SCIENTIFIC AMERICAN

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August 1961

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"Freon-115"	$CClF_2CF_3$	−37.7
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Established 1845 **SCIENTIFIC AMERICAN** August 1961 Volume 205 Number 2

ARTICLES

DEPARTMENTS

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THE COVER

The painting on the cover shows three pairs of marine organisms. The smaller organism in each pair lives partly by cleaning the larger one, eating parasites and dead tissue. Skin-diving marine biologists have recently discovered that this "cleaning symbiosis" is quite common among organisms that live in the sea (*see page 42*). In the pair at top left a smooth trunkfish (*Lactophrys triqueter*) is cleaned by a bluehead (*Thalassoma bifasciatum*). In the pair at center right the larger fish is a black angelfish (*Pomacanthus paru*); the smaller one, a neon goby (*Elecatinus oceanops*). In the pair at bottom a longjaw squirrelfish (*Holocentrus marianas*) is attended by a tiny, violet-spotted Pederson cleaning shrimp (*Periclimenes pedersoni*).

THE ILLUSTRATIONS

Cover painting by Rudolf Freund

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38	David Linton (*top*), Mary Russel (*bottom*)
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48	Charles H. Turner
49	F. M. Bayer, Smithsonian Institution (*top*); Conrad Limbaugh (*bottom*)
50	Robert Hargraves, University of the Witwatersrand (*top left*); C. W. Wilson, Jr., Vanderbilt University (*top right*); Robert S. Dietz, Navy Electronics Laboratory (*bottom*)
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53	Royal Canadian Air Force, courtesy Dominion Observatory
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109	Ivan J. Donaldson (*top left*); Pacific Salmon Investigations, U.S. Fish and Wildlife Service (*top right*); P. E. Purves, courtesy British Museum of Natural History (*middle*); Smithsonian Institution (*bottom left*); American Museum of Natural History (*bottom right*)
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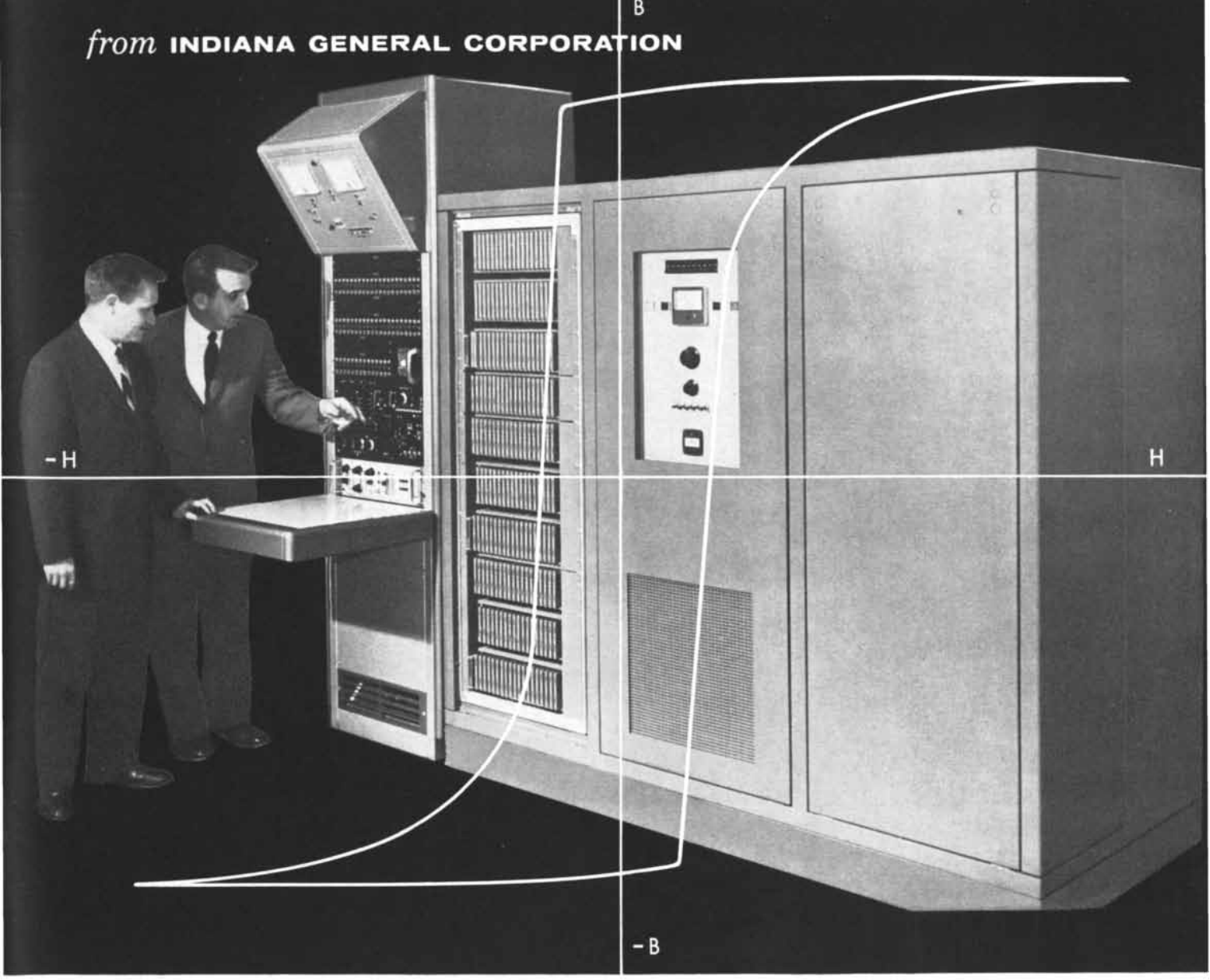

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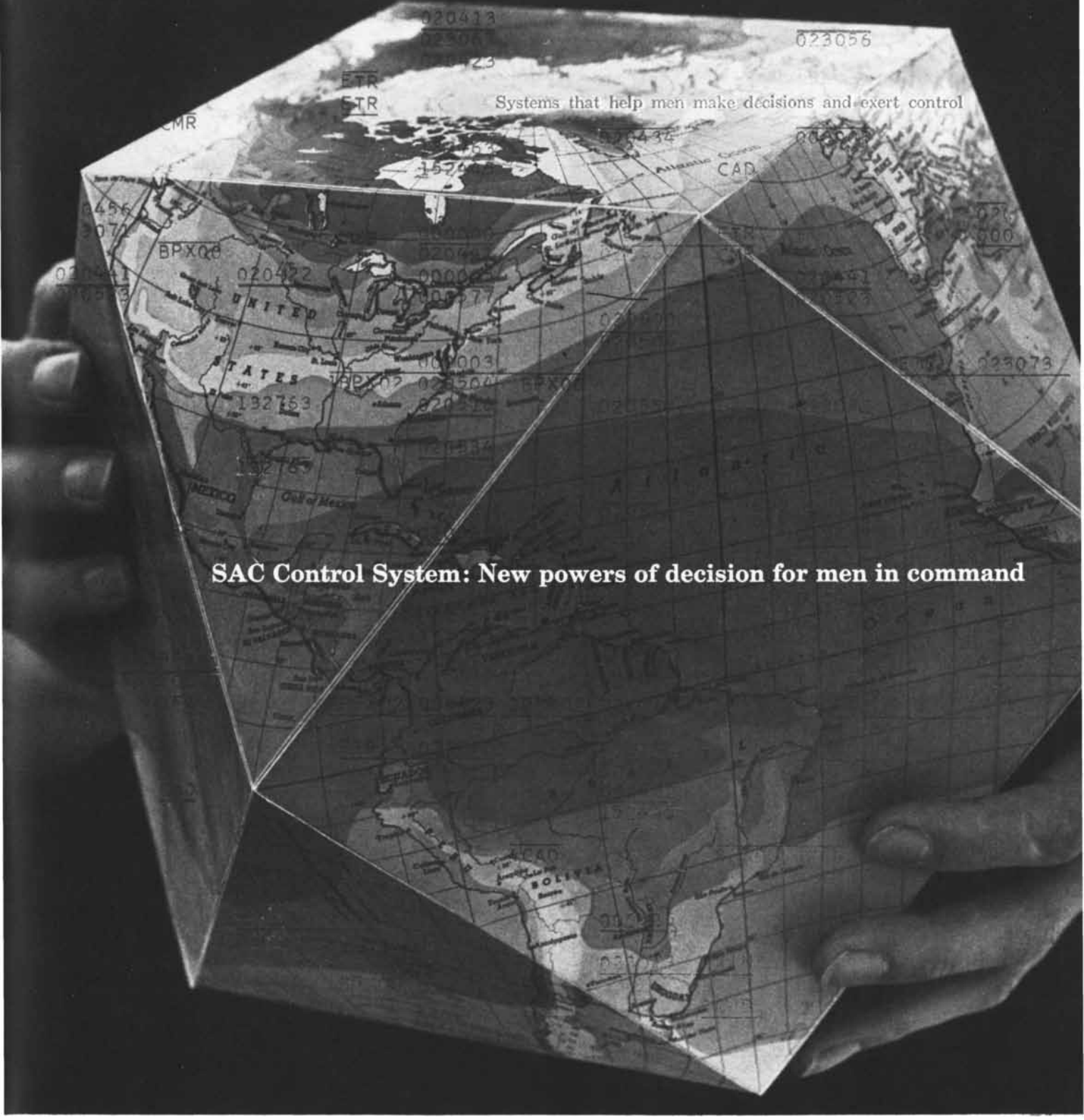

