbers* (right)



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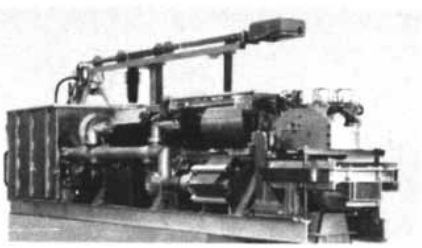

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po-si'tion

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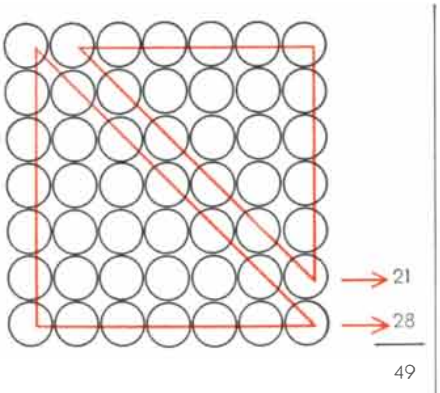
mula $\frac{1}{6}n(n + 1)(2n + 1)$. Just as a square can be divided by a straight line into two consecutive triangles, so square pyramids can be divided by a plane into two consecutive tetrahedral pyramids. (If you build a model of a pyramidal number, the bottom layer has to be kept from rolling apart. This can be done by placing rulers or other strips of wood along the sides.)

Many old puzzles exploit the properties of these two types of pyramidal number. For example, in making a courthouse monument out of cannon balls, what is the smallest number of balls that can first be arranged on the ground as a square, then piled in a square pyramid? The surprising thing about the answer (4,900) is that it is the *only* answer. (The proof of this is difficult, and was not achieved until 1918.) Another example: A grocer is displaying oranges in two tetrahedral pyramids. By putting together the oranges in both pyramids he is able to make one large tetrahedral pyramid. What is the smallest number of oranges he can have? If the two small pyramids are the same size, the unique answer is 20. If they are different sizes, what is the answer?

Imagine now that we have a very large box, say a crate for a piano, which we wish to fill with as many golf balls as we can. What packing procedure should we use? First we form a layer packed as shown by the black circles in the illustration below. The second layer is formed by placing balls in alternate hollows as indicated by the open gray circles. In making the third layer we have a choice of two different procedures:

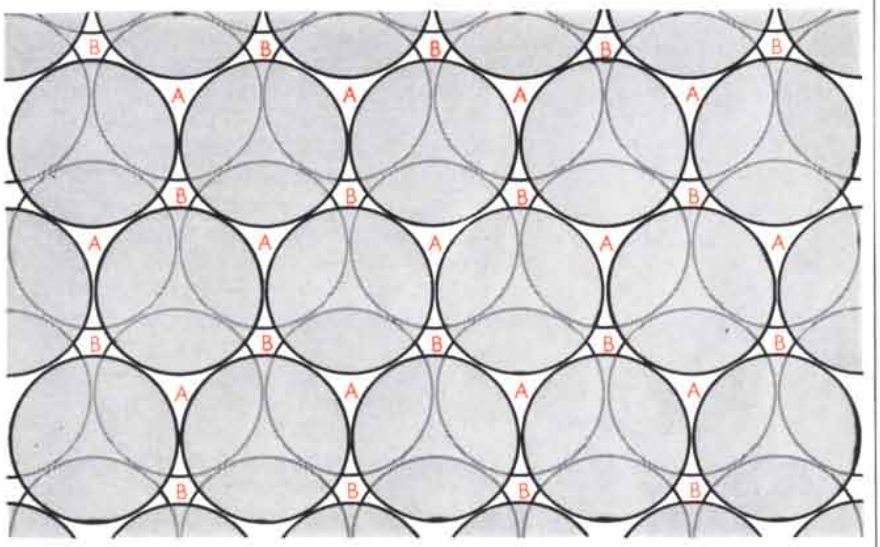


Square and triangular numbers are related

1. We place each ball on a hollow that is directly above a ball in the first layer. If we continue in this way, placing the balls of each layer directly over those in the next layer but one, we produce a structure called hexagonal close-packing.

2. We place each ball in a hollow directly above a hollow in the first layer. If we follow this procedure for each layer (each ball will be directly above a ball in the third layer beneath it), the result is known as cubic close-packing. Both the square and the tetrahedral pyramids have a packing structure of this type, though on a square pyramid the layers run parallel to the sides rather than to the base.

In forming the layers of a close packing we can switch back and forth whenever we please from hexagonal to cubic packing to produce various hybrid forms of close packing. In all these forms—cubic, hexagonal and hybrid—each ball touches 12 other balls that surround it, and the density of the packing (the ratio



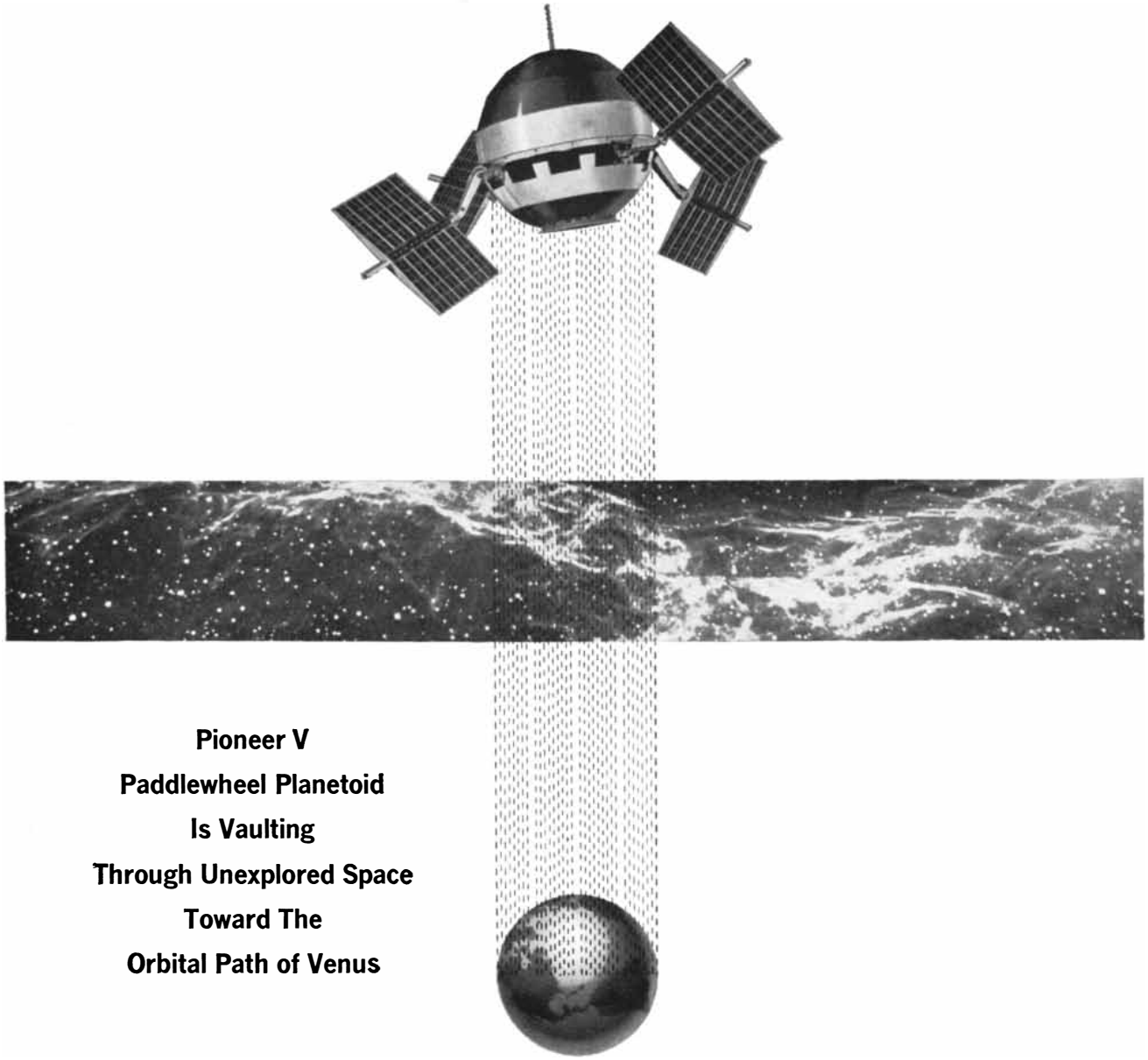
In hexagonal close packing balls go in hollows labeled A; in cubic, in hollows labeled B

of the volume of the spheres to the total space) is .74, or almost 75 per cent.

Is .74 the largest density obtainable? No denser packing is known, but in an article published in 1958 (on the relation of close packing to froth) H. S. M. Coxeter of the University of Toronto made the startling suggestion that perhaps the densest packing has not yet been found. It is true that no more than 12 balls can be placed so that all of them touch a central sphere, but a 13th ball can *almost* be added. The large leeway here in the spacing of the 12 balls, in contrast to the complete absence of leeway in the close packing of circles on a plane, suggests that there might be some form of irregular packing that would be denser than .74. No one has yet proved that no denser packing is possible, or even that 12 point-contacts for each sphere are necessary for densest packing. As a result of Coxeter's conjecture George D. Scott of the University of Toronto recently made some experiments in random packing by pouring large numbers of steel balls into spherical flasks, then weighing them to obtain the density. He found that stable random-packings had a density that varied from about .59 to .63. So if there is a packing denser than .74, it will have to be carefully constructed on a pattern that no one has yet thought of.

Assuming that close packing is the closest packing, readers may like to test their packing prowess on this exceedingly tricky little problem that will be answered here next month. The interior of a rectangular box is 10 inches on each side and five inches deep. What is the largest number of steel spheres one inch in diameter that can be packed in this space?

If close-packed circles on a plane expand uniformly until they fill the interstices between them, the result is the familiar hexagonal tiling of bathroom floors. (This explains why the pattern is so common in nature: the honeycomb of bees, a froth of bubbles between two flat surfaces almost in contact, pigments in the retina, the surface of certain diatoms and so on.) What happens when closely packed spheres expand uniformly in a closed vessel, or are subjected to uniform pressure from without? Each sphere becomes a polyhedron, its faces corresponding to planes that were tangent to its points of contact with other spheres. Cubic close-packing transforms each sphere into a rhombic dodecahedron [*see top illustration on page 180*], the 12 sides of which are congruent rhombi. Hexagonal close packing turns each ball into a trapezo-rhombic



Pioneer V
Paddlewheel Planetoid
Is Vaulting
Through Unexplored Space
Toward The
Orbital Path of Venus

At this moment Pioneer V, one of the most advanced space probe vehicles ever launched, is on a course toward the path of Venus—26 million miles from earth. Blasted aloft March 11 by a Thor Able-4 rocket booster, this miniature space laboratory will reach its destination in about 130 days.

The project, carried out by Space Technology Laboratories for the National Aeronautics and Space Administration under the direction of the Air Force Ballistic Missile Division, may confirm or disprove long-standing theories of the fundamental nature of the solar system and space itself.

Energy from the sun—captured by almost 5,000 cells mounted in the four paddles—is used to supply all of the electrical power to operate the sophisticated array of instrumentation packed into the 94-pound spacecraft which measures only 26″ in diameter.

By combining a phenomenal digital electronic brain (telebit) with a powerful radio transmitter inside the satellite, STL scientists and engineers expect to receive communications from Pioneer V at their command over interplanetary distances up to 50 million miles.

STL's technical staff brings to this space research the same talents which have provided over-all systems engineering and technical direction since 1954 to the Air Force missile programs including Atlas, Thor, Titan, Minuteman, and related space programs.

Important positions in connection with these activities are now available for scientists and engineers with outstanding capabilities. Inquiries and resumes are invited.

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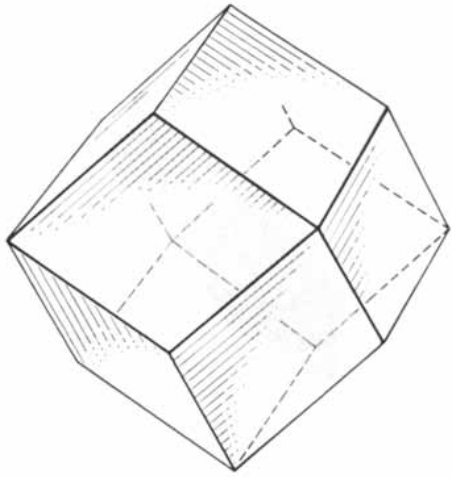
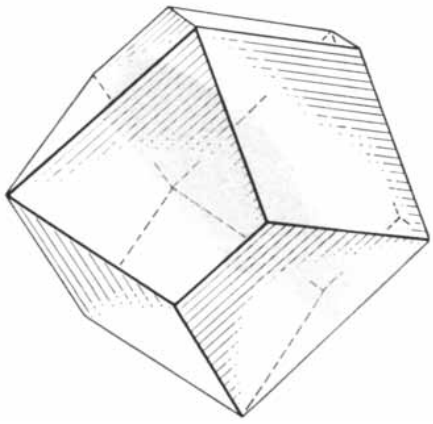
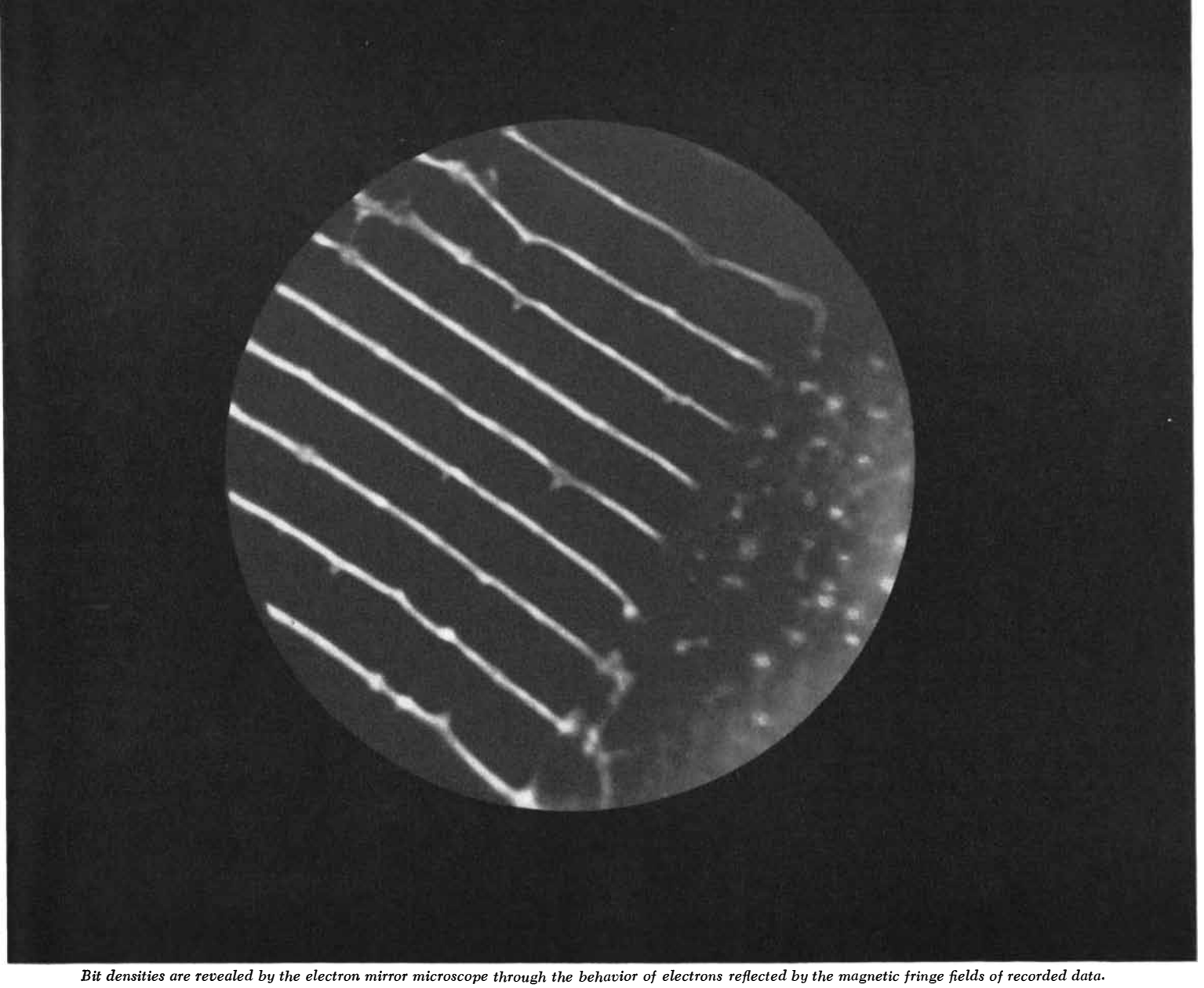




Packed spheres expand into dodecahedra

dodecahedron [*see bottom illustration*], six faces of which are rhombic and six trapezoidal. If this figure is sliced in half along the gray plane and one half is rotated 60 degrees, it becomes a rhombic dodecahedron.

In 1727 the English physiologist Stephen Hales wrote in his book *Vegetable Staticks* that he had poured some fresh peas into a pot, compressed them and had obtained "pretty regular dodecahedrons." The experiment became known as the "peas of Buffon" (because the Comte de Buffon later wrote about a similar experiment), and most biologists accepted it without question until Edwin B. Matzke, a botanist at Columbia University, repeated the experiment. Because of the irregular sizes and shapes of peas, their nonuniform consistency and the random packing that results when peas are poured into a container, the shapes of the peas after compression are too random to be identifiable. In experiments reported in 1939 Matzke compressed lead shot and found that if the spheres had been cubic close-packed, rhombic dodecahedra were formed; but if they had been randomly packed, irregular 14-faced bodies predominated.



Bit densities are revealed by the electron mirror microscope through the behavior of electrons reflected by the magnetic fringe fields of recorded data.

Reflections from an Electron Mirror

The photograph is a representation of the magnetic fringe fields above a small portion of a recording surface. Behind these magnified tracks of recorded data is the story of a device now decades old in principle, but which has only recently been applied to the study of high-density magnetic information storage.

The electron mirror microscope was constructed by IBM scientists as a laboratory instrument. Based on the excellent resolution capabilities of an electron beam, the electron mirror principle has its primary application in the observation of tiny magnetic fringe fields.

In the operation of an electron mirror microscope, an electron beam is accelerated down a tube toward a specimen mounted on a conductive plate with a negative potential relative to the cathode. At the zero equipotential surface in the tube, the electrons traveling toward the specimen change their directions and are reflected in somewhat the same way light rays are reflected by a mirror. By controlling the potentials of the cathode and the conductive plate, the "mirror" can be placed at any height above the magnetic surface. When the mirror is set close enough to the surface to be in the fringe fields of recorded information, these fields distort the return paths of electrons in the beam. Passing the return beam through a magnetic lens results in a magnified representation on a phosphor viewing plate, capable of resolving bit densities far greater than those in use in present systems.