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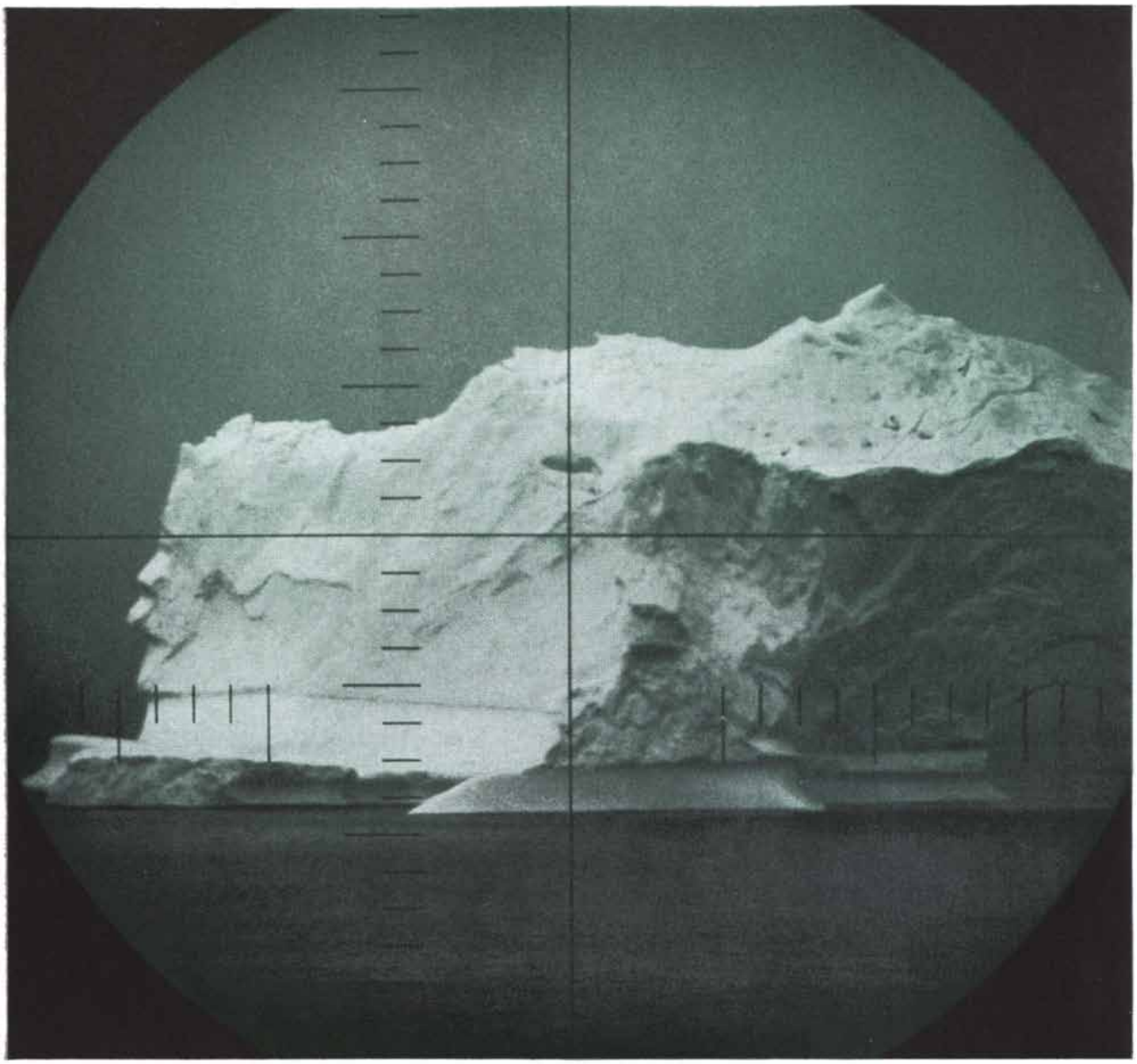

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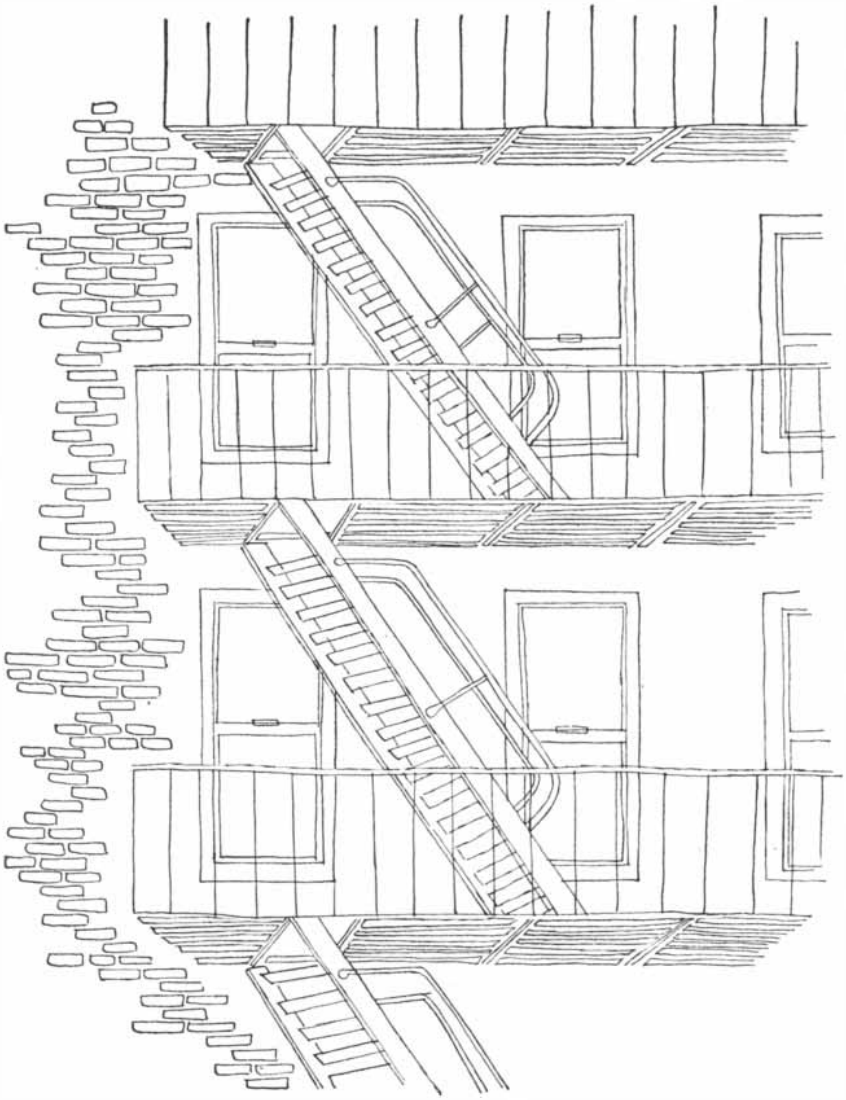

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LETTERS

Sirs:

Harold I. Sharlin's work in following magnetic induction "from Faraday to the dynamo" [SCIENTIFIC AMERICAN, May] made quite enjoyable reading but it does spur me to jot these few lines of criticism. In answer to his query "Why 50 years?" the author's comments did not include the enormous difficulties of obtaining insulated copper wire in the quality and quantity required in the earlier part of those 50 years.

In the latter half of the 19th century the self-excited dynamo at last approached practicality; one should not overlook the difference in efficiency of these machines nor lose sight of those who increased it. After all, Watt is recognized (with just cause) for his improvement of the steam engine's efficiency to the point of being considered its inventor. Gramme's dynamo did differ from Pacinotti's in that Gramme used iron wires in the armature to reduce drastically the eddy-current losses occurring in solid armatures.

One also laments the omission of the man who produced (beginning in 1873) the most efficient motor of this period—Edward Weston. By careful analysis and attention to detail Weston produced machines of better than 90 per cent efficiency by breaking up the armature to avoid eddy currents (as Gramme did), making a circular field and laminating the field core as well. By 1876 Weston's circular machine compared favorably with those of today, in contrast with Edison's "monster" of 1881, with its towering pole pieces. Weston also grasped the reciprocity of the dynamo-motor relation and rigged a motor to run some of his shop lathes and planers in 1873.

T. C. PENN

Richardson, Tex.

Sirs:

It came as a mild surprise to see how little weight Harold I. Sharlin placed on the discovery of the dynamo-electric principle in his otherwise so pleasingly encyclopedic article "From Faraday to the Dynamo." It was the discovery that the residual magnetism in even a soft-iron electromagnet, if used in the right way, is sufficient to make the machine regenerative or self-exciting that contributed something that had been lacking, namely efficiency.

The discovery is due to Werner von Siemens of Germany, cofounder of the firm of Siemens & Halske. Readers of his memoirs will find that he made the invention late in 1866 after theorizing on possibly advantageous applications of the disturbing extra currents in the Siemens & Halske igniter machines, and that a paper on it with a demonstration was read before the Berlin Academy of Sciences in January, 1867. Siemens also coined the term "dynamo-electric," mentioned in Sharlin's article.

Siemens immediately recognized the importance of his discovery and established the world's first dynamo plant as a new division of Siemens & Halske. As a first improvement over the Pacinotti and Gramme ring armature, he designed the double-T and triple-T armatures. Such armatures, incidentally, are still used in toy motors. The final improvement, F. von Hefner-Alteneck's drum winding, which Sharlin mentions in his article, was made while its inventor was an employee at Siemens & Halske. In my opinion, Werner von Siemens, the man who converted the contraption into a machine, could well have been included in Sharlin's article.

HARALD W. STRAUB

Diamond Ordnance Fuze Laboratories
Washington, D.C.

Sirs:

I differ with Messrs. Penn and Straub on only one point and that is the importance of the self-excited machine. My article tried to show the reasons for the engineering gap between Faraday's discovery and the development of a practical dynamo. My point was that an electromagnet produces a much stronger field than a permanent magnet and therefore generators built with electromagnets are more useful as a power source. I agree that the self-excited machine is more efficient than the separately excited one, if the losses of the exciter are included. But the important point is that no one picked up the idea of using the electromagnet as a means of building a large and therefore useful machine until many years after Faraday's discovery. The electromagnet had been invented and the generator principle was discovered but they were not put together until 30 years after Faraday's discovery. Incidentally, several people claimed priority in inventing the self-excited machine

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SC-1045

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and probably it was a simultaneous discovery by at least three men. All the more evidence that the ingredients were there; it only needed the efforts of some ingenious men to achieve success.

I would not argue with Mr. Penn about the importance of good conductors in a generator. Maximum efficiency was not possible until copper was used but good machines were built without copper. Copper is therefore not an essential part of my story.

I will not argue with Mr. Penn on the importance of Edward Weston's contribution or with Mr. Straub on Werner von Siemens' importance. In my story of the development of the dynamoelectric machine many important people were left out. It was not my purpose, as Mr. Straub suggests, to be "encyclopedic." I used only those facts which I thought were necessary to answer the question: If Faraday invented the generator, as many claim, why the delay before a useful machine was developed?

HAROLD I. SHARLIN

Polytechnic Institute of Brooklyn
Brooklyn, N.Y.

Sirs:

In your department "Mathematical Games" for June you have posed a very puzzling problem on the chessboard. I think this would indeed be a grand position if white could manage to get two bishops on white squares. I would appreciate it if you would inform me if the picture is correct, or if someone is trying to pull a joke.

WILLIAM NICHPARENKO

Warminster, Pa.

Sirs:

. . . one of the white bishops must be moved from a white square to a black square. Another solution would be to move the board to a vertical plane, spilling the chessmen in a heap.

D. R. GIBBONS

Manasquan, N.J.

Sirs:

. . . I consider it an unfair problem.

MAURICE J. GRAINGER

Redwood City, Calif.

Sirs:

Come now, let's not set up an impossible situation in your chess puzzle . . .

JOHN KNOX

Coronado, Calif.

Sirs:

Many letters such as these were received, apparently from readers who had forgotten that a pawn on the last row can be promoted to a rook, knight or bishop as well as a queen. In Karl Fabel's chess problem, either of the two missing white pawns could have been promoted to a second bishop on a white square, making the position a legitimate one.

It is easy to imagine situations in which the promotion of a pawn to a bishop is strategically desirable. For example, suppose that white can use either a new bishop or a new queen in a subtle play that may result in checkmate. If white calls for a queen, it will be immediately taken by a black rook, in turn captured by a white knight. But if white calls for a bishop, black may be reluctant to trade a rook for a bishop and so let the bishop stand.

MARTIN GARDNER

Dobbs Ferry, N.Y.

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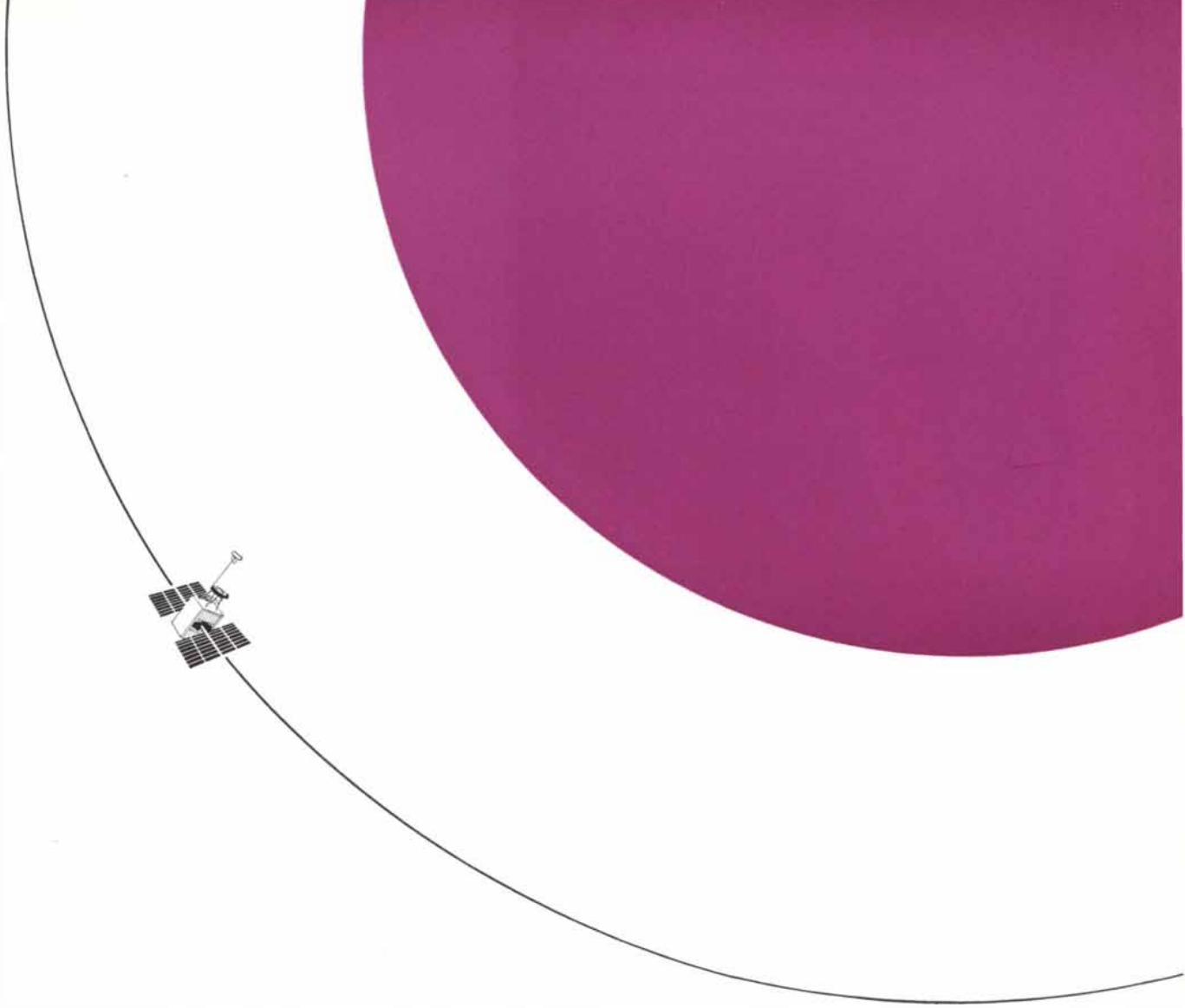

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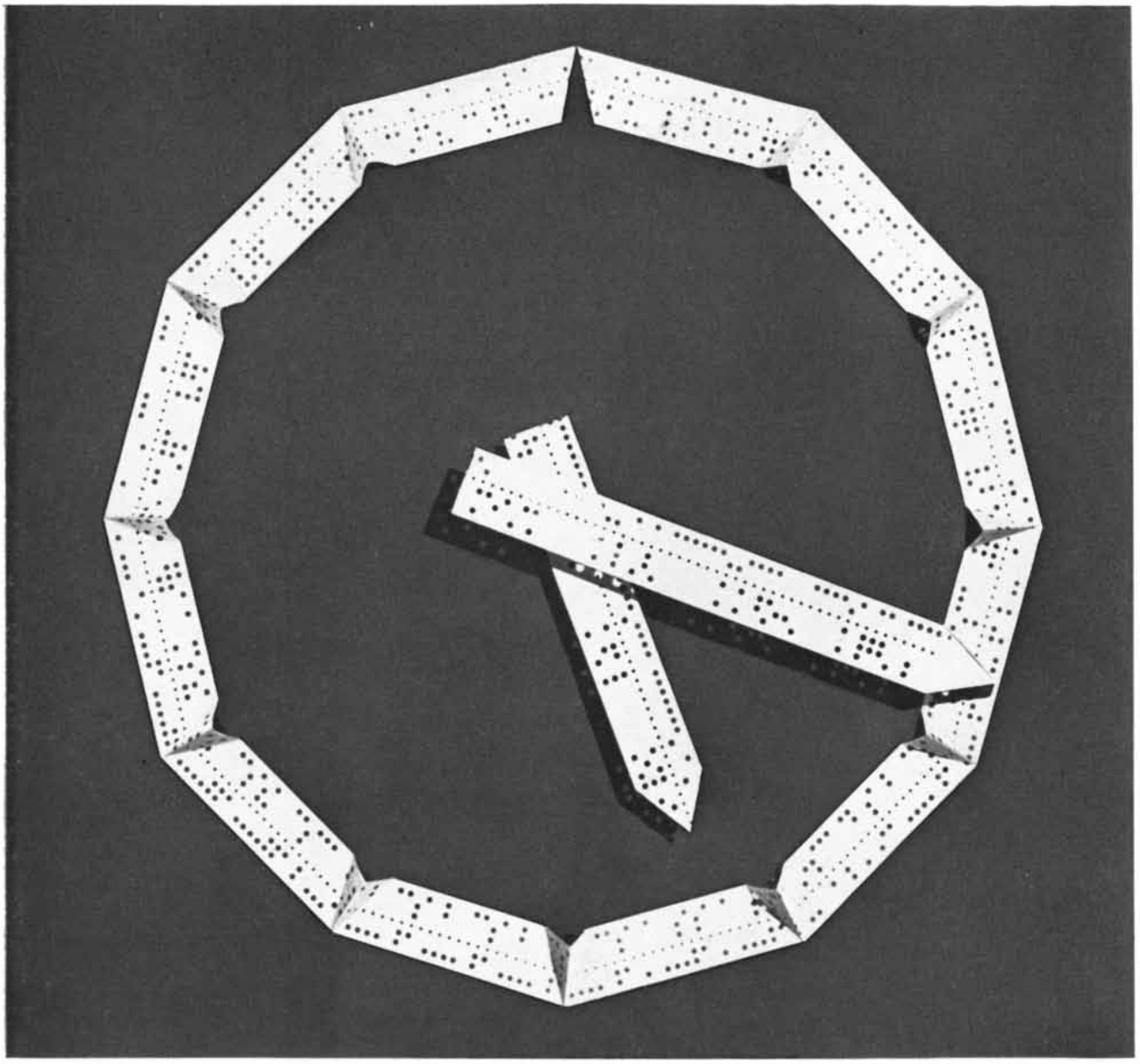