It is well known that the "writing" abilities of present magnetic recording transducers exceed their "reading" abilities. The mirror microscope produces accurate evidence of all-but-undetectable recorded information. Thus the magnetic recording process is no longer limited to verification by velocity-dependent readback capabilities. By the same token, the mirror microscope serves both as the spur to, and the measure of progress toward further refinements in the art of magnetic recording.

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These results have important bearing, Matzke has pointed out, on the study of such structures as foam, and living cells in undifferentiated tissues.

The problem of closest packing suggests the opposite question: What is the *loosest* packing; that is, what rigid structure will have the lowest possible density? For the structure to be rigid, each sphere must touch at least four others, and the contact points must not be all in one hemisphere or all on one equator of the sphere. In his *Geometry and the Imagination,* first published in Germany in 1932, David Hilbert describes what was then believed to be the loosest packing: a structure with a density of .123. In the following year, however, two other German mathematicians, Heinrich Heesch and Fritz Laves, published the details of a much looser packing with a density of only .0555. Whether there are still looser packings is another intriguing question that, like the question of the closest packing, remains undecided.

This is my first opportunity to comment on the flood of interesting letters that I have received regarding the problems presented here in February. Many readers sent detailed proofs that any obtuse triangle could be divided into seven acute triangles, that seven was the minimum number and that eight was the smallest number for the square. For readers who enjoyed those problems, here are two more of the same type. What is the smallest number of acute triangles into which a pentagram (a regular five-pointed star) can be divided? What is the smallest number for a Greek cross (a cross with arms of equal length) formed with five squares?

Hundreds of readers found fourth-degree equation solutions to the problem of the dog that trots around a square of marching cadets. The square is 50 feet on a side and advances at a constant rate while the dog moves at a constant rate around the perimeter. If the dog completes his round trip just as the square completes a 50-foot advance, how far has the dog traveled? I paraphrase an unusually clear and brief solution sent by Robert F. Jackson of the Computing Center at the University of Delaware:

To simplify the problem, let 1 be the side of the square and also the time it takes the cadets to go 50 feet. Their speed will then also be 1. Let x be the distance traveled by the dog and also his speed. The dog's speed with respect to the speed of the square will be $x - 1$ on his forward trip, $\sqrt{x^2 - 1}$ on each of his two transverse trips, and $x + 1$ on

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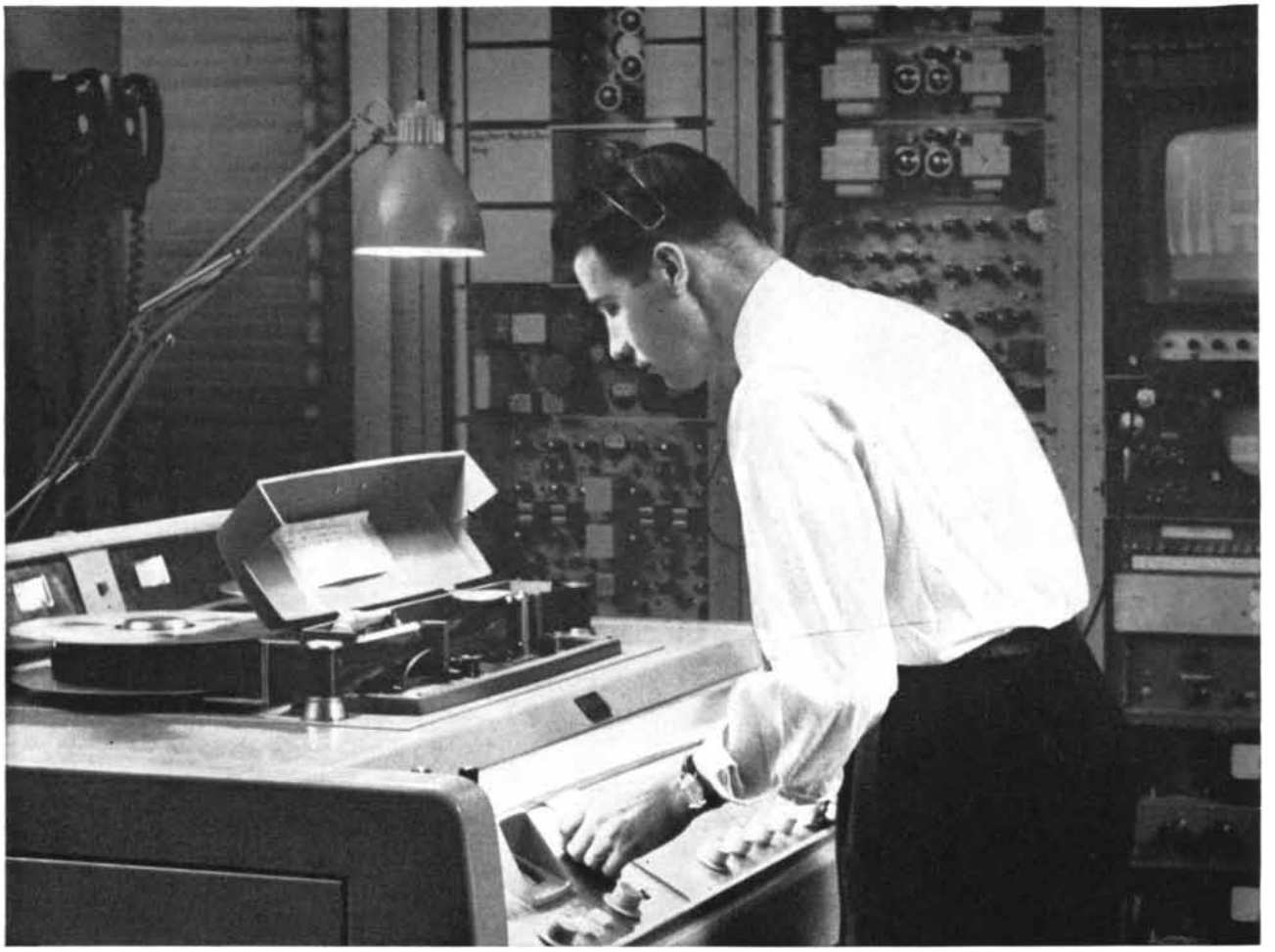

TV producers can cut studio time . . . eliminate costly processing by using video recording tape made with "Mylar".

Tough, thin Du Pont MYLAR helped solve a problem in developing video recording tape for the TV industry

"Mylar" has high strength. With an average tensile strength almost ⅓ that of machine steel, "Mylar" takes the crushing impact of fast traveling bowling ball.

Magnetic recording tape for use in electronic recording of sound and picture for TV broadcasting had to meet new standards of performance. The tape—called video recording tape—had to be thin enough to make intimate contact with revolving recording heads, yet tough enough to withstand relative recording speeds of 1,500 inches per second!

Alert tape manufacturers filled this need by using Du Pont "Mylar"* polyester film as the base for video recording tape. "Mylar", which had already proved its reliability in missile tracking and data computing, provided the necessary strength and toughness in thin gauges to meet the exacting demands of TV recording equipment.

This is but one of the many ways "Mylar" is helping industry improve product performance, develop new products and lower costs. Electric motors, for example, can be made smaller and more efficient with insulation of "Mylar". Manufacturers of electrical cable can cut material costs by using tough, thin "Mylar" as a core binder.

For additional information, write today for our new booklet. E. I. du Pont de Nemours & Co. (Inc.), Film Dept., Room SA-5, Wilmington 98, Del.

*"Mylar" is Du Pont's registered trademark for its brand of polyester film. Du Pont manufactures the base material "Mylar"—not finished video recording tape.

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his backward trip. The circuit is completed in unit time, so we can write this equation:

$$\frac{1}{x-1} + \frac{2}{\sqrt{x^2-1}} + \frac{1}{x+1} = 1$$

This can be expressed as the quadratic equation: $x^4 - 4x^3 - 2x^2 + 4x + 5 = 0$. Only one positive real root is not extraneous: 4.18112+. We multiply this by 50 to get the desired answer: 209.056+ feet.

Theodore W. Gibson of the University of Virginia found that the first form of the above equation can be written as follows, simply by taking the square root of each side:

$$\frac{1}{x-1} + \frac{1}{x+1} = 1$$

This is remarkably similar, Gibson pointed out, to the equation:

$$\frac{1}{\sqrt{x-1}} + \frac{1}{\sqrt{x+1}} = 1$$

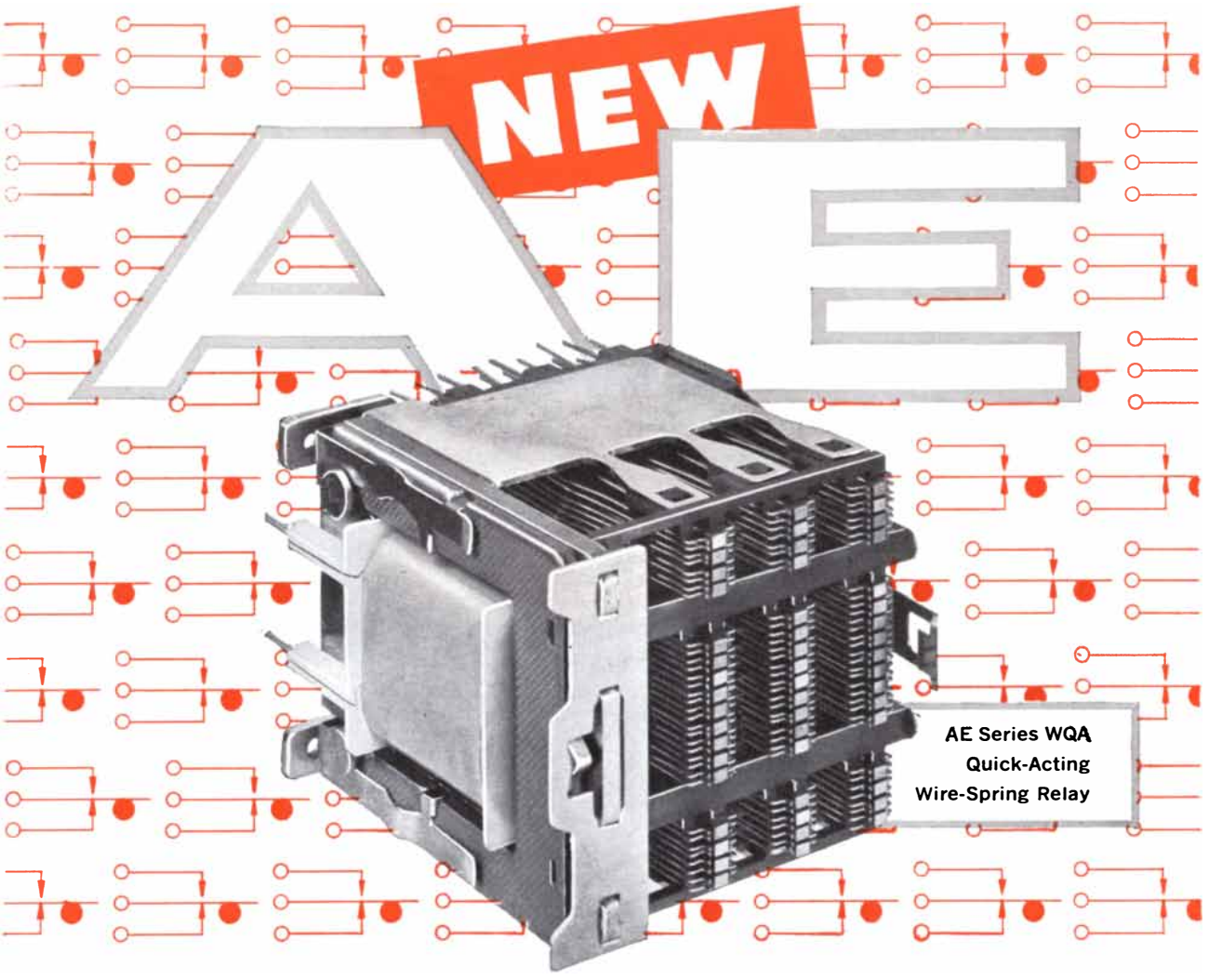
It solves the first version of the problem, in which the dog does not circle the square but simply trots from the rear to the front, then back to the rear again.

Last month we asked if it was possible for a player, in less than 10 moves, to win a game of reversi by eliminating all enemy pieces. The answer is yes. The game outlined below (known as the "fool's mate" of reversi) is won by Red on his eighth move. (Squares of the checkerboard reproduced last month were numbered left to right.)

Black now has a choice of eight cells, but in every case Red can eliminate all black pieces on his next move.

	RED	BLACK
1	28	29
2	36	37
3	22	35
4	43	21
5	20	27
6	19	44
7	45	

The answer to a problem of reversi



TO THE ENGINEER

who wants to transfer 51 circuits simultaneously

If you need simultaneous transfer of a large number of circuits without fail, take a look at AE's new WQA relay. It will do the work of four or more heavy-duty, general-purpose relays each with maximum spring pile-ups, and sustain 50 million or more operations without readjustment.

In the WQA relay, all moving springs pass through holes in a unique actuating "card." Moved directly by the armature, the card in turn actuates all the moving springs. This method of operation pre-establishes exact timing and sequence of all spring operations, and at the same time assures perfectly synchronized "break-before-make" on all circuits.

Contact capacities on WQA relays can be custom-tailored to your needs, with either one, two or three levels of contact assemblies available, each with a capacity of 17 Form C combinations. Other Forms available.

Our circuit engineers will be pleased to work with you in adapting the WQA to your specific design. Or, if you wish, they'll take on the complete packaging job.

If you'd like more information on the WQA relay, address your request for Circular 1957 to: Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois.

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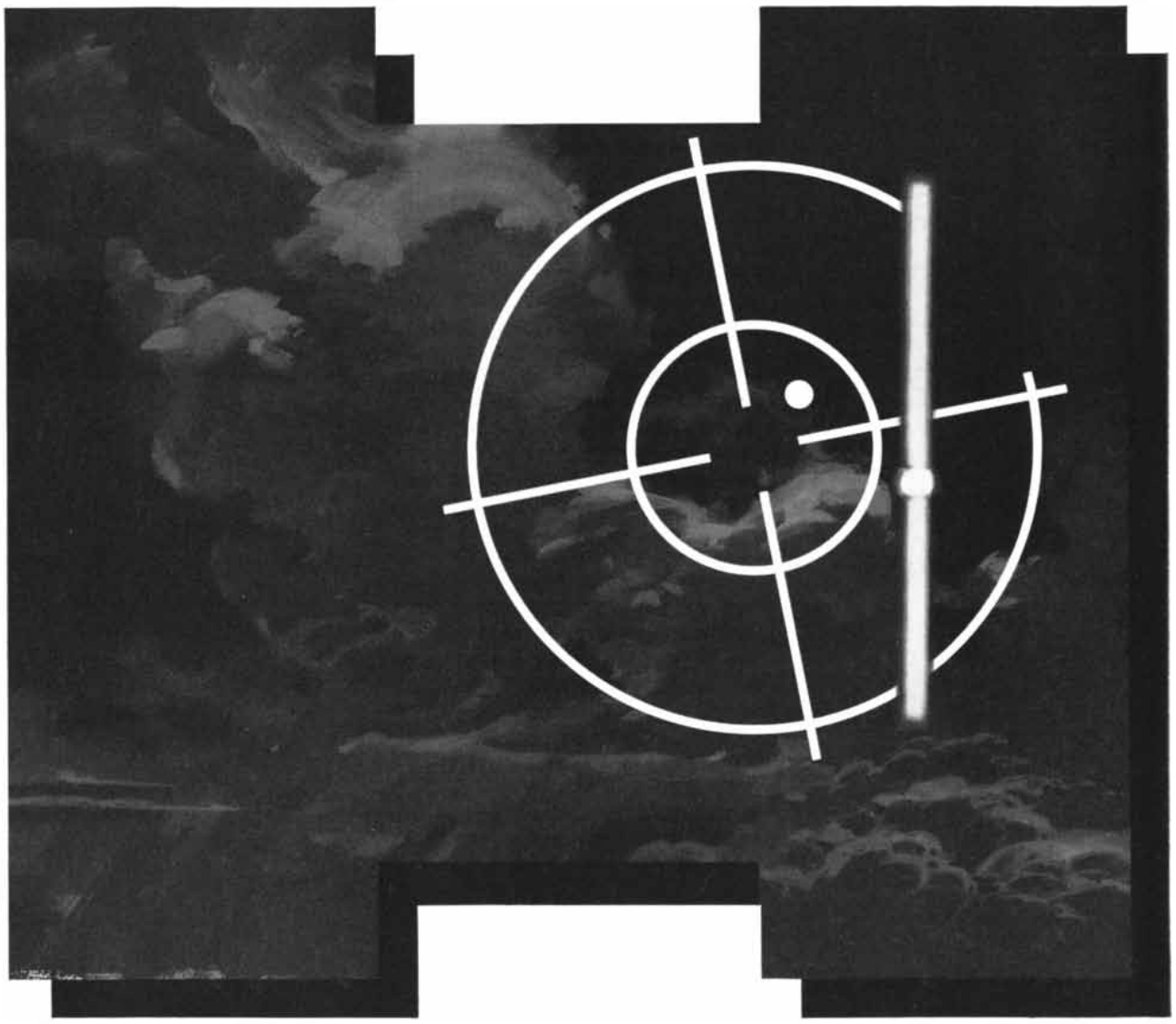
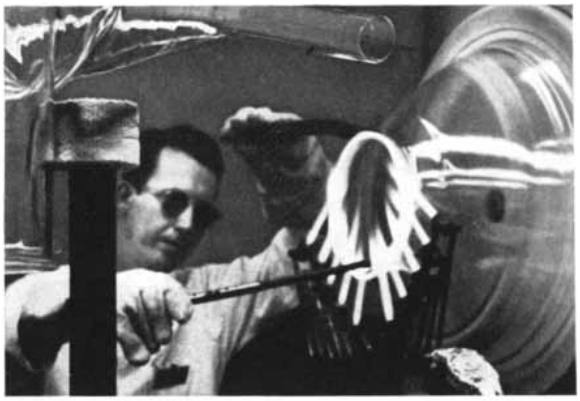
How to take a longer look



The development of advanced electron tubes is just one of the many projects now under way at the Hughes Research Laboratories in Malibu, California.



at air space

The problem presented to Hughes engineers: Build an airborne navigation, target acquisition, armament control system of far greater dimension than ever before.

Hughes engineers solved this challenging problem with several important state-of-the-art advances. One of the most significant was the development of a unique and highly advanced Traveling Wave Tube. This tube's two outstanding advantages: 1) higher power to provide greater range; 2) broader frequency band width for greater operational flexibility.

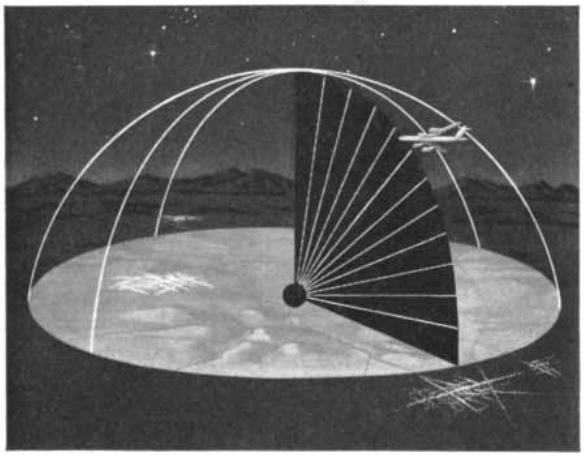
In addition, Hughes engineers designed a radar system that will discriminate against ground return and will detect targets at extreme ranges. Designed to operate in a "hard" counter-measures environment, the radar system was augmented with infrared detection and tracking.

This, and many other Hughes activities in virtually every area of advanced electronics provide the far-seeing engineer with a wide choice of interesting assignments.

A few representative project areas include: advanced data processing systems, molecular electronics, hydrofoil systems, anti-submarine warfare systems, advanced 3-D surface radar systems, space vehicles, nuclear electronics, miniaturized communication systems, ballistic missiles, infrared devices—and a great many others.

The commercial activities of Hughes have many interesting assignments open for imaginative engineers to perform research, development, manufacturing of semiconductors, storage tubes, microwave components, radiation devices, and microwave tubes.

Whatever your field of interest, you'll find Hughes' diversity of advanced projects gives you widest possible latitude for professional and personal growth.



FRESCANAR is a Hughes development that gives umbrella-like radar protection. It positions radar beams by electronic rather than mechanical means.

Newly instituted programs at Hughes have created immediate openings for engineers experienced in the following areas:

Electroluminescence	RF Network Engineering
Infrared	Microwave & Storage Tubes
Solid State Physics	Communications Systems
Digital Computers	Inertial Guidance
Reliability & Quality Assurance	Field Engineering
Systems Design & Analysis	Circuit Design & Evaluation

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Facets of Corrosion Research

Scientists in Argonne's Metallurgy Division are devoting time and energy to fundamental studies which shed new light on the mechanisms of corrosion of film-forming metals in pure water. Employing the basic research approach, a number of apparently fruitful avenues to tangible results are being explored. The Electron Microscope reveals that corrosion films can exhibit structural complexity not otherwise discovered. For example, under certain conditions the oxide film on an aluminum alloy grows as the complex maze of crystal filaments shown here. In another approach, a specially designed instrument measures polarized potentials and reveals details of corrosion processes. The accompanying polarization curves for pure aluminum in boiling water show the effect of the amount of electricity passed in the measurement.

Staff positions are available both at the site near Chicago, Illinois and the site near Idaho Falls, Idaho for qualified *physical metallurgists, chemical engineers, physicists, mechanical engineers, metallurgical engineers, chemists, electrical engineers, mathematicians, technical writers.*

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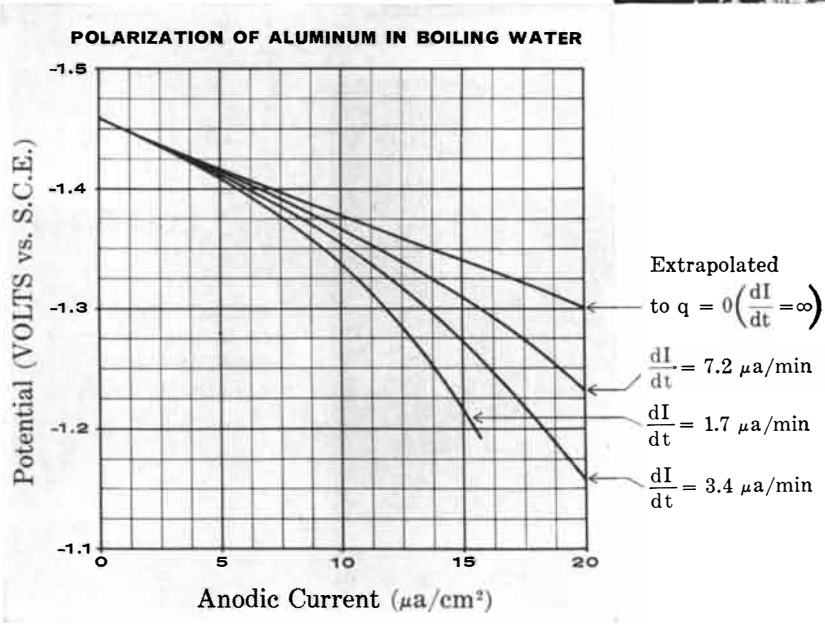


Direct inquiries to:
Louis A. Turner, Deputy Director
9700 South Cass Avenue—X4
Argonne, Illinois

THE AMATEUR SCIENTIST

How the amateur can perform experiments that call for the use of radioactive isotopes

Conducted by C. L. Stong

Can an amateur perform experiments that involve the use of radioactive isotopes? Many amateurs who have wanted to undertake such experiments have assumed that they could not, because the isotopes themselves could not be obtained. Not so. To obtain a substantial quantity of radioactive material requires a license from the Atomic Energy Commission, but amateurs can buy tiny amounts of many radioactive isotopes without a license and at modest cost. Sixty-five radioactive isotopes can now be purchased without a license, among them the biologically useful isotopes phosphorus 32, iodine 131, calcium 45, sodium 22 and zinc 65. In general the amount of each isotope in any one purchase is restricted to 10 microcuries. Among the exceptions are carbon 14, iron 55, manganese 56 and sulfur 35, which are dispensed in quantities of up to 50 microcuries. The isotope is usually shipped as a dry, water-soluble compound in a small bottle. The contents of the bottle weigh only a few trillionths of a gram; indeed, the bottle appears to be empty. By adding a prescribed amount of water to the bottle one obtains the isotope in a solution that is calibrated with fair accuracy.

In one microcurie of any radioactive substance nuclear disintegrations occur by definition at the rate of 37,000 per second. A 10-microcurie supply of an isotope should thus provide enough material for several experiments. A number of commercial suppliers make up kits designed for specific projects such as the study of soil characteristics, for biological investigations or for a series of experiments in nuclear physics.

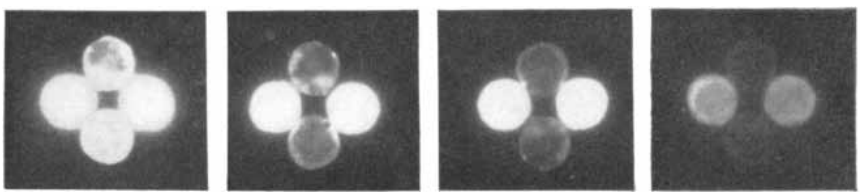
With a supply of radioactive isotopes and some homemade apparatus one can observe the effects of nuclear processes, measure the half-life of the isotopes, study the utilization of nutrients by plants and animals, analyze the properties of metals and make a variety of physical measurements. In the following discussion John H. Woodburn of the Department of Education at Johns Hopkins University describes some elementary experiments and how to perform them.

Woodburn writes: "If you already know something about atoms, you can skip the next few paragraphs. Even if you have read about atoms, however, a review of their principal characteristics may prove helpful. A particularly nice description of the atom is presented by the late Wolfgang Pauli in *World of Life:* 'If an atom could be magnified to the size of a house, it would probably look something like a great soap bubble, except that its outlines would be so hazy and indistinct that it would be impossible to tell just where the borders of the atom were. Within the misty outer shell would appear other more or less concentric or interlocking shells, each as hazy as the outer one. Deep in the center of this shimmering mass would be a denser, more solid looking structure, the nucleus, no larger than a dot. Most impressive, perhaps, would be the vast emptiness of the atom, a characteristic which it shares with all the universe around it. It is strange indeed to realize that man and all living things, the earth, and all the universe are constructed of such empty and seemingly fragile structures. It has been estimated that if all the atomic constituents of the human body could be packed together tightly, eliminating the spaces between them, they would be no larger than a grain of sand.

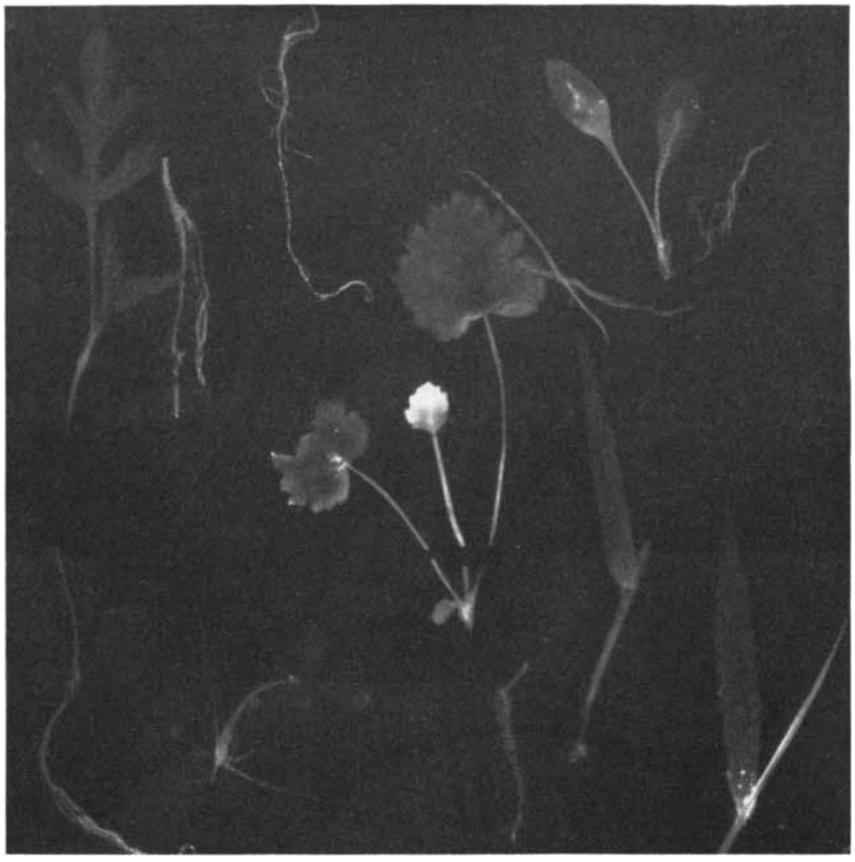
" 'The planetary electrons,' Pauli continues, 'which revolve around the nucleus must be visualized as endowed with a smashing, driving energy. Even in this house-sized atom, they would revolve in their orbits with such inconceivable speed that they would not be recognized as separate units, but would give the illusion of thin, transparent shells, as unreal as the disk described by the whirling blades of an electric fan. If their speed could be reduced so that they could be made visible, they might become vaguely outlined as intensely vibrating "objects" no larger than pinpoints; not solid but rather, says modern physics, whirlpools of energy, foci of energy, or similar intangible units!'

"To Pauli's picture of these gossamer shells 'endowed with a smashing, driving energy,' we must add a reservoir of far greater energy at the site of the nucleus. Some nuclei disintegrate spontaneously; they emit particles of matter that are sometimes accompanied by electromagnetic waves. The process changes the number of protons in the atom; in effect a new atom is born. When part of the nuclear substance of the radioactive isotope phosphorus 32 is ejected as an electron, for example, the residue is a nonradioactive atom of sulfur 32. If you begin an experiment with phosphorus 32 and expect subsequent chemical tests to show only this element, you are in for a surprise. At the end of two weeks you will have as much sulfur as phosphorus! This is another way of saying that the half-life of phosphorus 32 is two weeks.

"Bundles of energy ejected by disintegrating nuclei in the form of electromagnetic waves or particles provide useful signals for locating radioactive atoms. It is for this reason that radioactive isotopes are often called tracers. Before they disintegrate, radioactive atoms are



Successive autoradiographs of disks containing phosphorus 32 (horizontal) *and iodine 131*



An autoradiograph showing the different amounts of sulfur 35 taken up by various plants

An autoradiograph showing the different amounts of iodine 131 taken up by various plants

chemically indistinguishable from their nonradioactive counterparts. Phosphates containing phosphorus 32, for example, are taken up by growing plants just as readily as those containing the nonradioactive isotope phosphorus 31. However, when any atom of phosphorus 32 in the phosphate disintegrates, it sends out a powerful signal, and these signals make it possible to follow the life processes of a plant in some detail.

"It is well known these days that the radiations of disintegrating atoms can damage living tissue and even kill living organisms. How, then, is it possible to use radioactive isotopes for tracing life processes? Do they not injure the experimental plant or animal, induce abnormalities and lead the experimenter to false conclusions? It turns out that atomic bullets, whether in the form of waves or particles, can go through apparently solid stuff without disturbing it—without 'leaving a hole.' What is meant by 'leaving a hole'? Suppose one shoots a rifle bullet through a flock of geese on the wing. To make a hole in the flock, must a bullet actually hit a goose? If this is what is meant, it must be remembered that atoms are made up of a few very small 'geese' flying around in flocks that are distributed through a relatively immense volume of empty space. The average atom is composed of one part 'goose' to 10 trillion parts of space! This means that if we were to shoot a goose-sized bullet at the center of the atomic flock, we would have one chance in 10 trillion of hitting a goose, or that conversely we would have to shoot 10 trillion bullets to be reasonably certain of hitting a goose. So the probability is high that a radioactive tracer will not seriously injure a normal plant or animal, particularly if one is sparing in the use of radioactive material.

"The half-life of many radioactive isotopes is measured in minutes or days. That of iodine 131, for example, is 8.08 days; of phosphorus 32, 14.3 days; of barium 137, 2.6 minutes. Thus in the interests of economy the experimenter would be well advised to plan his experiments in advance of purchasing his radioactive material; otherwise he runs the risk of losing the material before the experiment is completed. By careful scheduling I have done as many as 40 experiments with a kit consisting of 10-microcurie quantities each of phosphorus 32, iodine 131, zinc 65, and 50 microcuries of sulfur 35.

"The power and convenience of the tracer technique are easy to demonstrate. Suppose you want to know whether dissolved salt (sodium chloride) is caught

up in the ice crystals of a freezing solution. If some of the sodium is in the form of the radioactive isotope sodium 22, you merely hold an ice cube close to a Geiger counter. If you have no counter, melt the ice, dip a disk of paper in the water, and after the paper has dried place it in contact with a piece of Plus X photographic film for 24 hours. (This must be done in a darkroom to prevent exposure by light.) Or suppose you are interested in the efficiency of fractional crystallization or distillation. A radioactive tracer will serve as a convenient tool to show if a particular element stayed (or went) where you think it did. Similarly you can determine whether one element or another in a chemical reaction formed the 'insoluble precipitate.' Another interesting question: Does the metal that is deposited during a particular electroplating process come from the bath or from the anode? To learn the answer check the anode for radioactivity, with either a Geiger counter or photographic film. If the anode is not radioactive, add a radioactive isotope of the same metal to the bath, plate a sample object and check it for radioactivity. A negative result would indicate that all the plated atoms come from the anode.

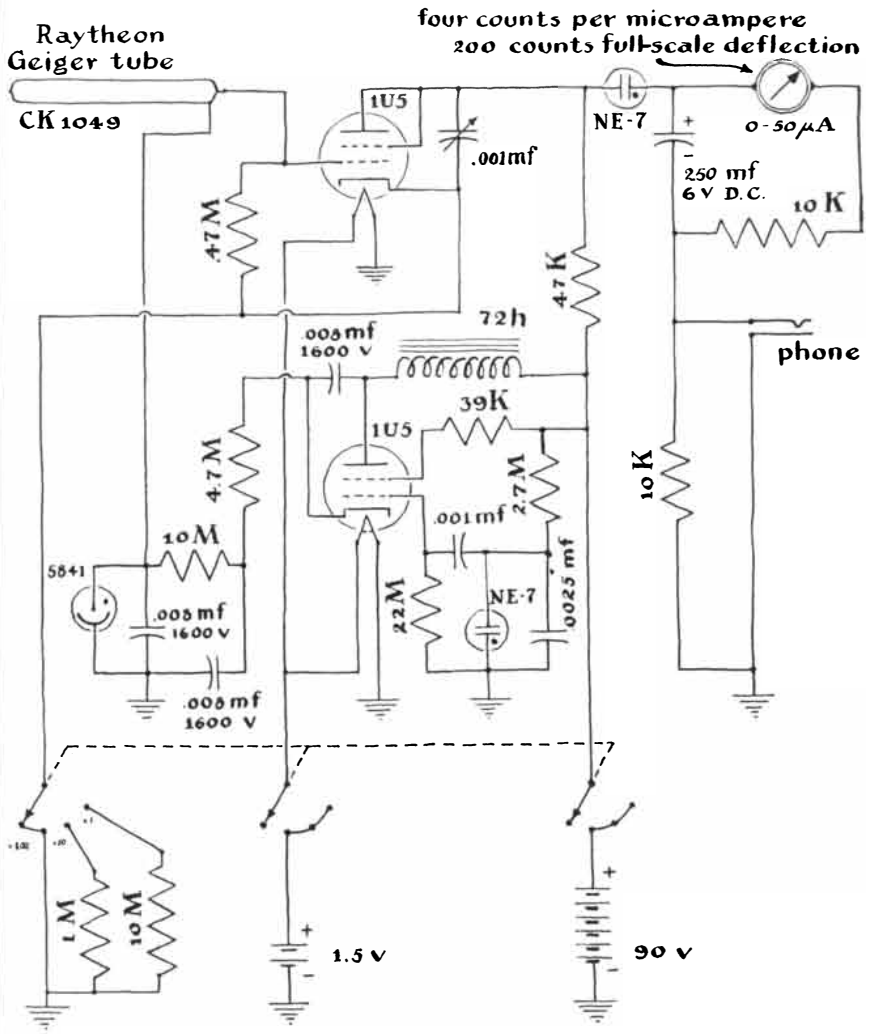
"To make these experiments and the more advanced ones described below, you should provide the facilities necessary for developing photographic film and either buy or build a Geiger counter. The detection of radioactivity by photographic film (autoradiography) dates from the accidental observation in 1896 by Henri Becquerel that a piece of uranium ore lying near a photographic plate darkened the plate even though the emulsion had been shielded from light by opaque paper. The basic principle underlying autoradiography is that alpha particles, beta particles, gamma rays and certain other nuclear radiations ionize molecules along their path. This ionization leads to the chemical reduction of the silver atoms in the salts contained by the emulsion, in much the same way that light acts on the salts.

"The quality of autoradiographs, that is, the clarity with which they show the distribution of radioactive isotopes, depends on a number of variables, including the distance between the emulsion and the specimen during exposure, the intensity of the exposure, the type of emulsion used and the care taken in processing the emulsion. In general the resolution, or sharpness of the image, improves as the emulsion and specimen approach direct contact. The location of radioactive material on the surface of a flat plate can be determined with con-

siderable precision, for example, by simply pressing a sheet of emulsion firmly against the plate. A reasonably good autoradiograph can similarly be made of a leaf that has taken up radioactive material. If the leaf is a thick one, however, radiation from the part of the leaf that is not in direct contact with the emulsion will strike the emulsion at an angle. In consequence the edges of the autoradiograph will appear diffuse. With many specimens it is necessary to separate the specimen and the emulsion by an inert barrier to prevent chemical reaction between the silver salts and the specimen. For this reason plant and animal tissues are commonly wrapped in a thin sheet of plastic such as Saran or cellophane. The resulting image loses sharpness, of course, in proportion to the thickness of the protective covering.