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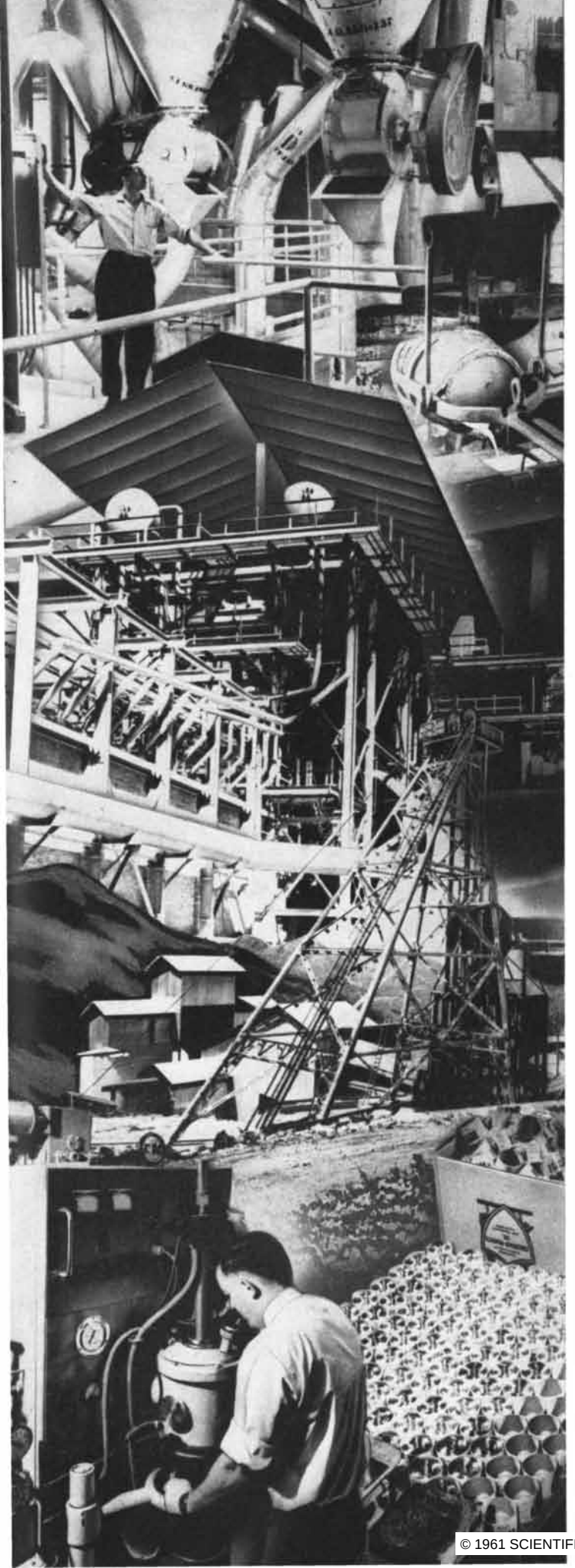

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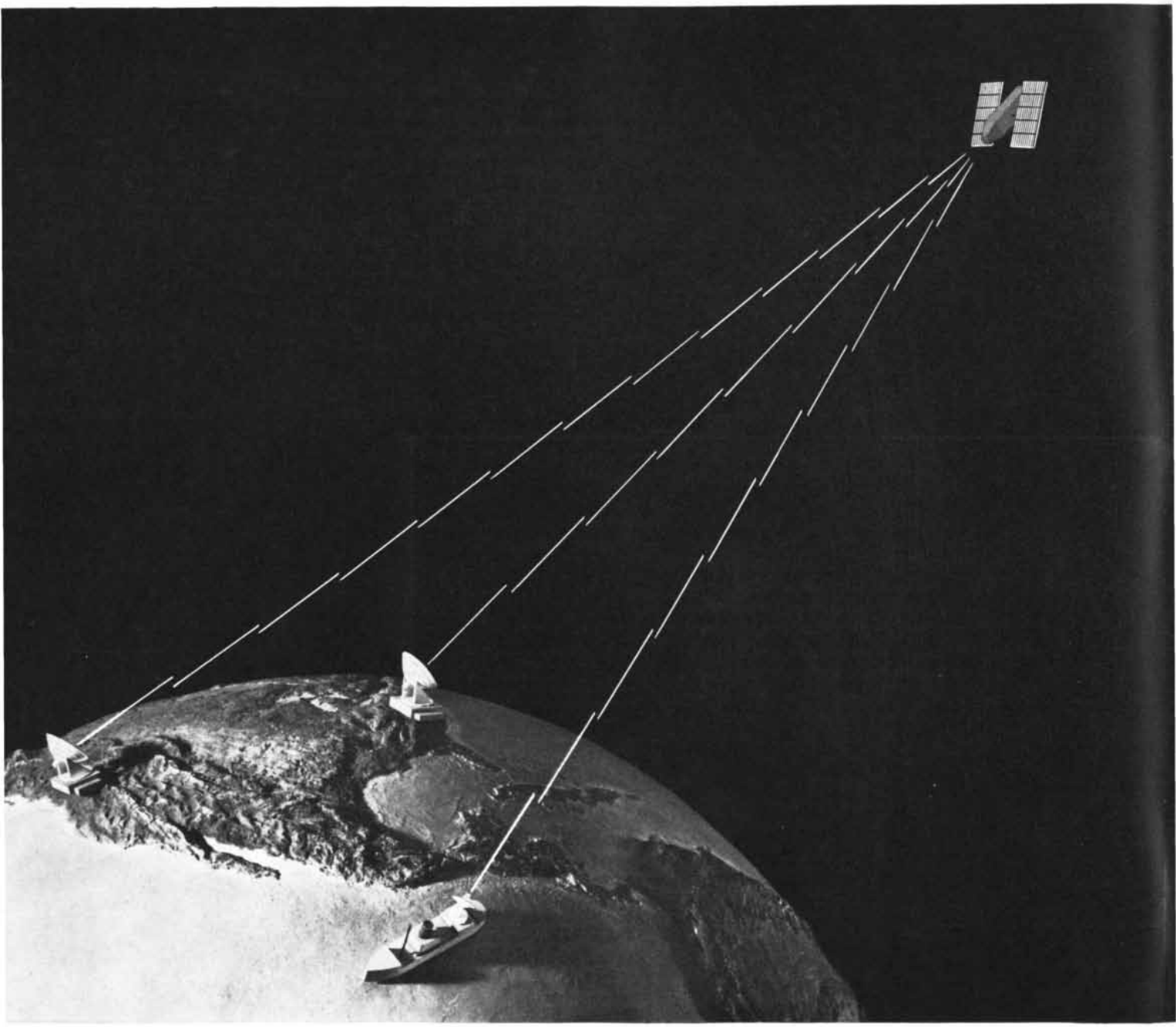

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Space-General Corporation combines the experience and capabilities of Aerojet's Spacecraft Division and Space Electronics Corporation into a new corporate entity which is dedicated to maximizing national progress in the exploration and utilization of the space environment. ■ Under the leadership of Dr. James Fletcher, President, and F. W. Lehan, Executive Vice President, Space-General Corporation will apply its capabilities to conceive and produce advanced ballistic missiles; launching vehicles; military, scientific and commercial space systems; space probes; and their component sub-systems.

To further enhance its capability, Space-General Corporation is now expanding its staff of able scientists and engineers. Those capable of bringing high levels of skill and energy to this growing organization will be considered, without regard to race, creed, color or national origin. Contact MR. PIERRE BROWN *at* SPACE-GENERAL CORPORATION, *777 Flower Street, Glendale, California.*

SPACE-GENERAL CORPORATION

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50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

AUGUST, 1911: "Reports come from England and France that the official postal aeroplane for the rapid transport of mail matter is soon to become an actual reality. On August 13 Jules Védrines, the veteran aviator, made one of 10 flights to demonstrate the possibility of an aero mail service. He left Issy-les-Moulineaux near Paris with mail aboard at 5:07 p.m. and reached Deauville, 112 miles from Issy, at 6:50 p.m., or 1 hour and 43 minutes later, or at the rate of a trifle over 65 miles an hour. The time of the fast express train going the same distance is 3 hours and 12 minutes, or 1 hour and 19 minutes longer. On the way Védrines dropped letter packages at Mantes-sur-Seine, Évreux and Lisieux. In London the Post Office Department is making preparations for the early inauguration of a special aerial postal service to be carried on between London and Windsor, a distance of twenty-three miles."

"It is a most humiliating fact that America must buy all her potassium salts from Germany—humiliating because they are absolutely necessary in renewing the fertility of our soils. Our farmers paid the Fatherland $8,000,000 last year for this one element, importing 160,000 tons of potassium chloride as well as large quantities of potassium sulphate. Their government has recently given official sanction to an effort of a German trust to put up the price, although the stuff is cheaply mined. Therefore our American problem is to make potassium chloride from our abundant feldspar by chemical means. It is encouraging to learn that the chemistry of this much-desired process has been fairly well developed. By heating finely ground feldspar with calcium chloride and some limestone the potassium can be extracted as the soluble potassium chloride. The residue is suitable material to calcine further into cement. The cost at present is much too high, but the sale of the cement would reduce this. One ton of feldspar may yield 190 pounds of potassium chloride worth $4.50 and five or six barrels of cement worth as much more."

"Is there any reason why we Americans, admitted to be the most ingenious people in the world, should suffer as our men do in the summer season because of our unreasonable style of dress? Notice a group of men and women in summer: while the women are attired in their cotton or linen garments, the men will have on coats as warm as those worn by many women in the depth of winter. No one has as yet been able to devise or suggest any acceptable summer dress for men, who continue summer after summer to swelter in warm woolen garments. Is this not a fit subject for invention?"

Scientific American.

AUGUST, 1861: "The long-anticipated advance of the grand central army, which has been entrenched south of Washington, has at last begun. This column was under the command of Brigadier General Irvin McDowell, of the regular army. On the 18th of July the first division arrived at Bull's Run, a small stream running through a valley three and a half miles from Manassas Junction, and here a brisk skirmish took place. After the skirmish of the 18th our forces were advanced ready for an attack on the secession batteries at Bull's Run, and this took place on the 21st, the fight finally resulting in one of the most disgraceful panics and flights on the part of the Union forces that is recorded in the annals of war. A large portion of the army, however, maintained its order with a heroism and coolness worthy of veterans. Very false accounts of this battle were telegraphed over the country, representing it as a complete rout and dispersion of the whole army, causing considerable gloom but nerving the spirit of the people with additional resolution and firmness. General McClellan has been ordered to Washington, it is supposed to take command of the army there. The effect of the engagement will be to cause the war to assume larger proportions and to be more protracted."

"The sickly season of malarious districts has just commenced, and it will continue for three months. Camps that are located in such districts during August, September and October will become mere hospitals. We have already

What was Bell Telephone Laboratories doing

ON FRIDAY, JUNE 30, 1961?