"Occasionally it is necessary to make autoradiographs of rough objects or those of irregular shape. Here one can strip the emulsion from its backing and, while it is moist, press it against the specimen. Emulsions that are easily detached from their backing material are employed in the photoengraving industry and can be procured through a dealer in commercial photographic supplies. Special developing processes are usually specified by the supplier for each type of emulsion and should be followed carefully for optimum results. Exposure time varies both with the energy of the radiation and with the rate at which it enters the emulsion. Optimum exposure time is determined by trial and error.

"Autoradiographs are especially useful to the amateur because they give him plenty of time and require very little radioactive material. But they permit only rough estimates to be made of the radioactivity present in a specimen. Precise measurements require the use of an instrument that can be calibrated, such as the Geiger counter. An excellent Geiger counter can be assembled from commercial parts for about $25. As with photographic emulsions, the sensing element of the instrument, the Geiger tube,

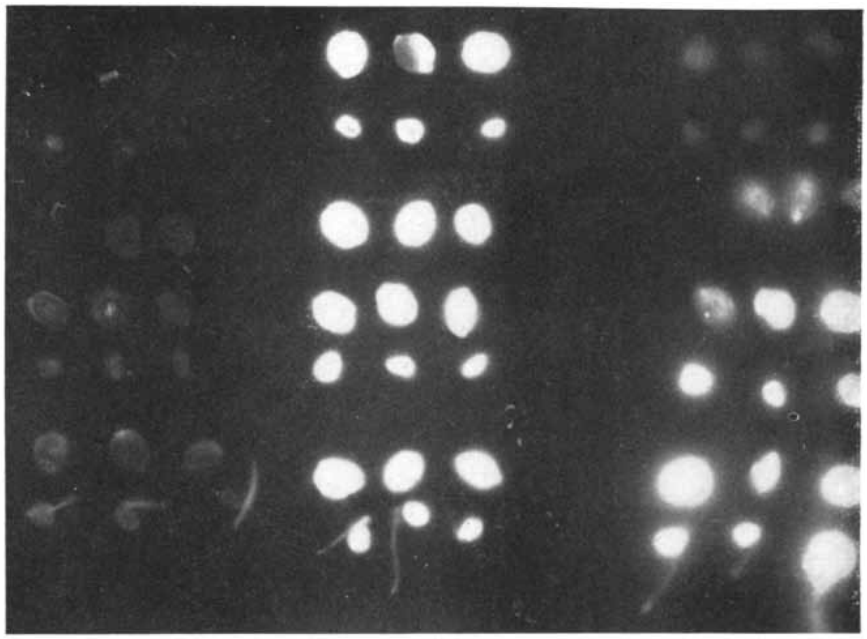


Circuit diagram for a Geiger counter that can be made by the amateur

takes advantage of the ionizing properties of alpha, beta and gamma rays. The most efficient Geiger tubes contain a mixture of two or more gases under moderately low pressure in an electric field of several hundred volts. The field is maintained between coaxial electrodes; usually one electrode is a cylinder of thin metal and the other a wire on the cylinder's long axis. The wire is made electrically positive and the cylinder negative. When a penetrating ray or particle dislodges an electron from a molecule of gas, the dislodged electron is strongly accelerated by the electric field toward the anode and quickly acquires sufficient velocity to dislodge other electrons from the molecules in its path. These electrons are similarly accelerated toward the anode, and thereby acquire sufficient energy to ionize still other molecules. An avalanche of electrons thus develops. Within a few microseconds the swarm of electrons enters the anode and flows through the external circuit as a pulse of current.

"The pulse may be amplified to actuate a headphone, a meter or a counter. Meanwhile the positive ions formed by the radiation are accelerated toward the cylindrical cathode. If permitted to strike the cathode, these energetic ions dislodge electrons from it and thus initiate a series of avalanches that paralyze the tube. This is prevented by introducing into the tube a 'quenching' vapor: a small quantity of alcohol or a halogen such as bromine. The accelerated ions collide with and give up energy to the molecules of the quenching vapor; they usually acquire an electron during the encounter and thus become passive. In the case of organic quenchers such encounters result in the permanent dissociation of the quenching molecules; on the average a billion molecules of alcohol are dissociated per count. In consequence the useful life of the tube is limited to about 100 million counts. Halogen molecules, on the other hand, are merely raised to an excited state by such collisions and return to their low-energy state within 24 hours.

"In theory the life of halogen-quenched tubes is unlimited, but in practice they must be replaced after about 10 billion counts. The electrodes of most Geiger tubes are enclosed by a glass envelope so thin that it can barely withstand the difference in pressure between its gas and that of the atmosphere. Thick glass would block the entry of low-energy particles. For this reason Geiger tubes are among the most fragile items of scientific apparatus. An eggshell is strong in comparison with the tubes used in the

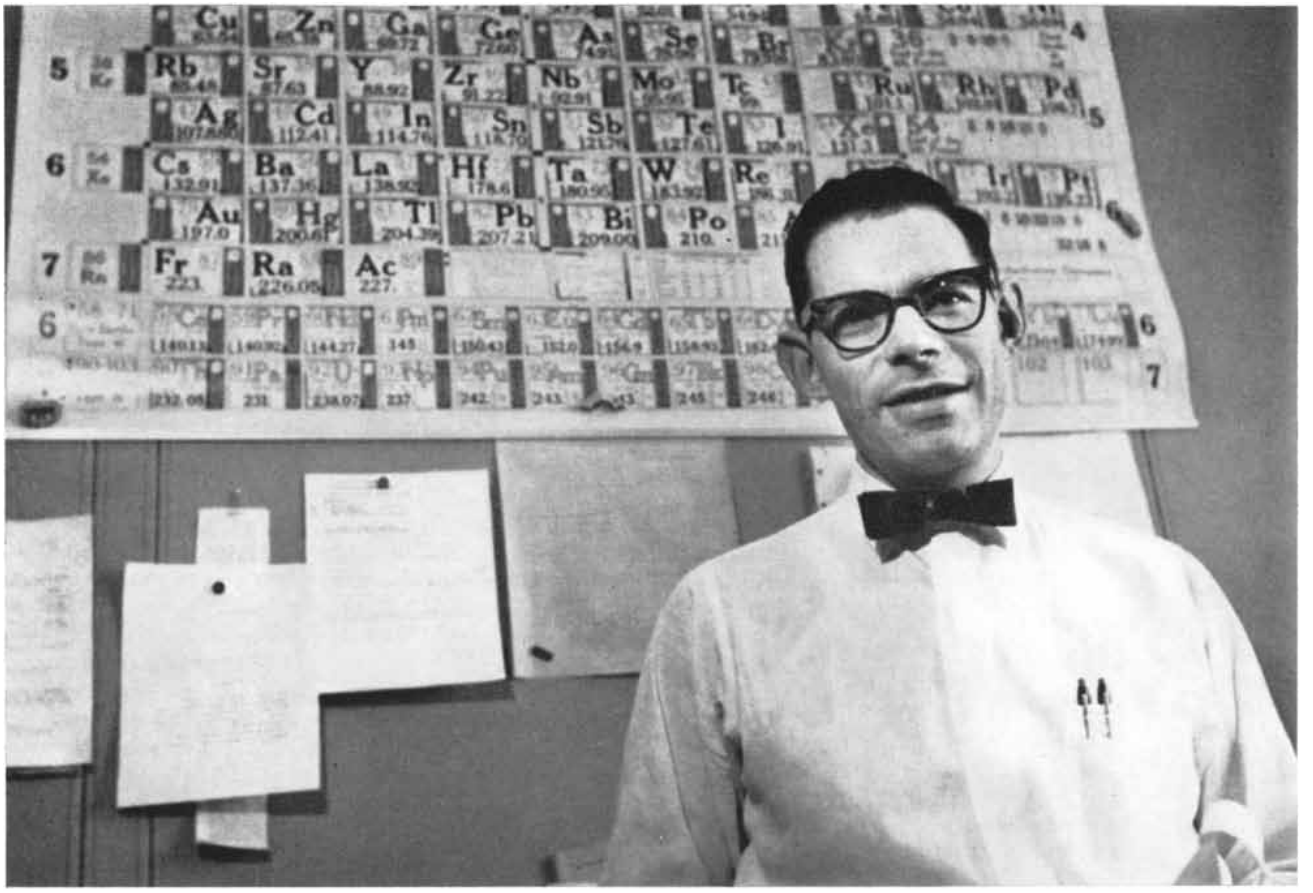


Relative absorption of radioactive atoms by parsnip (large) *and tomato seeds* (small)

most sensitive counters. Handle the tubes accordingly.

"A primitive counter can be made by supplying voltage to a Geiger tube through a 10-megohm resistor and connecting a headphone, in series with a .001-microfarad capacitor, across the terminals of the tube. Each triggering particle will be heard in the headphone as a sharp click. Although interesting as a demonstration, an instrument made this way is of little use in experimental work because you are likely to hear so many counts that you cannot record them. The circuit of a self-contained, battery-powered counter of more advanced design is shown in the accompanying diagram [*page 192*]. In this instrument current pulses from the Geiger tube are amplified by the vacuum tube in the upper part of the diagram. Successive pulses from the amplifier are fed into the 250-microfarad capacitor at upper right. The rate at which charge accumulates in the capacitor is determined by the frequency of the current pulses. The capacitor discharges through a microammeter calibrated in counts per minute. The circuit includes provision for a headphone so that the counts can also be monitored by ear. The entire assembly, including the batteries, can be housed in a box three inches wide, four inches high and six inches long. The counter tube should be protected by an appropriate length of rigid plastic tubing. If you have no experience in assembling and wiring electronic components, look up a neighboring radio amateur. One or more will be found in every community, and I have yet to meet one who has not welcomed the opportunity to lend a hand. It is possible to add an accessory to this instrument for registering total count during a specified interval. This provision more than doubles the cost, however, and is not essential for the experiments I shall describe.

"The relative merits of the autoradiograph and Geiger-counter techniques can be demonstrated by an experiment designed for determining the half-life of a radioisotope. Iodine 131, with a known half-life of 8.08 days, makes a convenient specimen. To determine its half-life, first add 10 milliliters of distilled water to the bottle containing 10 microcuries of the isotope, replace the cap on the bottle and swirl the contents gently for a few minutes. (Incidentally, a one-microcurie-per-milliliter solution is a convenient dilution for many experiments.) Now with a punch of the kind used for perforating notebook paper cut two disks from a sheet of blotting paper and transfer two drops of the solution to each disk. Dry the disks, cement them to cardboard, label them with the name of the isotope, date the card and wrap it with a single sheet of thin plastic. Next, switch the Geiger counter to its most sensitive position and move the card toward the counter tube until the meter shows a deflection of approximately 80 per cent of the full scale. A wooden fixture is now made for holding the card and counter tube at this empirically determined distance. The fixture must be designed so that card and tube can be returned precisely to their respective po-



I. A. Lesk, Univ. of Alberta, B.Sc. 1948; Univ. of Illinois Ph.D. 1951. Joined General Electric in 1951. Holds patents on unijunction transistor and tetrode. Has published material on diffused-meltback, minicrystal, diffused shot-melt processes, PNPN switches and tunnel diodes. Now working on advanced semiconductor devices and techniques.

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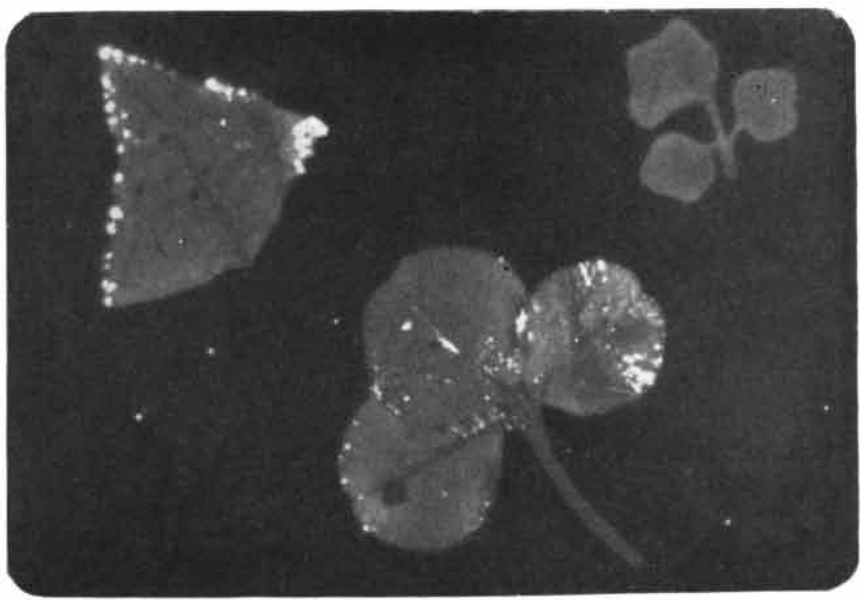
sitions whenever desired. The instrument reading is then recorded, along with the date.

"Next the card is placed in contact with a sheet of film and weighted down. A similar card is prepared on the following day, its rate of count is measured and it is placed in contact with the film. This is repeated every day for two weeks. Each film is exposed for 12 hours and then developed. When all films have been developed, the tabulated readings of the Geiger counter are plotted as the ordinate on semilog graph paper against the time in days (in intervals of equal length) on the abscissa. If the intervals of the log scale are numbered from 0 to 1, a horizontal coordinate drawn from .5 on the ordinate to the graph and a perpendicular dropped from this point of intersection to the abscissa, will show the half-life of the isotope. Compare the slope of the graph with the gradually diminishing intensity of the autoradiographs. Do not be too disappointed if the half-life as indicated by your initial experiment fails to agree with the known value. You will come closer with practice.

"As a variation of the experiment you can put a pair of disks on each card, one pair charged with iodine 131 and the other with phosphorus 32 [*see illustration on page 189*]. Solving the resulting graph for the half-life of each radioisotope is an intriguing problem. In interpreting the data remember that the beta particles from phosphorus 32 are more likely to reach and trigger the Geiger counter than are the lower-energy particles of iodine 131. The analysis is further complicated by the fact that the disintegration of radioactive iodine is accompanied by the emission of both a beta particle and a gamma ray. The gamma ray travels through a much greater thickness of air before expending its energy than does the beta particle, but only a small percentage of gamma rays trigger a count.

"The application of radioisotopes for measuring physical quantities such as thickness can be demonstrated by a simple experiment based on the absorption of beta rays. A source of penetrating beta rays, such as those emitted by phosphorus 32, is placed at that distance from the counter tube which drives the meter to full scale. A rubber sheet of known thickness is then placed between the source and counter tube and the count recorded. Several additional sheets are then added successively to the first, the count being recorded for each added sheet. The known thickness of the sheets is then plotted against the respective rates of count. One or more sheets may then be stretched. The unknown thickness of the stretched rubber is determined by referring the observed reading for the stretched sheets to the graph. Rubber stock for the experiment may be cut from an old inner tube.

"Tracers have become powerful tools in biological experiments for probing such matters as the distribution of a given element in the structure of a growing plant. For example, some familiar house plants have leaves that are partly green and partly white; is phosphorus more likely to be deposited in the green portion of the leaf than in the colorless



Distribution of sulfur 35 in leaves of dandelion (left), *clover* (middle) *and mustard* (right)

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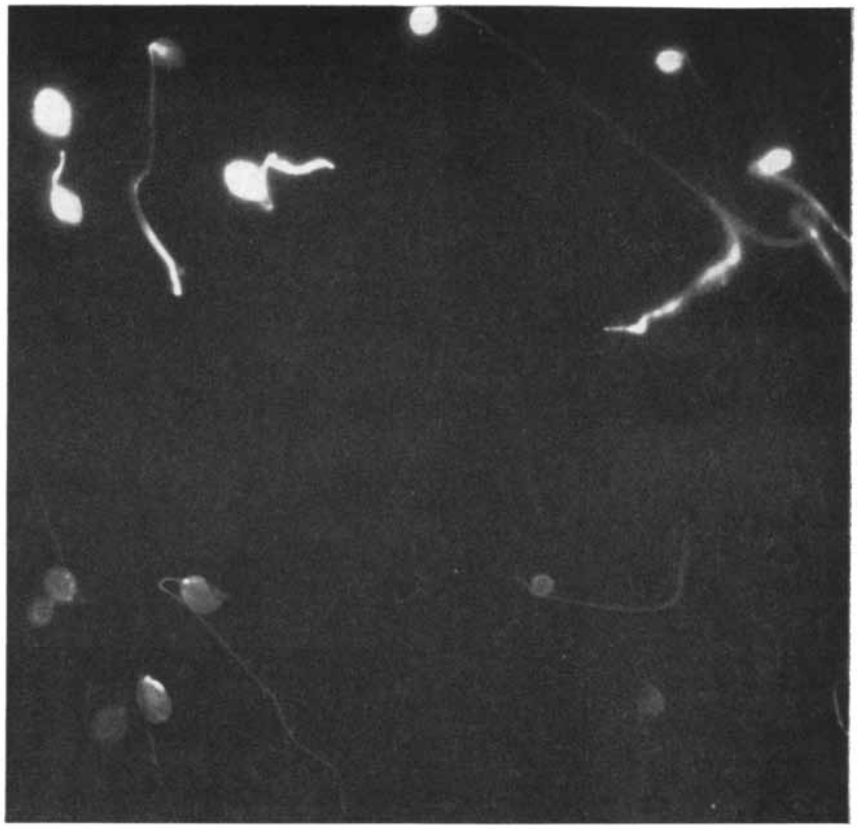

Distribution of sulfur 35 in growing tomato seedlings

portion? To study this question the roots of a plant with such leaves were placed in 30 milliliters of water containing one microcurie of phosphorus 32. Individual leaves were removed after one, two, three, four and five hours, laid on a sheet of cardboard, wrapped with plastic film, placed in contact with X-ray film in light-proof envelopes and pressed under a book for 10 hours. No radioactivity was apparent on the developed film. When the experiment was repeated and the film was exposed for 24 hours, however, radioactive phosphorus was detected in all the leaves. There was no difference in the amount of phosphorus taken up by the green and by the white portions of the tissue. It should be interesting to try this experiment with isotopes of other elements and to vary the light, temperature and other conditions under which the plants are grown.

"Do plants of various species differ in their absorption of the radioactive isotopes sulfur 35 and iodine 131? Plants of six different species were placed in separate solutions of 20 milliliters of water, to each of which one microcurie of sulfur 35 and one of iodine 131 had been added. The accompanying autoradiographs [*page 190*] show the relative absorption of each of the species after they had been in the solutions for 29 hours. As noted earlier, it is difficult to gain quantitative data from autoradiographs, particularly when two isotopes are combined that emit beta rays of differing energies. The beta particles from sulfur 35 have scarcely enough energy to penetrate the tissues of the plant, but the radiations from iodine 131 are capable of exposing the emulsion strongly even though they originate deep within the plant tissue.

"Tracer isotopes may also be used to follow the transport and utilization of nutrients during the germination and development of seeds into young plants. In one procedure thin disks cut from sponge are floated on a dilute solution containing the isotope, and a few seeds are 'planted' on the disks at regular time intervals, say every five days, until the first seeds planted develop into seedlings. All specimens are then removed, washed briefly, dried and mounted on cardboard for exposure. Autoradiographs made by exposing no-screen X-ray film for 10 to 20 hours will show when and where a specific nutrient migrated during the growth process. A typical autoradiograph made in this way appears in the accompanying illustration [*page 194*]. Observe the variation in the absorption of sulfur 35 [*left column*], calcium 45 [*middle column*] and phos-

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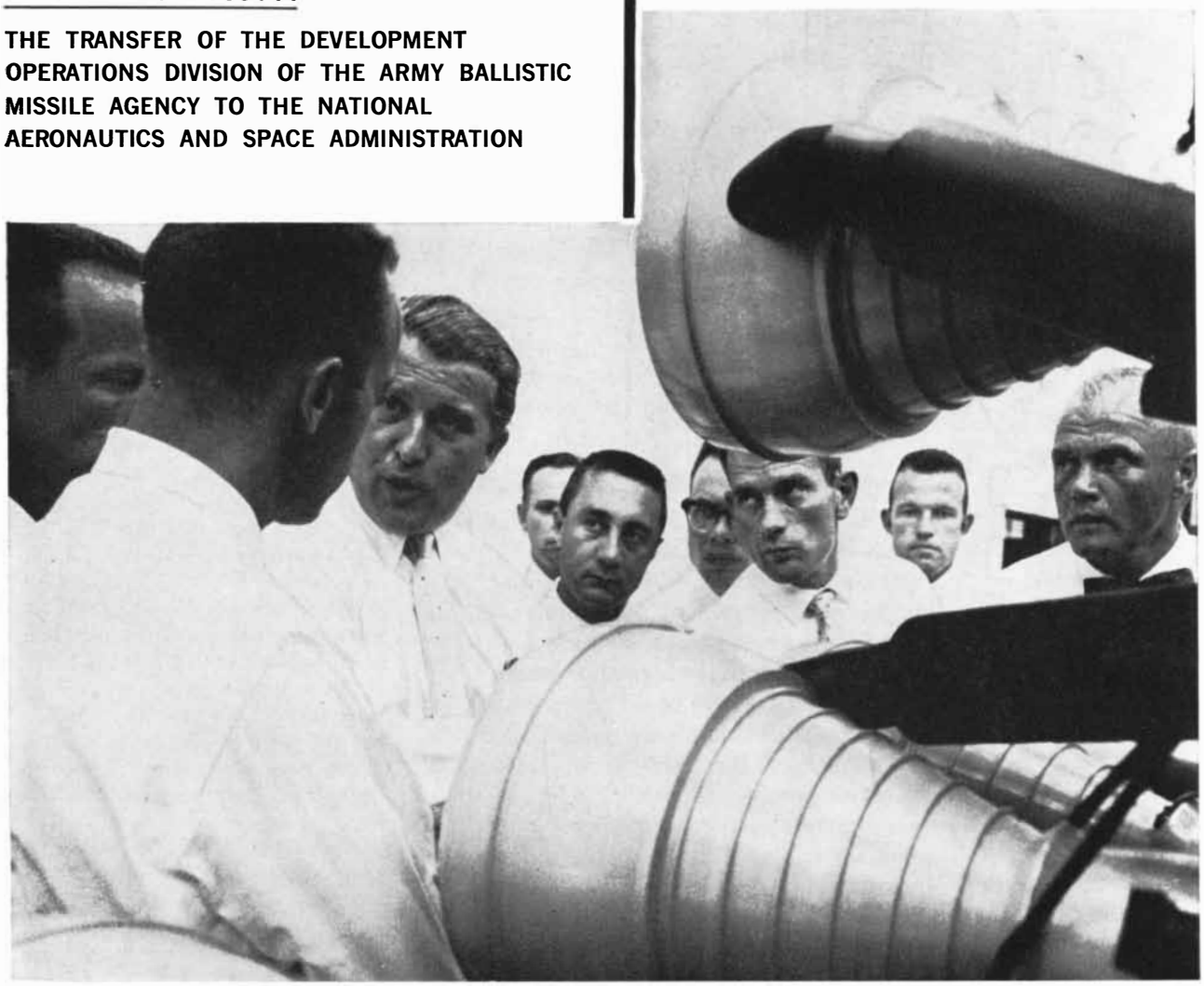

Dr. Wernher von Braun, director of the new NASA Marshall Space Flight Center in Huntsville, Ala., pictured with NASA's Mercury Astronauts

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phorus 32 [*right column*] by parsnip and tomato seeds.

"Do minerals move only upward in plant roots? To answer this question divide the root system of a plant, say ragweed or clover, let half of the roots dip into a dilute solution of radioactive phosphorus and the other half into a separate container of plain water. After seven hours remove the plant, being careful to prevent the two halves of the root system from touching. Blot dry and examine by autoradiography or by Geiger counter. (I found that phosphorus apparently moved down into the roots that were immersed in plain water.)

"Some parts of a growing organism require more of a certain nutrient than other parts. One of the substances selectively distributed is sulfur. In some cases the distribution follows a logical pattern. In others the pattern is random. The accompanying autoradiograph [*page 196*] is enlarged from 35-millimeter X-ray film that had been in contact with a portion of a dandelion leaf [*upper left*], clover [*center*] and wild mustard [*upper right*] for 20 hours after the plants had been in a solution containing one microcurie of sulfur 35 for 66 hours. As a teacher I find that 35-mm. film is excellent for making autoradiographs. It is more economical and more convenient than the larger sizes and, when properly used, yields as much information as they do. After exposure and development it can be mounted in ordinary two-by-two-inch slide binders for projection at meetings or in the classroom. Another example, made by following much the same technique, shows the absorption of sulfur 35 by growing tomato seedlings [*see illustration on page 198*]. Note the uniform distribution of this nutrient in the very young plants [*top*] and the beginning of characteristic clumping in the older seedlings [*bottom*].

"This experiment, like many made with radioisotopes, raises more questions than it answers. How long do the concentrations of sulfur remain in these sites? To what specific physiological processes are they related? What accounts for their occasional random distribution in the plant? Which of the other elements, if any, exhibit a similar tendency to clump? The design of experiments to probe such questions can in itself become an engrossing enterprise.

"In taking up this avocation you should never lose sight of the fact that you are working with potentially dangerous materials. Just as corrosive acids, explosive salts or poisonous compounds, if handled improperly, can cause accidents, so can radioactive isotopes. That

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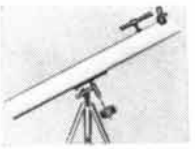

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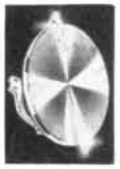

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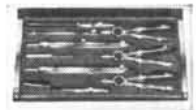

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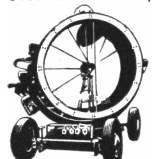

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The Oak Ridge National Laboratory and a number of commercial firms dispense radioactive isotopes in amounts that do not require a license. Oak Ridge provides the isotopes free, but charges for each shipment a $20 handling fee plus the transportation cost. The Abbott Laboratories Division of Radioactive Pharmaceuticals in Oak Ridge, which is not associated with the Oak Ridge National Laboratory, has advised this department that it sells radioactive isotopes in a "two pack" and a "nine pack." The two pack, which costs $7.50, consists of 10 microcuries each of phosphorus 32 and iodine 131. The nine pack, which costs $18, includes these isotopes and various amounts of seven others. Shipments are made by air on Friday on all orders arriving up to noon on Thursday.

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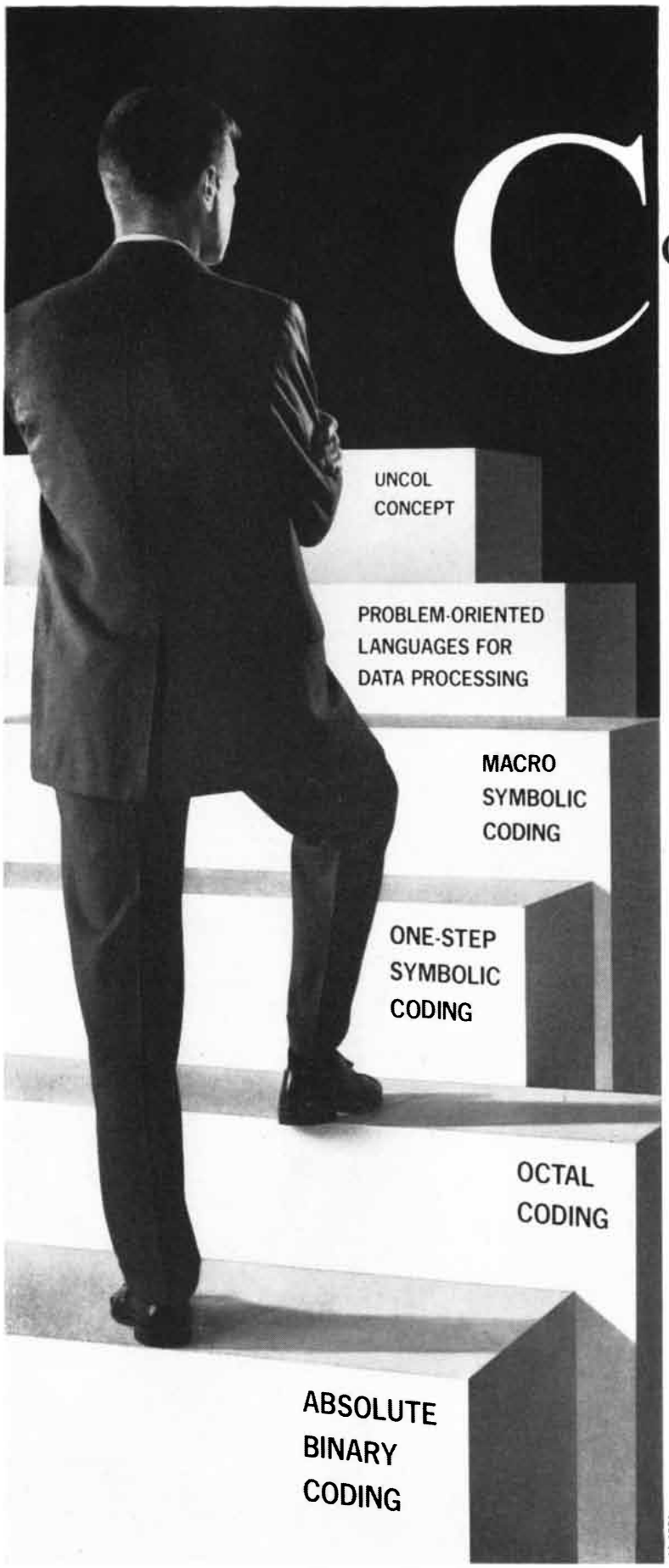

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"SP-127 ANCHOR An Algorithm for Analysis of Algebraic and Logical Expressions," a paper by Howard Manelowitz of SDC's staff is available upon request. Send request to Mr. Price at SDC.

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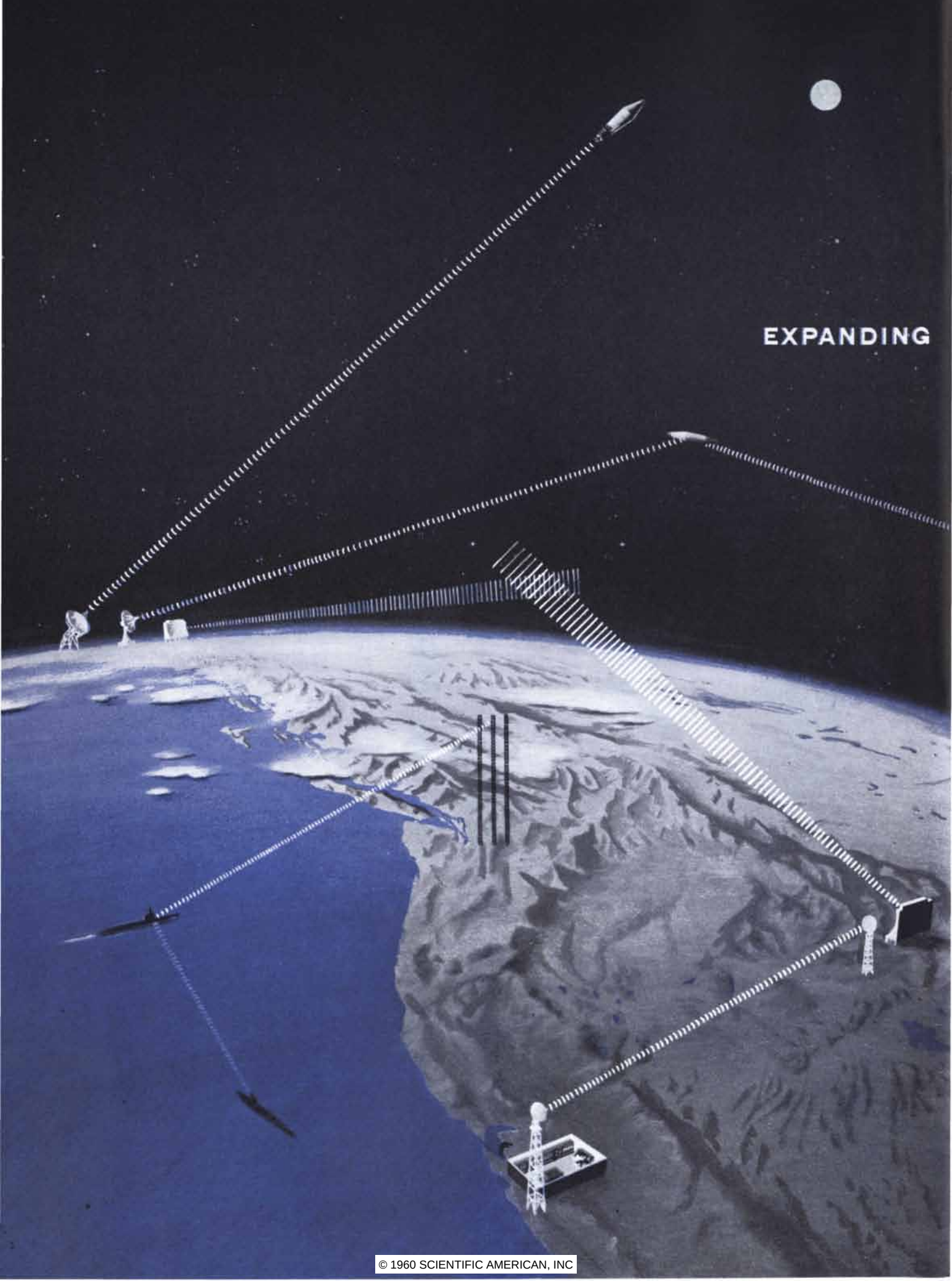

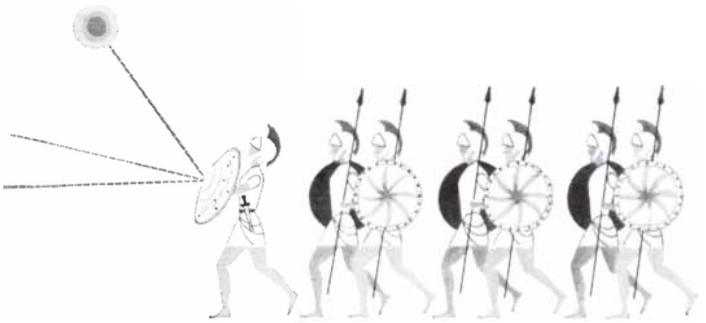

Herodotus, the historian, records (490 B.C.) the use of burnished shields for military signaling. This was the forerunner of the heliograph, invented by Sir Henry C. Mance, which came into wide use centuries later.

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Lockheed's interest in developing the science of communications extends from the depths of the oceans to deep space. Its Missiles and Space Division research programs deal with the development and application of statistical communication and decision theory in such areas as countermeasures; telemetry multiplexing and modulation; scatter communications; multiple vehicle tracking; millimeter wave generation and utilization; sonic signal detection and processing; avoidance of multipath degradation; and interference avoidance.

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BOOKS

How the basic mechanisms of speech have been studied by brain surgeons

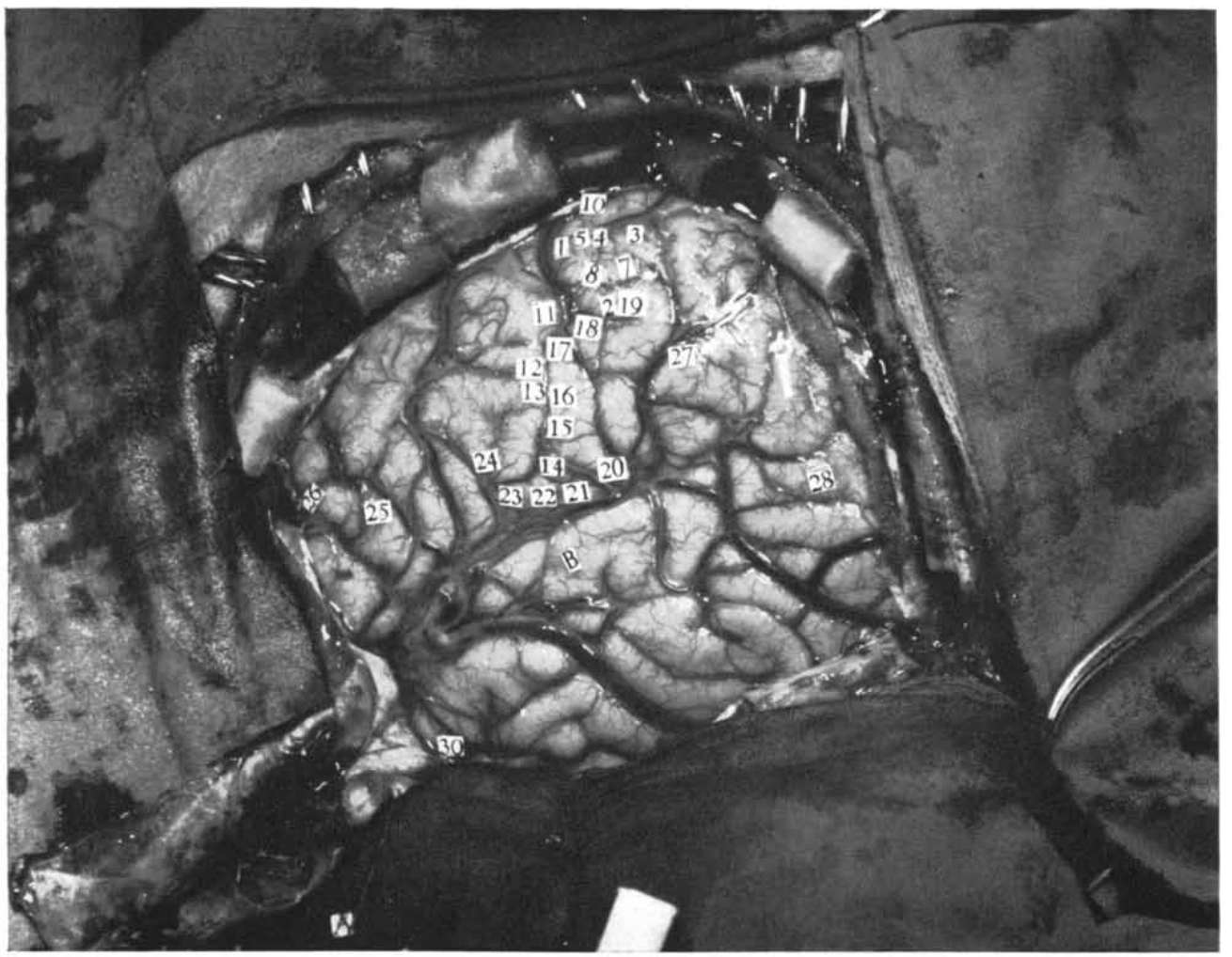
by Lord Adrian

SPEECH AND BRAIN-MECHANISMS, by Wilder Penfield and Lamar Roberts. Princeton University Press ($6).