It was exploring the communications possibilities of the gaseous optical maser — a device which generates continuous coherent infrared radiation in a narrow beam.

It was preparing an experiment in world-wide communications using "active" satellites powered by the solar battery, a Bell Laboratories invention.

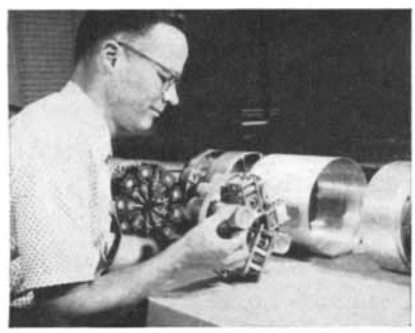
It was completing the development of a new "heavy route" Long Distance microwave system capable of handling over 11,000 two-way conversations at once.

It was developing an anti-missile defense system designed to detect, track, intercept and destroy an enemy ICBM — in a matter of minutes.

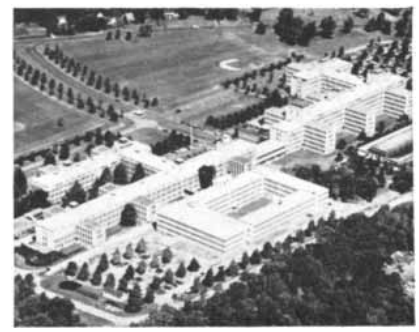
It was demonstrating the potentialities of the superconducting compound of niobium and tin for generating, with little power, magnetic fields of great strength.

It was experimenting with an electronic central office at Morris, Ill., which is capable of providing a wide range of new telephone services.

It was perfecting the card dialer which permits, through insertion of a punched card into a slot, automatic dialing of frequently used numbers.



It was developing improved repeaters or "amplifiers" to increase greatly the capacity and economy of undersea telephone cable systems.



It was continuing its endless search for new knowledge under the leadership of scientists and engineers with world-wide reputations in their chosen fields.

Bell Laboratories scientists and engineers work with every art and science that can benefit communications. Their inquiries range from the ocean floor to outer space, from atomic physics to the design of new telephone sets, from the tiny transistor to massive transcontinental radio systems. The goal is constant—ever-improving Bell System communications services.

BELL TELEPHONE LABORATORIES

World center of communications research and development

advised the soldiers whose camps are in malarious regions to take a little quinine every morning through these months; and we now respectfully suggest to the colonels or surgeons of the several regiments, as a better plan, to have a small quantity of this prophylactic mixed once a day with the coffee of every mess. This we recommend not as a substitute but as an addition to those other sanitary measures that have been found so effectual in preserving the health of armies."

"The following instructive extract from the London *Chemical News* is a portion of a lecture lately delivered by Professor A. W. von Hofmann, F.R.S.:—'Valuable as have been the fruits of chemical inquiry, still more may be expected from the further prosecution of this study. The notion that the action of most of our medicines is chemical is daily growing into a general conviction. Medicine some years ago found itself in a predicament very similar to that of agriculture at the same period: its resources appeared to be in a state of exhaustion; the rich capital of facts accumulated in the department of organic morphology by the industry of the anatomist and by the acumen of the physiologist could not yield its full fruits until an equivalent of knowledge had been drawn from the study of biochemical phenomena. The special zeal with which the field of organic chemistry has been cultivated during the last thirty years, the simple and accurate methods that we now possess for determining the composition of organic products hold out the promise that the connexion between medicine and chemistry, becoming daily more intimate, will be productive of benefits the importance of which we can scarcely venture to estimate in the present state of our knowledge.'"

"Barnum has on exhibition at his famous museum a living hippopotamus, which is certainly worth seeing by all who take interest in natural history. We have no recollection that such an animal has ever before been exhibited in this country—and we well remember with what interest we first saw the specimens in the Royal Zoological Gardens in London and the Jardin des Plantes in Paris. Barnum charges only twenty-five cents for a sight that is worth a journey of a hundred miles to see. Barnum gives more novelties at his museum for twenty-five cents than can be found elsewhere on this continent. This is one of his peculiar ways of humbugging the public."

Metals are *born* in refractories. And most new ideas in metallurgy call for a new idea in refractory science . . . because a metal can be only as good as the refractory which contains it. Norton makes the finest.

The crucible of the reduction bomb, where uranium and plutonium burst into being, is a Norton product, pure magnesium oxide.

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More super-alloys for missiles, submarines and space vehicles are possible through new vacuum melting techniques with high purity fused magnesia made by Norton. And in the aluminum industry, new efficiencies are being achieved with reduction cell linings of silicon carbide and cathode bars of titanium diboride.

In metallurgy as in other fields, Norton is crystallizing ideas into products to solve many problems . . . through oxide fusion and in probing experiments in carbides, nitrides and borides. Norton is ready to work with you in engineering materials to meet your needs. Write NORTON COMPANY, Refractories Division, 547 New Bond St., Worcester, Mass.

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REFRACTORIES
Crystallizing ideas into products

LUNAR PROBE

The moon — lacking an erosive atmosphere — may hold the key to the history of the solar system. Because of this lack of atmosphere, oceans, and wind, lunar explorations may help solve fundamental, universal questions.

Logically, the moon will be the first objective in the exploration of space. Initially the moon itself will be photographed and instrumented; then manned observation stations will be established for astronomical and meteorological purposes. In time, the moon will serve as an intermediate station enroute to other planets — step by step into infinite space.

The National Aeronautics and Space Administration's Lunar Program will utilize Lockheed's AGENA B satellite to play a significant part in forthcoming lunar explorations — as well as a host of other scientific space missions. The NASA lunar launch in 1961-62 will utilize the highly reliable Lockheed AGENA as second stage to carry the RANGER spacecraft. The AGENA will provide the extremely critical guidance and controls necessary to place the RANGER on the required lunar impact trajectory.

The lunar probe application demonstrates the versatility, reliability and success of the AGENA vehicle in Lockheed's satellite and spacecraft programs. Developed for the Air Force for use in the DISCOVERER program, the AGENA also is utilized in the MIDAS missile defense alarm system. Noted for a record of outstanding accomplishments, the AGENA is credited with being the first to be placed on a polar orbit; first to achieve a precise, predicted and nearly circular orbit; first to attain attitude control on orbit; first to eject a reentry capsule which was successfully recovered. The AGENA can be modified for a variety of missions such as navigation, geophysical investigations, long-range communications and deep space probes.

Lockheed's capability in satellites and spacecraft, manifested by such an achievement as the AGENA, encompasses the entire field. It includes current and long-range programs such as interplanetary probes, global and space communication systems, and manned space travel.

Engineers and Scientists: The accomplishment of such programs offers challenging opportunities to engineers and scientists in the research, design, development, test and operation phases of these programs. If you are experienced in work related to any of the above areas, you are invited to write: Research and Development Staff, Dept. M-29D, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense industrial security clearance required. All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Lockheed / **MISSILES AND SPACE DIVISION**

Systems Manager for the Navy POLARIS FBM and the Air Force AGENA Satellite in the DISCOVERER and MIDAS Programs

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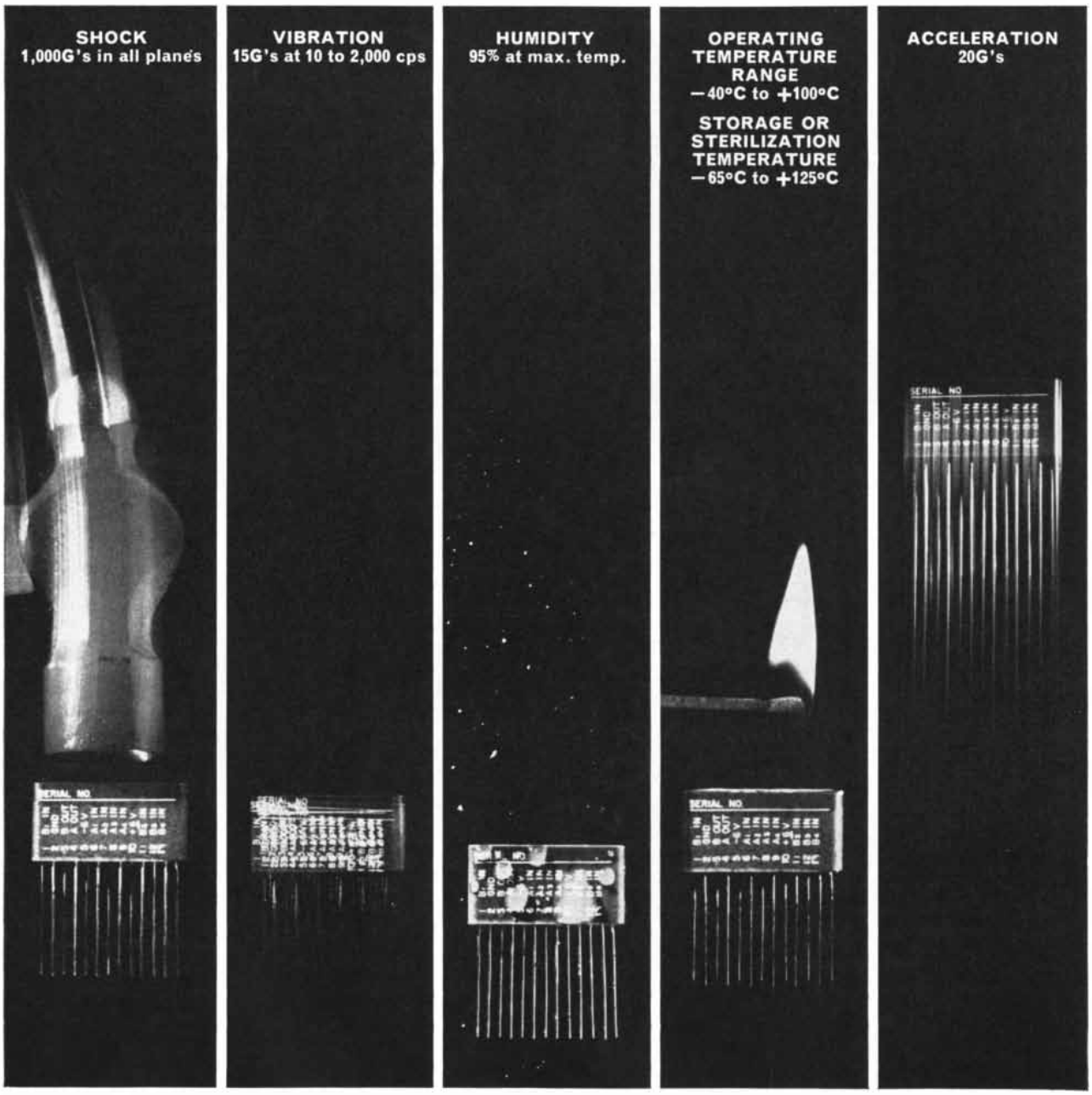
Delco Radio's new silicon digital modules operate on less than 4 mw. of power per logic stage. They are rugged enough to withstand extreme environmental conditions and are small and lightweight. Encapsulated in light foamy epoxy, each module weighs less than 12 grams and occupies less than one-half cubic inch. The basic set of modules includes a bistable multivibrator, a diode NOR gate, a power driver, a monostable multivibrator and an astable multivibrator. From these basic units larger computer subassemblies can be assembled, such as shift registers, adders, binary counters, decimal counters and timing devices. A range of applications—from small scale switching circuits to large computers can be satisfied with these modules. Environmentally proved to:



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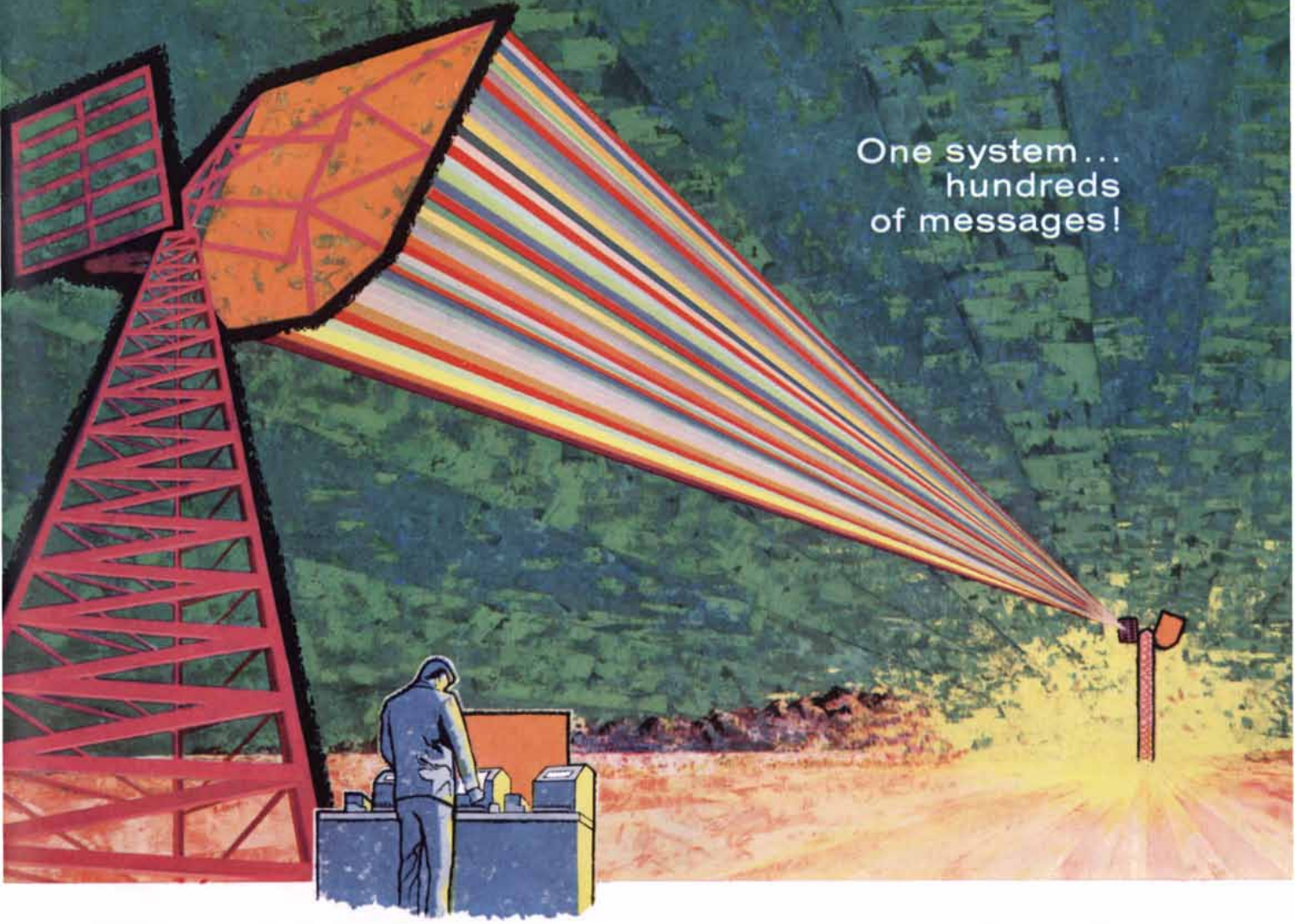


Automation through communications

works wonders in speeding the flow of business information

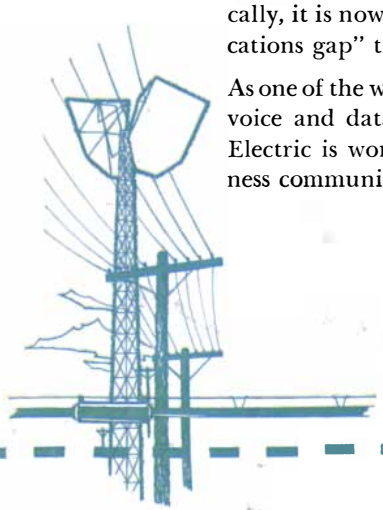
A revolution in communications is taking place —a revolution that opens vast opportunities to step up business efficiency while lowering costs. Thanks to advances in the high-speed, high-volume transmission of information electronically, it is now possible to close the "communications gap" that hampers so many industries.

As one of the world's leading specialists in video, voice and data transmission systems, Lenkurt Electric is working wonders on this new business communications frontier.

For example, a single microwave system can accommodate hundreds of separate communications channels *simultaneously*—link remote points for instantaneous telephone, teletype, video, business data, supervisory control and telemetering services.

Lenkurt Electric is working in close alliance with telephone companies to bring the modern-day benefits of *automation through communications* to business and industry.

Lenkurt Electric Co., Inc., San Carlos, Calif.



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THE AUTHORS

GIULIO NATTA ("Precisely Constructed Polymers") is director of the Institute of Industrial Chemistry at the Politecnico di Milano. Born at Imperia on the Italian Riviera in 1903, Natta studied chemical engineering at the Politecnico di Milano, where he received a degree in 1924. From 1926 to 1933 he taught at the University of Pavia, and from 1933 to 1939 he was professor of physical chemistry at the University of Rome. He joined the Institute of Industrial Chemistry in 1939. A fellow of Italy's famous Society of Lynxes (to which Galileo belonged), Natta was the first chemist to synthesize wood alcohol. His development of a method for converting alcohol to butadiene became the basis of the Italian synthetic-rubber industry. Natta was the author of "How Giant Molecules Are Made," which appeared in the September 1957 issue of SCIENTIFIC AMERICAN.

CONRAD LIMBAUGH ("Cleaning Symbiosis") was an underwater naturalist and chief diving officer at the Scripps Institution of Oceanography, where he directed the Institution's diving program. He was killed in a skin-diving accident in the Mediterranean on March 20, 1960. Before his death Limbaugh had written a preliminary draft of the present article, which was later completed by his brother-in-law, Howard M. Feder of Hartnell College in California. Limbaugh was graduated from Whittier College in 1948 and did graduate work at the University of California at Los Angeles before going to the Scripps Institution in 1950. He was largely responsible for developing the diver-training program at Scripps, as well as many of the techniques now used by skin divers. Feder, a marine biologist on the faculty of Hartnell College since 1955, holds a Ph.D. from Stanford University. He is currently engaged in assembling and publishing the results of Limbaugh's numerous and diverse research projects.

ROBERT S. DIETZ ("Astroblemes") is an oceanographer at the Navy Electronics Laboratory in San Diego, Calif. Although his basic scientific work is in marine geology, Dietz is also interested in meteorites and the "shatter cones" they produce upon impact with the earth. He took three degrees at the University of Illinois, receiving a Ph.D. in geology in 1941. He served with the Army Air Force until 1946, after which he accompanied Admiral Byrd's last expedition to Antarctica. Dietz joined the staff of the Navy Electronics Laboratory in 1947 and remained there until 1952. As a member of the London branch of the Office of Naval Research, he was responsible for getting the U.S. to support the development of Auguste Piccard's bathyscaph. He was coauthor, with Jacques Piccard, of *Seven Miles Down*, a description of the latter's bathyscaph descent into the Marianas Trench in the Pacific Ocean in 1960. He was also coauthor (with Russel V. Lewis and Andreas B. Rechnitzer) of "The Bathyscaph," which appeared in the April 1958 issue of SCIENTIFIC AMERICAN. Dietz returned to the Navy Electronics Laboratory in 1958.

EDWARD E. DAVID, JR. ("The Reproduction of Sound"), is director of visual and acoustics research at the Bell Telephone Laboratories. A native of North Carolina, David studied electrical engineering at the Georgia Institute of Technology while serving with the Navy in World War II. He received his degree in 1945, completed his service a year later and then did graduate work on microwaves and noise theory at the Massachusetts Institute of Technology, receiving a D.Sc. degree in 1950. He is at present doing research in acoustical psychophysics and the processing of neural information by the brain. This is his second article for SCIENTIFIC AMERICAN; the first, "Ears for Computers," appeared in February, 1955.