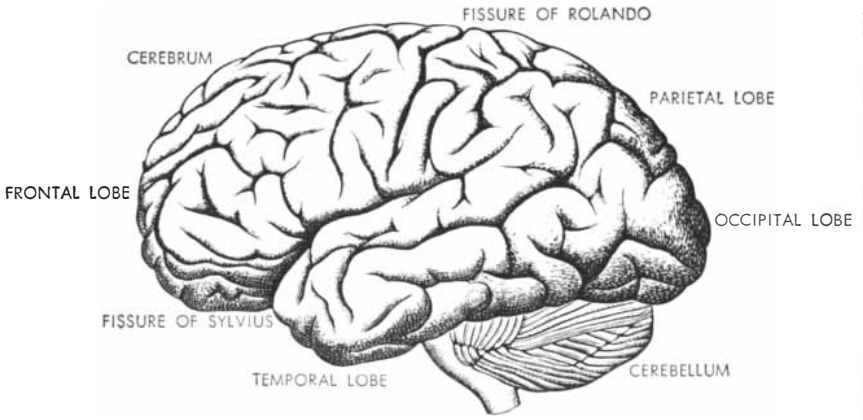
Penfield and Roberts have written a book that makes many other books out-of-date. The human species owes its success to the ability to communicate ideas by speech and so to the brain mechanism that makes speech possible. In the past the only way of learning about this mechanism was to study the disturbances of speech caused by brain disease. Now neurosurgery has made the diseased brain far more accessible and has opened a new chapter in the study of aphasia: the loss of the power to speak or to understand speech.

The study began 99 years ago when the French neurologist Paul Broca showed that the power to speak depended on a particular region in the frontal part of the brain. He had two patients who died after an illness in which the chief symptom was loss of speech; in both of them the chief damage to the brain was found in this limited region. It was the first clear evidence not only of a special area for speech, but also of any difference in the function of different parts of the brain surface.

It was not, however, the first time that men had looked for such differences. The nature of the relationship between brain and mind is an old puzzle, and it is a little less baffling if it can be shown that particular parts of the brain



During an operation at the Montreal Neurological Institute areas of the brain that have been stimulated are labeled with numbers



The left hemisphere of the brain, with its principal features labeled

can be assigned to particular mental activities. The place to look for these differences is in the brain's surface sheet of nerve cells, the cerebral cortex, for it is the special enlargement of the cortex in the human brain that seems to be responsible for the special powers of the human intellect.

Fifty years before Broca the German anatomist Franz Joseph Gall had tried to relate the shape of the head, and therefore of the brain inside it, to the character and abilities of individuals. He thought that a relationship could be found, and for a time his method, phrenology, was hailed as a new way to connect the mind with the brain. But the prospect was too attractive and the evidence too easy to misread. Gall and his followers claimed too much; phrenology was discredited, and there was nothing to take its place until Broca started the advance on another line.

Animal experiments had by then become more feasible; they soon gave even stronger evidence of local differences in the function of different parts of the cortex. The stimulation of animal brains revealed that there was a motor area, and it was shown that there were other areas associated with different kinds of sensation. By the end of the 19th century there was very little doubt that the human brain has the same kind of arrangement.

Animal experiments could throw little light on the mechanisms concerned with purely human abilities like that of speech, but clinical neurologists had the evidence provided by human disease, and they had Broca's cases to encourage them. Broca's patients could not speak, but they could understand at least something of what was said to them. There were many cases, however, in which the speech disturbance took a different form; where the chief defect lay not in speaking words but in writing, or in understanding speech or writing. Broca's area for speaking suggested the existence of areas in the brain concerned with the use of words in ways other than speaking. The neurologists looked for evidence in cases of aphasia in this wider sense, and they used the term Broca's aphasia for the loss of active speech that he described.

Once more the prospect of equating the mind to a map of the brain was too tempting. The extent and position of brain damage could not be investigated during the lifetime of the patient, and there were very few aphasic patients who did not have some general defect in understanding. Nonetheless maps of the speech mechanism were made, with centers for all the different mental operations involving words, centers concerned with reading and writing, with numbers, with finding the right name, with appreciating a joke.

These maps had some value in suggesting how a systematic examination should be conducted in order to show just what had gone wrong. Could the patient produce words; could he repeat words spoken to him; could he carry out verbal or written commands; could he name a key or a coin? But it became increasingly clear that there were very few cases of aphasia with symptoms that could be fitted to such a detailed scheme of speech centers. All that could be said was that Broca's frontal area was concerned mainly with the power to produce spoken words, and that damage in a fairly large region farther back on the brain surface could interfere with the power to recognize words or to use them in thinking.

That would be all that could be said today if neurosurgery had not made it far less dangerous to expose and operate on the brain. The foremost research center in this work is the Montreal Neurological Institute; Penfield and his col-

Mars

Because its reddish glow may have suggested blood and violence to the ancients, Mars was named for the God of War. Of all the planets it is the only one we can readily observe. Mercury is too near the sun and heavy clouds veil the surfaces of the rest.

About once every two years you may see a bright star rising in the heavens as the sun sets. The ancients named Mars for the God of War, perhaps because to them its ruddy color suggested blood.

Of all the planets, we know Mars best. We see it most clearly. We study it most closely. Yet, Mars has always been a mystery to man. And so it is today.

Of course, we know something

Changing Concepts of the Cosmos

Reproduction of one of the finest, current drawings of Mars, showing the visible markings of the planet, and a yellow dust storm sweeping across its surface. The original is by Dr. de Vaucouleurs of Harvard College Observatory.

about Mars. It rotates on its axis with a day of 24 hours, 37 minutes. It has changing seasons, and a diameter about half that of the earth.

Through a large telescope Mars looks reddish-yellow with patches of grey or grey-green. What are these patches? Oceans, said early astronomers. Vegetation, we believe today.

We can see the polar caps of Mars: most likely thin layers of frozen water, for they vanish in summer and return in winter.

On Mars, you would find the atmosphere thin and probably composed of carbon dioxide and water vapor. There would be very little water. The Martian sky would be nearly black, and dotted with high-floating blue or violet clouds of fine ice powder.

You would face storms at times. And strong winds that sweep up large clouds of yellow dust as they drift across the planet.

Some observers have said they see a complex web of fine lines on Mars. Other, equally reliable observers have seen nothing. Most astronomers now agree that these controversial "canals" may be only an optical illusion. But they are surely not artificial waterways.

Where vegetation exists—and we believe it does on Mars—animal life is possible, too, though it is not likely that human-like life will be found. But here we have no relevant observations. Only exploration of the planet—first by probes and then by manned expeditions—can answer this question in a final way.

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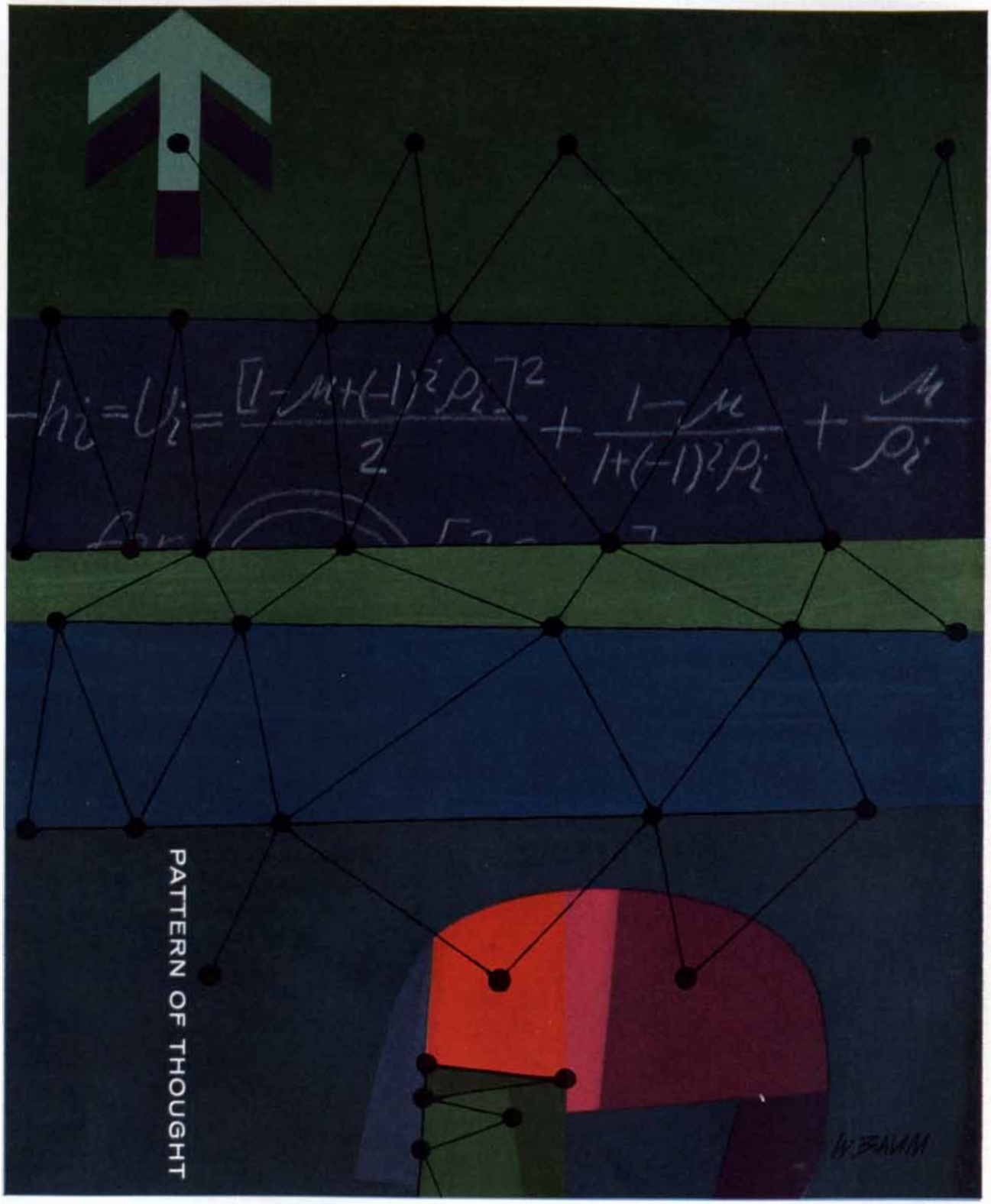

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leagues who work there have had to make a neurosurgeon's map of the human brain—a map showing what sort of disturbance to expect if different parts have to be removed and how those parts are to be recognized during an operation. They have been particularly concerned with the surgical treatment of epilepsy, because there is one kind of epilepsy in which the seizures appear to start from a focus in the cerebral cortex when there has been local damage followed by scarring. The search for this focus involves the electrical stimulation of the suspected region and the making of electrical records of its activity; and if the focus is found and removed, the attacks usually cease. These operations have been amply justified by results, and in the course of them the human brain-surface has been explored in detail, as the brains of various animals were explored many years earlier.

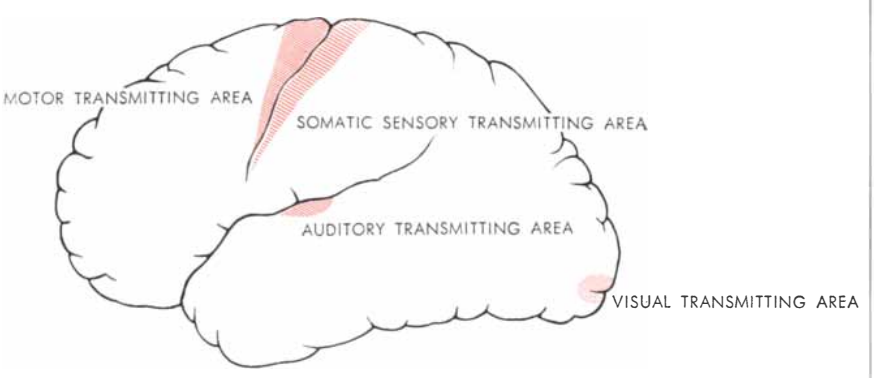
In its more obvious landmarks the human map has the expected pattern, having a motor area responsible for skilled movements and various sensory areas to which messages are sent from the different sense organs. These areas are all that can be looked for in the brain of an animal under an anesthetic, but in the human brain the search can go further. It can be conducted by examining the brain of a patient who is fully conscious, and so it can tell us something about the regions that play a part in our conscious processes, not only in our use of words but also in our memories and in our thought in general. As usually happens, it has not given us the kind of information we expected, but there is quite enough to raise our hopes.

As regards speech it tells us not to expect a rigid separation of different functions in the regions concerned with it. There is Broca's area, which is chiefly concerned with the production of the spoken words, and there are larger regions farther back on the brain surface for what Penfield calls ideational speech. But stimulating these different regions can produce a variety of speech disturbances, and it is not safe to predict the particular form they will take.

An electrical stimulus will not produce speech. The explosive kind of activity it sets up in the nerve cells can only prevent their normal work; and the effect is always an interference with speech. The patient is told to talk or to count aloud or to describe a picture, and when Broca's area is stimulated he may become silent. He reports afterward that he found himself unable to say anything. But the result of stimulation of Broca's area and of other regions is more often a partial interference and is limited to some particular kind of verbal activity. When the stimulus is applied, the patient may speak indistinctly and repeat syllables or words. He may count numbers in the wrong order or find himself unable to name a familiar object. For instance, a patient shown a picture of a foot could only say: "That is what you put in your shoes." He said "Foot" as soon as the stimulus was cut off.

All these varieties of speech defect are found in cases of aphasia resulting from brain disease or brain injury. There are also many of us who are not recognizably aphasic but who are uncomfortably aware that we are sometimes at a complete loss to recall the name of someone we know very well. If we have this difficulty, we know that it is occasional and capricious; it is no surprise to learn that the defects caused by stimulating the speech areas can be equally capricious. Only 50 per cent of the stimulations are effective. The arrest of speech may be caused by the stimulation of one point but not by the stimulation of another close by within the same speech area. And although particular kinds of defect tend to be associated with particular regions, there is no certainty that they will be associated with them in any given case.

In fact, the chief conclusion we can



The projection areas of the cerebral cortex are indicated in color

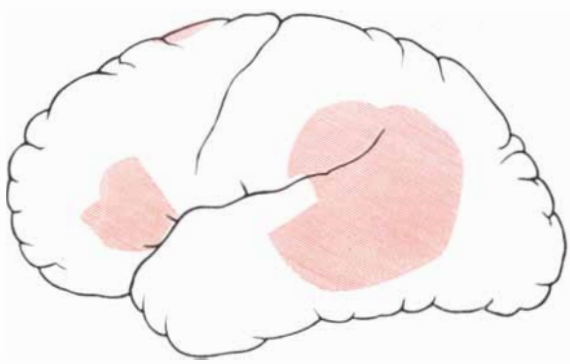
draw is that the speech mechanism cannot be analyzed in terms of a number of different assemblies, each dealing with one or another of the ways in which words are used. We can, of course, distinguish parts of the brain mechanism that are used in any kind of intelligent activity. If we are to understand what we read, the message from the eyes must be received in the visual area of the brain. If we are to speak or write, the motor area must send the correct signals to the muscles of the larynx or of the hand. Yet although we cannot find special regions for different subdivisions of ideational speech, we can at least say that there are large areas of the brain surface that seem to have nothing to do with it—areas where injury or stimulation makes no difference at all to our ability to use words.

This leads us to a remarkable fact that came to light when aphasia was first recognized: the fact that the areas concerned with speech are found only on one side of the brain. It is usually the left side, and since the left hemisphere of the brain is related to the right side of the body and controls the right hand, it has been considered the dominant hemisphere, and for that reason has been thought to be the hemisphere in which the speech mechanism is found. Because there have been some cases of aphasia in left-handed people with disease of the right hemisphere, it is usually supposed that in left-handed people the right hemisphere is dominant instead of the left, and that the speech mechanism is there too. Penfield's results throw some doubt on this. It appears that in many left-handed people the speech areas are on the left as usual, although it is true that in a small number of cases they are on the right. Whatever the reason for it, the usual arrangement leaves one half of the brain with no sign of any function connected with words.

This does not necessarily mean that the nonverbal hemisphere has no function connected with thinking. Mental activity can go on without words. Memories are often pictures, and the need for words comes in only when we want to communicate our ideas or reduce them to order for our own use. But there is little evidence to connect the nonverbal side of the brain with nonverbal thinking. Indeed, there is not much to show that it has any relation to the mind.

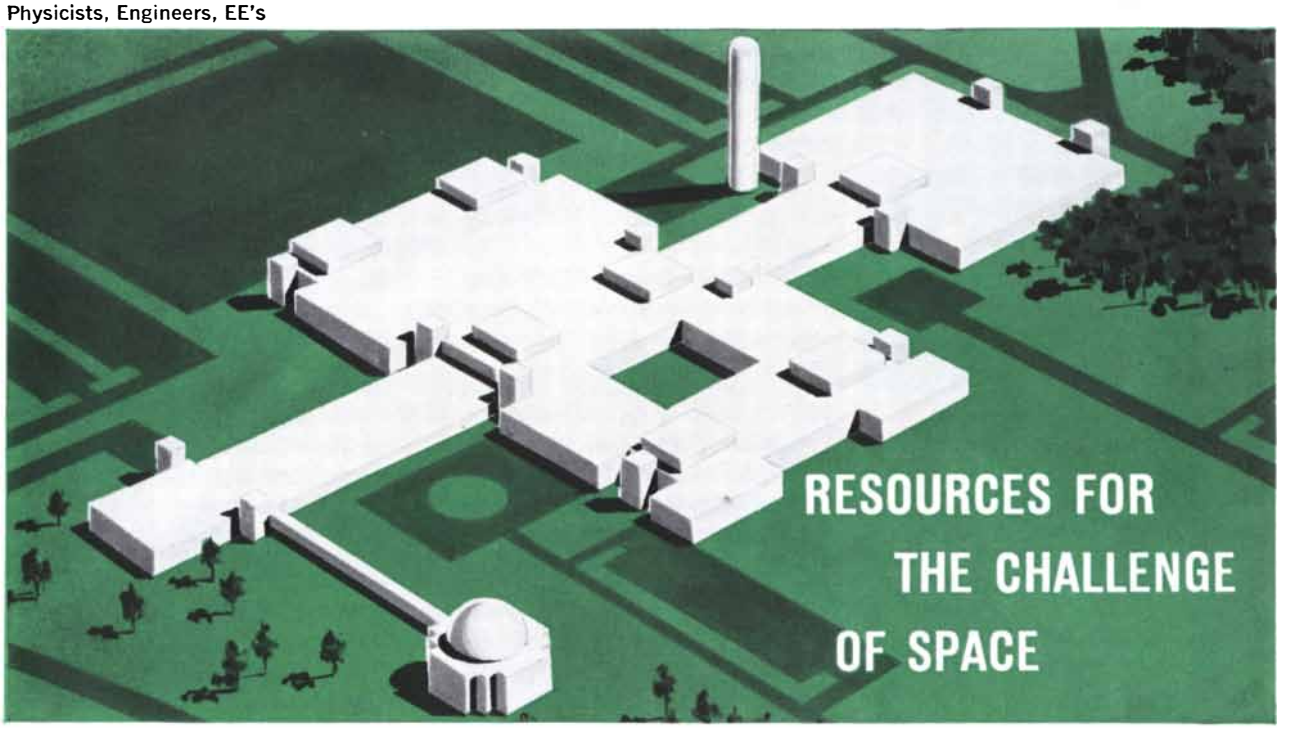
There are a few hints that it has, but it is difficult to see where they lead. Injury in a particular area of the right, or nonverbal, hemisphere can disturb notions of body position in space: Penfield finds that stimulating an epileptic focus in the temporal lobe in either hemisphere will sometimes arouse a vivid experience of some past event, though stimulating the normal brain surface will never do so. But the whole of the right cerebral hemisphere has been removed from time to time without producing a gross loss of memories or a disturbance in thinking.

We have to be very careful, however, in interpreting the results that follow injury or removal of part of the human brain. Memory and intellectual capacity may seem to be unimpaired, but we can never be sure that the patient has not lost some of the whole store of memories that used to be at his disposal, or that he would be able to write as good a novel, or cross-examine a witness as well, as he would have done before. Another difficulty comes from the remarkable way in which living organisms in general manage to adapt themselves to injury. It is clear, for instance, that the use of words is not irrevocably tied to one side of the brain. Extensive damage to the left hemisphere at birth does not necessarily prevent a child from learning to speak. The speech mechanism may be set up in the right hemisphere; even in an adult there may be considerable recovery of speech after the normal mech-



The speech areas of the dominant (usually left) hemisphere are indicated in color

Physicists, Engineers, EE's



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anism is destroyed. We must remember, therefore, that the parts of the brain that may need removal by the neurosurgeon are parts that have already been damaged. If they have lost some of their function, another part of the brain may have begun to take it over. The symptoms that follow are a doubtful guide to the normal function of the part that is removed.

The degree of recovery of function, of reorganizing the mechanism when the original site for it is destroyed, depends heavily on the age of the patient and no doubt on the extent to which the mechanism involves a special structural arrangement. But in most of the cerebral cortex the structure is nearly uniform. There are the same layers of nerve cells with interlacing fibers. There are differences in the sensory and motor areas, where messages enter and leave the cortex, but the uniform arrangement and lack of distinctive features in the rest of the sheet make it easier to accept its power of reorganizing its activity. At all events it appears that the normal location of areas with special functions is decided more by the general distribution of cortical activity than by the presence of special types of nerve cell or special linkages between cells.

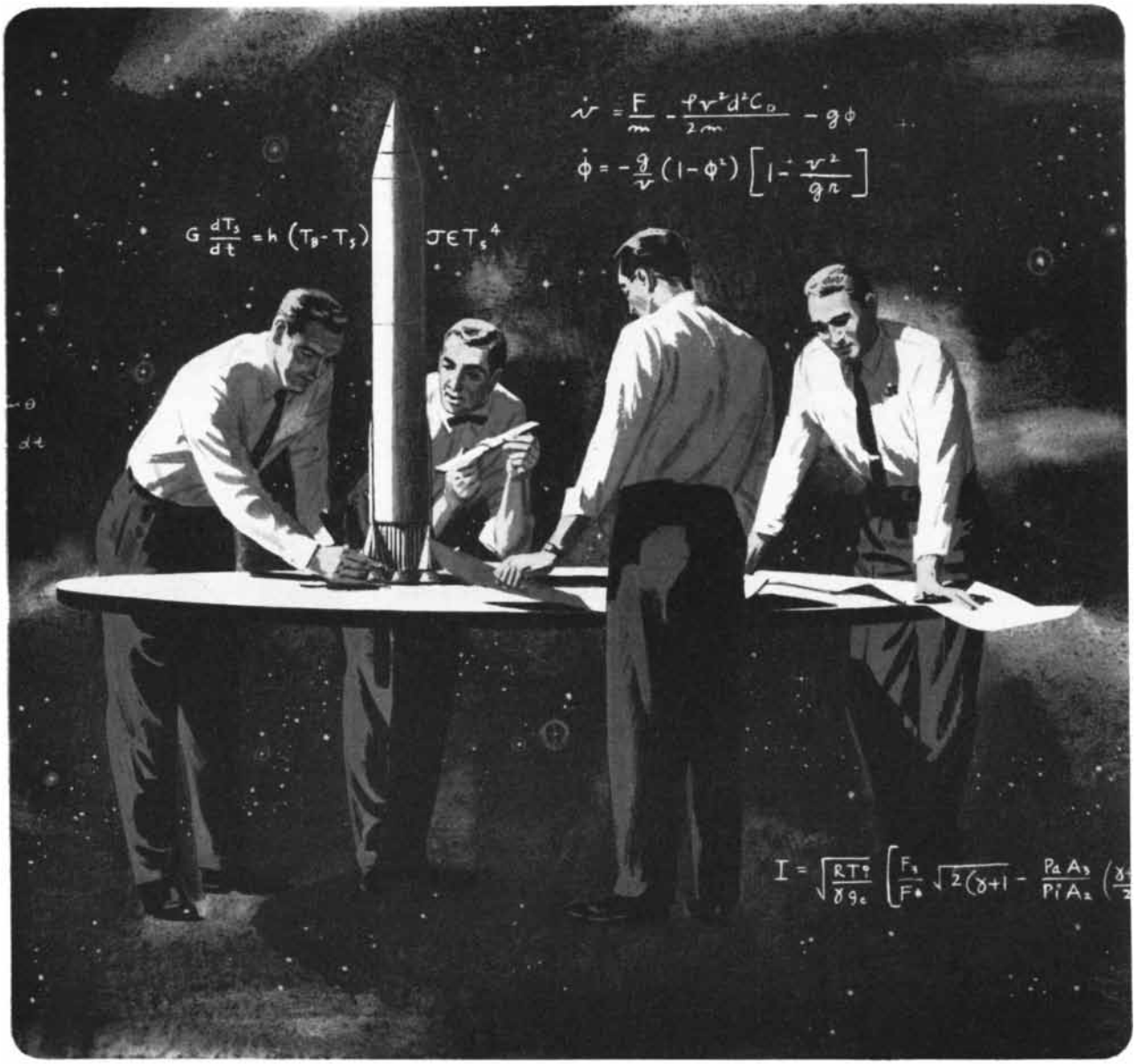
Modern investigation has thus emphasized the view that there are no well-defined areas for particular verbal and still less for particular mental activities. The realization of this is shown by the growing confidence of neurosurgeons. Fifty years ago large areas on the left side of the brain were still out of bounds to the surgeon for fear that some irrevocable aphasia would follow if they were interfered with. Now, with the far better mapping techniques and better methods of treating the exposed brain, what Penfield calls the forbidden territory has shrunk progressively. Even the removal of Broca's area has seldom led to more than a transient speech defect.

Moreover, the frontal lobes were supposed to have some special association with intellectual processes, since they are highly developed in the human brain, but prefrontal leucotomy, the operation that damages their deep structure, was found to relieve anxiety and has led to much more extensive operations. Though they have certainly produced changes in the general outlook and disposition of the patient, there is surprisingly little interference with any mental process that can be measured by psychological tests. Intelligent actions are still carried out, and memory seems no worse.

But there must be some location in the brain for storing the physical traces that evoke our memories. The temporal lobes may have special access to that store, because verbal associations suffer from temporal injuries on the left side and on both sides. There is also the curious phenomenon, described by Penfield, wherein electric stimulation of the temporal lobe revives some past experience. The frontal lobes may regulate our depth of feeling, yet the modern neurosurgeon has found no place where he can "raze out the written troubles of the mind." All he can do is to make us less concerned about them.

Why is it so hard to find a place for any mental activity other than the use of words? Perhaps we are trying to solve a problem that is unsolvable because we are stating it wrongly. Mental activities and the structure of the brain are in such different categories that our comparisons may have started out in the wrong direction. For the physiologist, however, the answer may be that we cannot see clearly where any of the traces are written, because the writing is spread out so widely over the cerebrum. The writing must establish a tendency for the cerebral activity to take a particular pattern when the incoming signals have a pattern of their own. We must suppose that such a tendency, and a vast number of others, can be impressed in every part of a large area of the cortex in a way that can survive a limited destruction of any part of it. And although partial destruction seems to have little effect, we must suppose that it is the large extent of the sheet that has given it this power to elaborate the appropriate response. There have been various suggestions as to the kind of nerve-cell mechanism that might work in this way. Most of them involve the notion that a pattern can be a sequence in time as well as an arrangement in space; they have shown that a mechanism with these properties is not an impossibility, though they have scarcely reached the stage at which they can be tested.

Experiments on the brain have at least shown that the mechanism must be held to exist not only in the surface sheet but also in the parts beneath it. The Penfield and Roberts book emphasizes the role of the large central masses of nerve cells: the "centrencephalic region." This is linked with the cortex and with the "reticular formation," the important part of the brain stem that decides the general level of activity in the cortical sheet. Signals from the sense organs, for instance those aroused by hearing a familiar voice, influence the central regions as well as the cortex. To begin with, each



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region may react to particular qualities of the voice; for example, the brain stem may respond to the sound, and the cortex to its familiarity. But at once there will be widespread interactions of every level. These will decide that the sound has a meaning and deserves an answer and will arouse the activities that search out the traces of past experience to find who is speaking and how he should be answered.

The physiologist and the neurosurgeon can only try to explore the mechanisms of the brain in the hope of finding the chain of physical and chemical events that leads us to behave as we do in response to the events in our surroundings, to call the friend who speaks to us by his name and to give the right answer to his questions. How such events in the brain are linked to our thoughts is for philosophers to debate. Calling the brain events conditioned reflexes does not settle the problem or satisfy us that an electronic machine could be as self-conscious as we are.

But now that we are so much more able to explore the human brain we are beginning to see what kind of mechanisms we have to consider. There are definite pathways in and out, and important controlling regions in the brain stem and the central parts, but it is the enlargement of the surface that distinguishes the human brain: our intelligence seems to depend on the great extent of our cerebral cortex. It is possible that a large cortex might promote intelligent behavior because it would allow for the presence of special regions for special intellectual activities, along the lines of the phrenologists' maps; there are certainly regions specially concerned with words. But the speech areas take up less than a 10th of the surface, and elsewhere we have only a few hints at any functional subdivision. The cortex has a uniform structure, and the removal of different regions outside the speech areas seems to have no distinctive effect on any department of memory or thought. We must fall back, therefore, on the contrary hypothesis, that our enlarged cortex gives us our intelligence, not by allowing all kinds of specialized machinery to exist side by side, but by providing a large mass of nervous material in which every unit can take some part in every activity.

Hypothesis is perhaps the wrong word; this is a statement of facts to be explained and not much of a guide to their explanation. It is not, of course, a complete statement, but it points to the major problem that brain physiology must try to solve: How a large, uniform sheet of nervous tissue can help us be-

have as intelligent organisms. Neurosurgery has enabled us to examine the sheet in detail and has made us less afraid of tampering with it. Electrical records can show what the different elements are doing. Before very long the methods that Penfield and Roberts have used in their study of the speech mechanism may throw more light on what the rest of the brain is doing, how it makes us interested in such problems and gives us the hope of solving them.

Short Reviews

MATHEMATICS AND THE PHYSICAL WORLD, by Morris Kline. Thomas Y. Crowell Company ($6). The teaching of mathematics has for many years been a center of controversy. Especially in the last decade or so the lines have been sharply drawn between those who feel that current methods of instruction are outmoded because they are not sufficiently abstract, general and rigorous, and those who, while no less critical of the methods in use, feel that the proposed cure is worse than the disease, and that what mathematics teaching needs is more, not less, emphasis on the applications of the discipline to physical problems. Morris Kline belongs to the latter group. He has written this book to prove his thesis by displaying the incomparable role of mathematics, today as in the past, in the study of nature. His presentation is confined to elementary mathematics, from arithmetic through the elements of the calculus and non-Euclidean geometry; but with these tools he is able to make an entry into a wide variety of physical questions. His exposition follows a historical course. Mathematics has been used in practical affairs such as computing taxes, determining land boundaries, measuring volumes, reckoning distances, navigation; and also in more exalted inquiries, about the size of the earth, the motions of the planets, the path of light, the harmonics of strings, the speed of falling bodies, the nature of electricity and magnetism. Kline is a first-class teacher and an able writer. He knows the sticking points in mathematical learning, the places where the average student is apt to go astray, get lost and abandon the whole business. This is a rare gift of intelligence and sympathy, and the reader receives the full benefit of it. Innumerable examples could be cited: Kline's explanation of the indefinite integral, of Fourier series, of Galileo's discoveries, of Newton's achievement in proving that the gravitational attraction exerted by a sphere acts as though the entire mass of the sphere

were concentrated at the center, of the calculus of variations, of the electromagnetic theory of James Clerk Maxwell, of William Rowan Hamilton's minimum principle. It becomes increasingly clear as one follows the exposition why mathematics is today the "heart of our best scientific theories," why it is the primary goal of modern scientific theory to subsume an ever broadening array of observational results under a handful of terse mathematical principles. We depend upon experiments; yet the more facts we gather, the more uncertain we become of piercing their reality and the more we come to rely on the relations and symmetries and order we can impose upon them through mathematics. This is an enlarging and a brilliant book, better even than Kline's *Mathematics in Western Culture*. If there were more teachers like Kline, there would be less wrangling about how mathematics should be taught.

HISTORY OF THE ROYAL SOCIETY, by Thomas Sprat. Edited by Jackson I. Cope and Harold Whitmore Jones. Washington University Press ($7.50). Sprat's *History*, published in 1667, is a rare book, yet one which, as the editors of this attractive reproduction point out, "has been as frequently quoted (and misquoted) as any single document used to interpret the intellectual history of the later seventeenth century." Sprat was a young churchman of 28 (he later became Lord Bishop of Rochester) when he was admitted to the Royal Society in 1663. He had entered Oxford just in time to grow up in the exciting environment of the "Invisible College" meetings at Gresham College, and it is likely that he was invited to accept membership in the Royal Society to write a defense of the Society, for it had become involved in a battle of propaganda and counterpropaganda, and had been attacked for its "learned impiety and folly." Even Charles II, who had in 1662 given the scientists a charter, could a few months later be found, in Samuel Pepys's words, spending "an hour or two laughing at Sir W. Petty . . . about his boat; and at Gresham College in general . . . for spending time only in weighing of ayre, and doing nothing else since they sat." The writing of the *History* was interrupted by the terrible plague and the great fire which followed so closely upon it, and its final form was shaped by the further attacks on the Society that these catastrophes inspired—or at any rate for which they provided a convenient pretext. "Antiroyalists, enthusiasts, millennialists saw the tragedies of London as a

curse upon the King from an angry God"; there was fear of a second religious rebellion, and anti-Greshamites renewed the opportunity to calumniate the makers of "vulgar prophecies" and others so misguided by pride as to believe they could divine the course of nature. But Sprat in the *History* turned the gloom and fears of the time against the prophets of doom: "It is now the fittest season for EXPERIMENTS to arise, to teach us a Wisdome, which springs from the depths of KNOWLEDGE, to shake off the shadows, and to scatter the mists, which fill the minds of men with a vain consternation." Sprat explains how and why the Society came into being, its justification, its objectives, its philosophy, its promise. He acknowledges that the style of the writing is "larger and more contentious than becomes that purity and shortness which are the chief beauties of Historical Writings: But the blame of this ought not so much to be laid upon me, as upon the Detractors of so noble an Institution"; for their objections and cavils have sometimes forced him away from "plain History" to the way of an "Apology." Nonetheless his discourse is both palatable and clear as he points to the mistakes of the "Talkative Sects" among the ancients who made a "hasty Fabrick" of the "Building of Sciences"; and as he champions the cause of now creating "fairer, and more moving Images: to represent TRUTH, cloth'd with Bodies; and to bring KNOWLEDGE back again to our very senses, from whence it was first deriv'd to our understandings." The editors have written an informative introduction, have added a large number of valuable notes and several useful appendices. An index, however, is much needed. This is a praiseworthy piece of scholarship, and the Washington University Press is to be congratulated on the physical appearance of the volume.

TURNING POINTS IN PHYSICS, by R. J. Blin-Stoyle, D. ter Haar, K. Mendelssohn, G. Temple, F. Waismann and D. H. Wilkinson. North-Holland Publishing Company and Interscience Publishers, Inc. ($3.50). This book presents a series of lectures, given at the University of Oxford in 1958, that was addressed to philosophers and scientists who were not physicists. The turning points described are the end of mechanistic philosophy and the rise of field physics, the quantum theory, the entry of probability into physics, relativity, the causality crisis, new concepts of elementary particles. The publishers say that the book is for laymen as well as

specialists, but most of the lectures call for both a background of knowledge and close attention. Conceding these requirements, the book is highly instructive as well as revealing. It explains a good deal of what has happened in and to physics since James Clerk Maxwell and Michael Faraday, and it also explains why the subject is so active, so fruitful, so magnificently successful and so nervously unsure of itself—not only moving from strength to strength, but lurching from crisis to crisis.