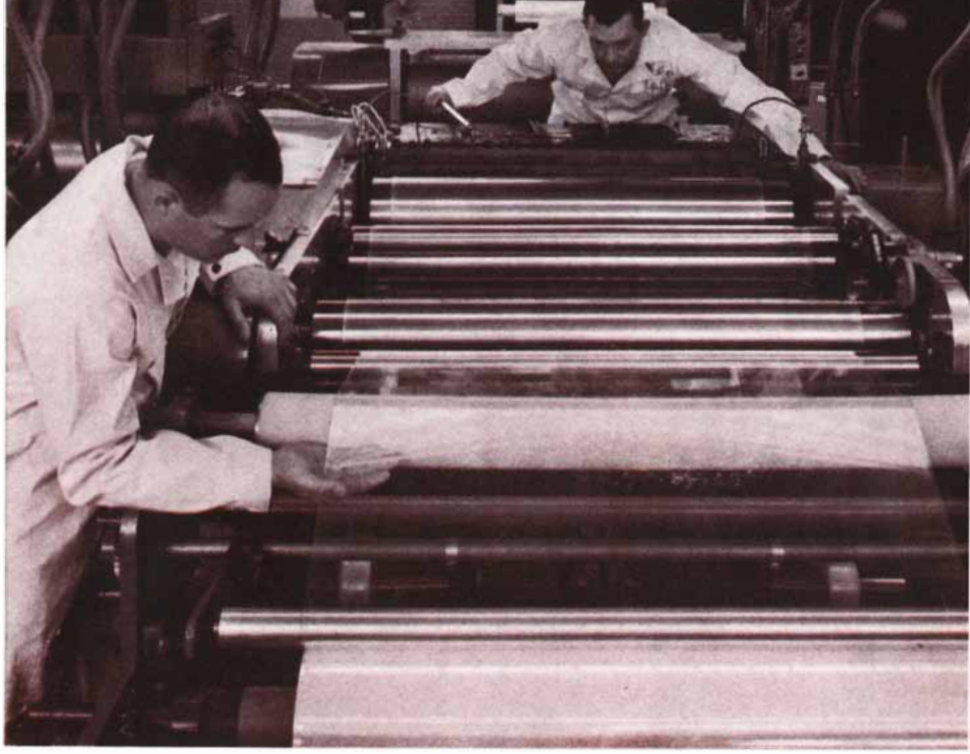
JAMES MELLAART ("Hacilar: A Neolithic Village Site") is an archaeologist who has lived and excavated archaeological sites in Turkey for the past decade. Of Scottish and Dutch extraction, Mellaart was born in London in 1925 and educated in the Netherlands, where his family moved when he was four years old. He studied Egyptology for a year at the University of Leyden, returned to England in 1947 and acquired a B.A. honors degree in ancient history and Egyptology at the University of London in 1951. The international situation in the Middle East at that time made any practical work in Egypt impossible, and Mellaart went to Turkey on a scholarship from the British Institute of Archaeology at Ankara to make a survey of archaeological sites in southern Turkey. The survey led to the excavation of Beycesultan by Seton Lloyd, then director of the British Institute at Ankara [see "A Forgotten Nation in

Turkey," by Seton Lloyd; SCIENTIFIC AMERICAN, July, 1955]. This and subsequent excavations in which Mellaart took part provided a rather complete sequence of cultural life in southwestern Turkey from the end of the Bronze Age to the beginning of the late Chalcolithic period, a span of some 4,000 years. "But my discovery of Hacilar in 1956," he writes, "promised to produce even earlier evidence for settlements on the Anatolian plateau. Hence the Hacilar excavations, which added nearly another thousand years to the cultural sequence."

FELIX WRÓBLEWSKI ("Enzymes in Medical Diagnosis") is head of medical enzymology at the Sloan-Kettering Institute for Cancer Research and associate professor of clinical medicine at the Cornell University Medical College. He received a B.A. in chemistry from New York University in 1942 and an M.D. degree from that institution's College of Medicine in 1945. Wróblewski went to the Sloan-Kettering Institute in 1949. He joined the faculty of the Cornell Medical College in 1952.

ALEX COMFORT ("The Life Span of Animals") is a biologist, poet and novelist who has divided his time between medical biology and literature since 1944, when he was graduated from Trinity College, Cambridge, with degrees in medicine and surgery. He holds three other degrees, including a Ph.D. in biochemistry from the University of London. He has been a Nuffield Research Fellow in the biology of old age for the past 10 years. In addition to five novels, half a dozen volumes of poetry and assorted books of essays on literary, political, social and scientific subjects, Comfort is the author of *The Biology of Senescence*, published in 1956.

MORTON L. BARAD ("Low-Altitude Jet Streams") is chief of the Boundary Layer Processes Branch of the Atmospheric Analysis Laboratory at the Air Force Cambridge Research Center. Barad acquired a B.S. in mathematics at the College of the City of New York in 1939, and an M.A. at New York University in 1941. Barad's military service during World War II took him to the South Pacific as a weather officer for the Army Air Force until 1945. He received a Ph.D. in meteorology from N.Y.U. in 1950 and spent two years at the Hanford Works in Washington as head of the General Electric Company's Experimental Meteorology Group. In 1953 he joined the Atmospheric Analysis Laboratory as a project scientist.



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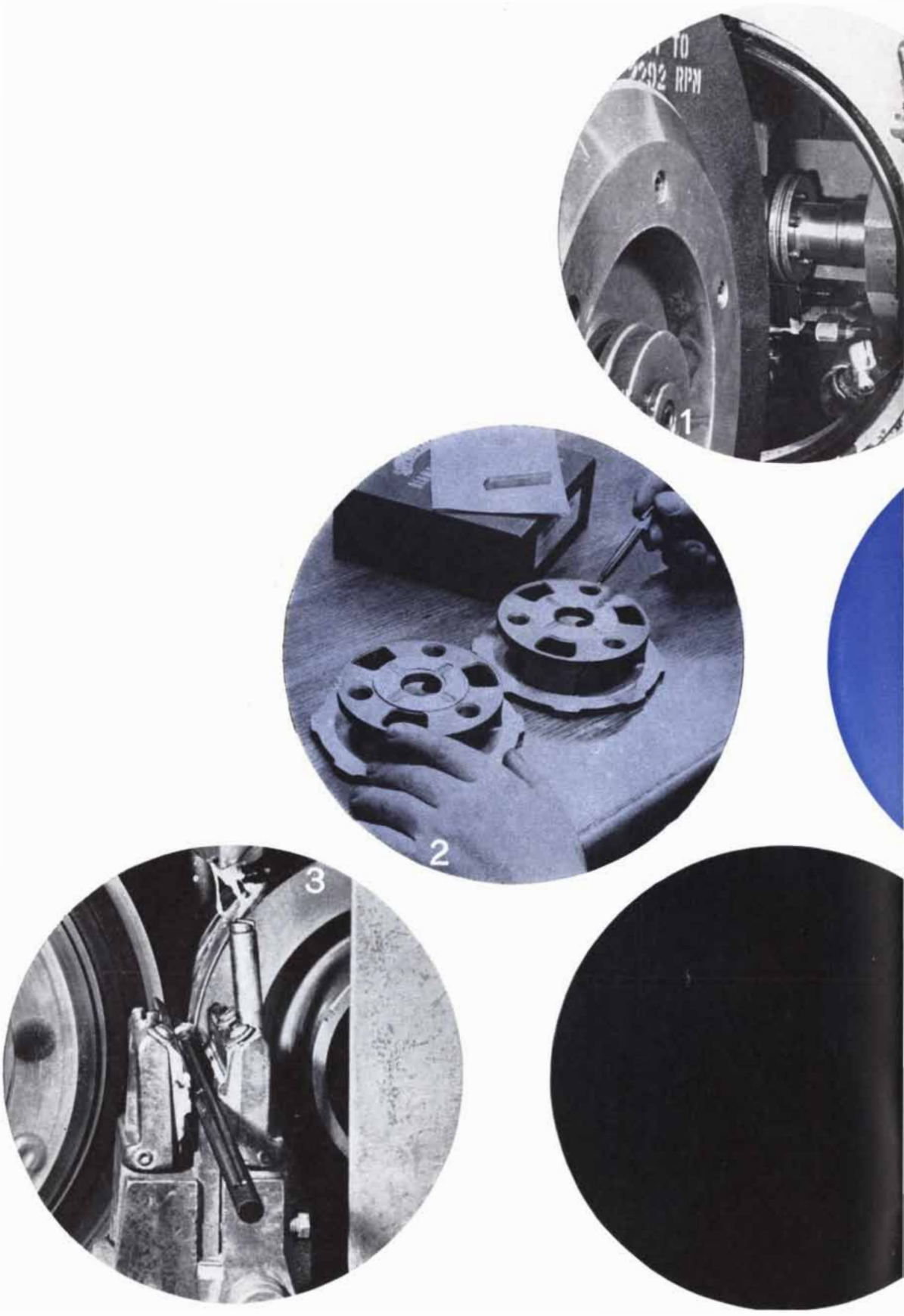