SUSPECT DOCUMENTS, by Wilson R. Harrison. Frederick A. Praeger, Inc. ($15). The author of this book, who has had 24 years of practical experience in the British Government's Home Office Forensic Science Laboratory, gives a minutely detailed account of the scientific methods for nosing out ingenious hanky-panky in various documents—letters, leases, wills, receipts, checks, literary manuscripts, diplomas, etc.—which have figured in cases ranging from murder to the sending of anonymous letters. He discusses the materials from which documents are made, the examination procedure, the equipment of a document laboratory (microscopes, chromatographic apparatus, X-ray machines, spectroscopes, infrared apparatus), the photography of documents, dating problems, typescripts, handwriting disguise, forged signatures, the presentation of a document case at court. Perfect for both professional and sofa sleuths.

PRINCIPLES OF OPTICS, by Max Born and Emil Wolf. Pergamon Press ($15). A first-class comprehensive survey of the electromagnetic theory of the propagation, interference and diffraction of light. The authors have deliberately restricted their compass to those optical phenomena that may be treated in terms of James Clerk Maxwell's theory as expressed in his basic equations, including all situations "in which the atomistic structure of matter plays no decisive part." Brief references to atomic physics, quantum mechanics and physiology are given where necessary. That this book, despite its restrictions, is much larger than Max Born's *Optik*, which appeared some years ago in German, gives some indication of the extent of the researches in classical optics in recent times.

GREAT EXPERIMENTS IN PHYSICS, edited by Morris H. Shamos. Henry Holt and Company ($4.50). This compilation used by liberal-arts students in a physics course at New York University gives excerpts from the classic accounts

of Galileo, Boyle, Newton, Charles Coulomb, Henry Cavendish, Thomas Young, Augustin Fresnel, Hans Christian Oersted, Michael Faraday, Heinrich Lenz, James Joule, Heinrich Hertz, James Clerk Maxwell, Wilhelm Konrad Röntgen, Henri Becquerel, J. J. Thomson, Max Planck, Albert Einstein, Robert Millikan, Niels Bohr, Ernest Rutherford, James Chadwick, Arthur Compton. Although a good deal of the material offered here appears in William Francis Magie's *Source Book in Physics* and in other compendia, the editor usually presents larger excerpts than others have done, and his marginal notations and introductory comments will help the nonphysicist to follow the argument. An enjoyable and instructive anthology.

THE RAINBOW, by Carl B. Boyer. Thomas Yoseloff ($10). Speculations about the cause of the rainbow have a long history, but this book makes it seem longer. In 375 well-illustrated pages the author has set forth every flight of ideas on the subject, from supernatural explanations to the modern theory based on optical principles. While a moderate amount of the material is interesting, much of the story is taken up with earlier conjectures that are not engrossing and do not greatly enlarge one's understanding of the growth of scientific thought. Boyer has dug up everything that the most relentless historian of science would consider even remotely relevant; it is doubtful anyone will ever have to or want to do the job again.

THE ARTERIAL WALL, edited by Albert I. Lansing. The Williams & Wilkins Company ($7.50). Approximately two out of three adult deaths are caused directly or indirectly by cardiovascular disease. Knowledge of the biology of arteries is of considerable importance in making headway against this disease. The papers in this volume review the information currently available on the structure, function and chemistry of arteries, which are now recognized as being not mere conducting tubes but "hard working organs with personalities of their own."

INTRODUCTION TO MATHEMATICAL THINKING, by Friedrich Waismann. Harper Torchbooks ($1.40). A paperback reprint of Waismann's exceptionally lucid introduction to the fundamental concepts of modern mathematics. The treatment is philosophical and rich in insights into the style and substance of the mathematical way of thinking; the difficulties are not evaded, but the se-

rious reader will not be left behind to flounder in technicalities.

DRAWINGS FOR A LIVING ARCHITECTURE, by Frank Lloyd Wright. Horizon Press ($35). A collection of some 200 of Wright's architectural drawings, 75 of them in color, covering 70 years of his work in designing community structures, country clubs, public buildings, residences, buildings for "recreation and rural delight," tall buildings, structures for business. The text, apart from captions, consists of two essays, an interpretation of Wright's architecture by a leading Italian critic, Giuseppe Samonà, and an estimate of the drawings as a contribution to the evolution of draughtsmanship by A. Hyatt Mayor, Curator of Prints at the Metropolitan Museum of Art. Some of the drawings are superb and afford unique insight into Wright's ideas and methods, especially where one can follow the progress from casual sketches to finished renderings; others are so fragmentary or specialized as to carry little meaning except perhaps for professionals. The book itself is a splendid artifact, and the reproductions are beautifully executed.

ETRUSCAN ART, by Raymond Bloch. New York Graphic Society ($25). A large, handsome volume of 100 plates, 71 in color, showing examples of the painting, major sculpture, jewelry, ceramics and magnificent relief work of one of the most extraordinary and mysterious of vanished cultures. The French scholar Raymond Bloch, whose excellent study of the Etruscans was reviewed in these columns some months ago, provides an enlightening text on the origins of Etruscan art and traces the motifs which were to reappear in Roman works and much later in the sculptures of the Italian renaissance. This attractive contribution to both art and archaeology has been executed with the care and finish characteristic of the publications of the New York Graphic Society, among which the admirable UNESCO World Art Series are perhaps best known.

THE BIRDS OF THE BRITISH ISLES, VOLUME 8, by David Armitage Bannerman. Oliver and Boyd (63 shillings). Bannerman's eighth volume embraces the webfooted birds (including the cormorant, shag, frigate bird and gannet), the tubinares (petrels, shearwaters and albatrosses), diving birds, the order Columbiformes (pigeons and doves) and Pallas's sand grouse (the sole representative of the order Ptericletiformes), which has visited Britain from its home

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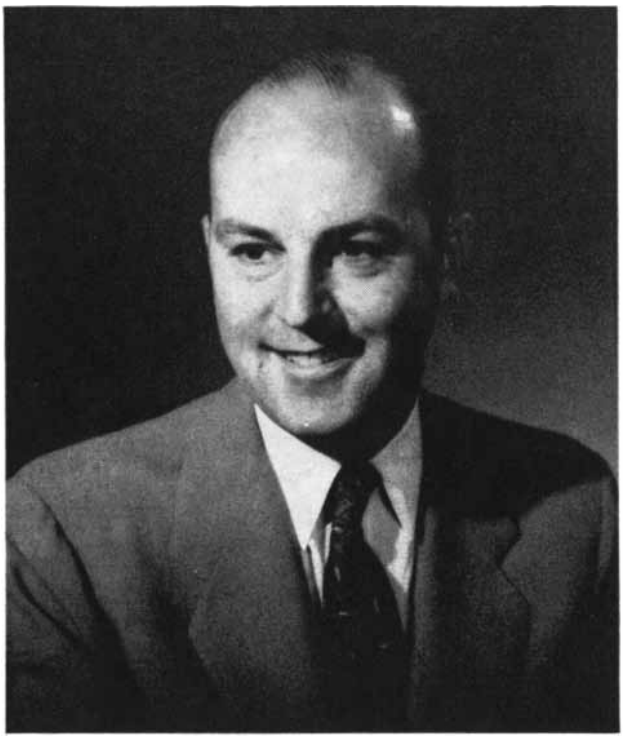

by Charles A. Kerner

Chief Engineer, Systems Support,
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in the deserts of Asia. Many other specialists have contributed to these essays, and there are 26 color plates by the late George E. Lodge. To those who have followed the notices in these columns of earlier volumes of this splendid work, it is sufficient to say that the author does not falter and that the style and accuracy of this volume measure up fully to the distinguished standard established in the past.

RACE FOR THE POLE, by John Edward Weems. Henry Holt and Company ($4.50). A highly entertaining and laudably dispassionate account of the historic Peary-Cook battle over who first got to the North Pole, including an excellent summary of each man's own account of his exploit. Robert E. Peary very likely reached the Pole, and Frederick Albert Cook almost certainly didn't; but as the late Peter Freuchen, an admirer of Peary, was fond of saying: "Cook was a liar and a gentleman; Peary was neither." The result was that Cook, holding an obviously worthless hand, managed to keep supporters, and that Peary, holding all the trumps, managed to increase the tribe of his enemies.

EVIDENCE AND INFERENCE, edited by Daniel Lerner. The Free Press ($4). Six lectures that attempt to show the contemporary role of evidence and inference in a wide range of fields: history and law, psychoanalysis and social psychology, nuclear physics, "attitude research." There are some nutritious items, but the claim which is made that one can gain from this volume a unified view of these classic problems of knowledge in their modern setting is nonsense. This is a chowder that the chef hasn't even tried to blend.

Notes

TOWARD A SYSTEMATIC PRAGMATICS, by R. M. Martin. North-Holland Publishing Company ($3.25). The logical study of a language or language system is usually one of three kinds: syntactical, semantical or pragmatical. In this book several tentative but systematic theories of pragmatics of a restricted kind are presented.

THE POPULATION OF THE UNITED STATES, by Donald J. Bogue. The Free Press ($17.50). An invaluable reference compendium by a University of Chicago sociologist, presenting a wealth of information and statistics on the size and growth of U. S. population, population distribution, age and sex composition,

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THE SKY OBSERVER'S GUIDE, by Newton Mayall, Margaret Mayall and Jerome Wyckoff. Golden Press, Inc. ($2.95). A clearly written handbook for amateur astronomers that covers first principles, tells how to use binoculars and telescopes, describes the sun, the moon and the planets and other celestial objects, offers instruction on sky photography and advises on the care of equipment. Many illustrations. Useful and unpretentious.

A BOOK ABOUT BEES, by Edwin Way Teale. Indiana University Press ($1.95). Paper-back reprint of this well-known naturalist's readable survey, originally published as *The Golden Throng*. Eighty-five photographs by the author.

NIGHT VISION, by Gaetan E. Jayle, Albert G. Ourgaud, L. F. Baisinger, William John Holmes. Charles C. Thomas ($13.50). A translation from the French, with modifications, of a monograph on night vision and its derangements.

CLOSE BINARY SYSTEMS, by Zdenek Kopal. John Wiley & Sons, Inc. ($16.75). A general account of our knowledge of close double stars, including an exposition of modern methods for the analysis of light changes of eclipsing double stars, and certain conclusions concerning the general physical characteristics and evolutionary trends in such systems.

AN INTRODUCTION TO THE KINETIC THEORY OF GASES, by Sir James Jeans. Cambridge University Press ($2.95). A paper-back edition—the first of a promising new series issued by Cambridge University Press—of Jeans's students' edition of his noted *The Dynamical Theory of Gases.*

THE LATER PHILOSOPHY OF WITTGENSTEIN, by David Pole. Essential Books-Oxford University Press. ($2.40). A short exposition and critique of Ludwig Wittgenstein's later opinions, expressed in his *Philosophical Investigations* and *Remarks on the Foundations of Mathematics.* An able book, but one that presupposes an acquaintance with Wittgenstein's thought.

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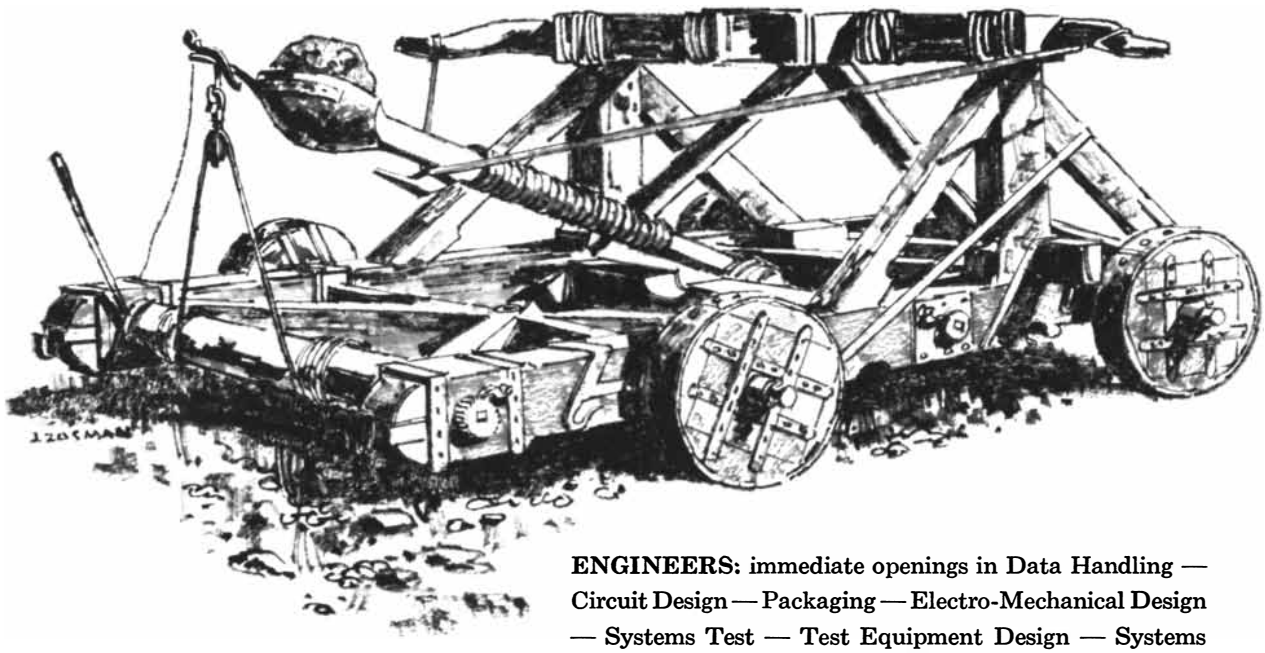

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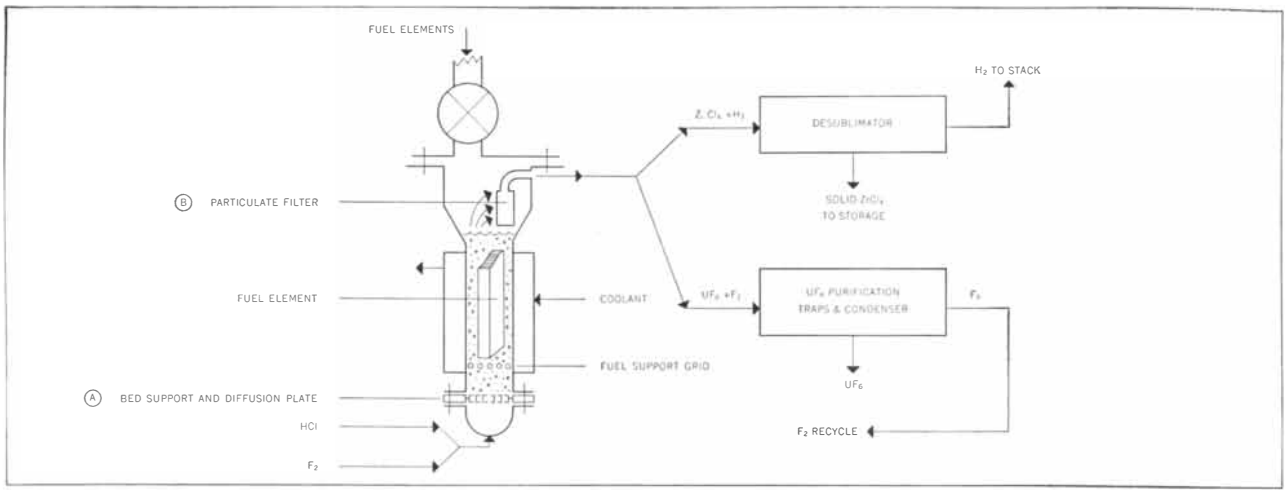

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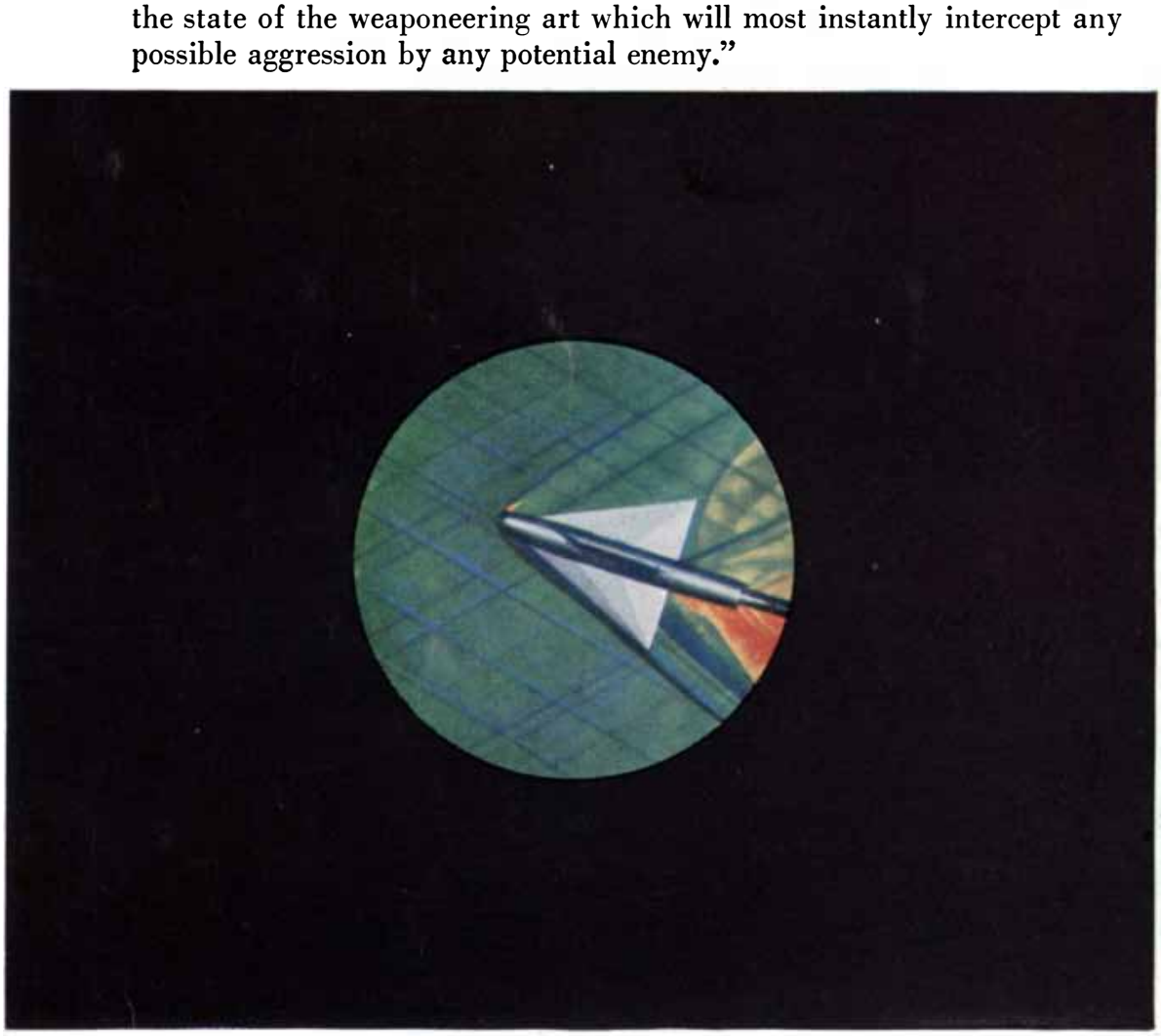

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