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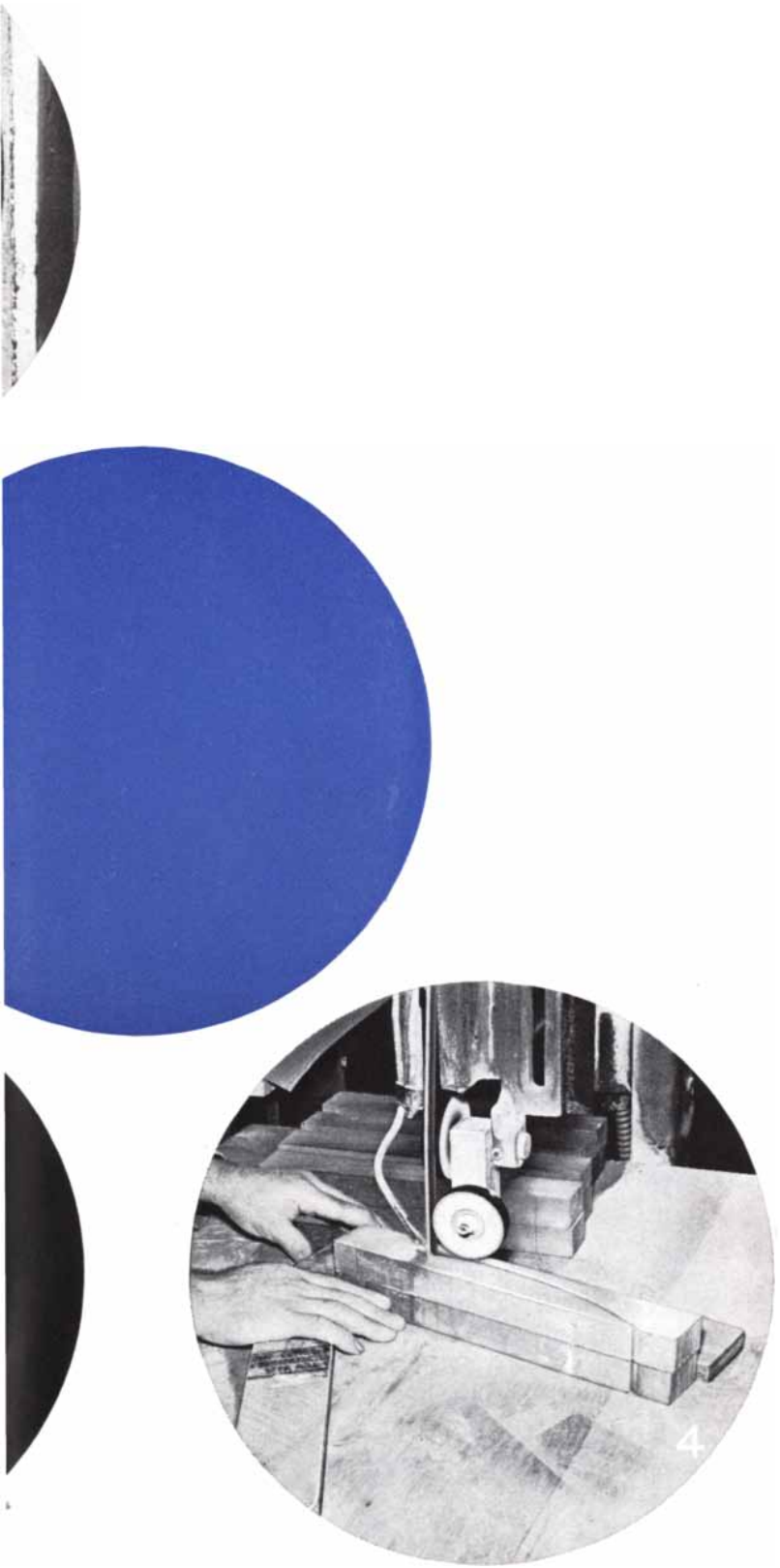

1 **Dressing Grinding Wheels** *that groove propeller shafts for Evinrude Motors, Milwaukee. Cutters are powdered metal matrix impregnated with small, blocky natural diamonds. They show no wear after months of use.*

2 **Boring and Facing Aluminum** *pinion carriers for Chrysler Corporation, Detroit. Dimensions are held within ±.001 inch, producing finishes to 20 microinches. Conventional tools could not withstand aluminum's abrasiveness, nor meet these tolerances.*

3 **Grinding Synthetic Sapphire** *and quartz rods with diamond grinding wheel. Tolerances for diameters: ±.0002 inch; concentricity: ±.0002 inch. After trying every other grinding method, this diamond-coated unit was installed by Duncan-Inglewood, Inc., Inglewood, Calif. Rods are now being turned out on a production basis.*

4 **Band-Sawing Optical Glass.** *New diamond-coated band-saw blade cuts optical glass to pattern shapes at Dia-Chrome, Inc., Glendale, Calif. Diamond band saw can also cut reinforced plastics, ceramics, marble. Thin materials can be cut without coolant; dense materials require water or water-oil emulsion.*

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Samuel Taylor Coleridge . . . on genius

"To find no contradiction in the union of old and new; to contemplate the Ancient of Days and all His works with feelings as fresh as if all had then sprang forth at the first creative fiat; characterizes the mind that feels the riddle of the world, and may help to unravel it. To carry on the feelings of childhood into the powers of manhood; to combine the child's sense of wonder and novelty with the appearances which every day for perhaps forty years had rendered familiar . . . this is the character and privilege of genius, and one of the marks which distinguish genius from talents. And, therefore, it is the prime merit of genius, and its most unequivocal mode of manifestation, so to represent familiar objects, as to awaken in the minds of others a kindred feeling concerning them, and that freshness of sensation which is the constant accompaniment of mental, no less than of bodily, convalescence."

—*Biographia Literaria*, 1817.

Established 1845 SCIENTIFIC AMERICAN August 1961 Volume 205 Number 2

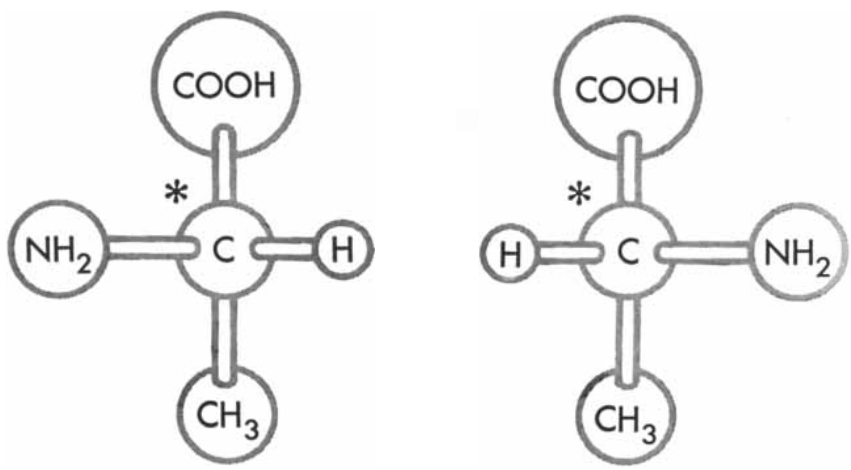
Precisely Constructed Polymers

In the chainlike giant molecules made by man, the units in the chain are generally oriented at random. Now these units can be oriented in regular sequence, giving rise to polymers with useful new properties

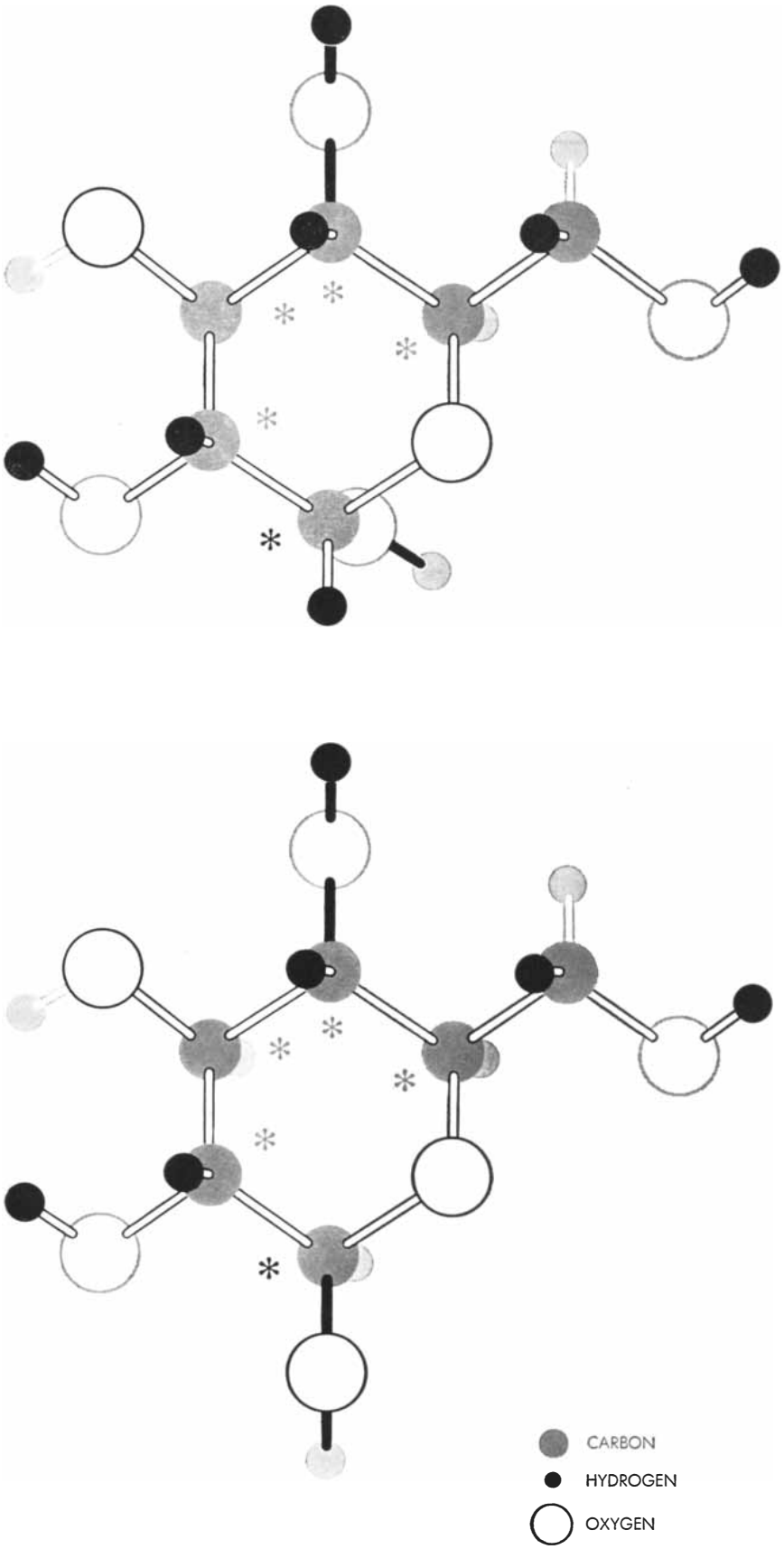
by Giulio Natta

It is often said in the chemical industry that 10 years are required to carry a new product from the test tube to tank-car production. Seven years have now passed since our laboratory in the Politecnico di Milano discovered "stereospecific" catalytic processes for creating "stereoregular" polymers from simple asymmetric hydrocarbon molecules such as those of propylene. The term "stereospecific" signifies that the catalysts are able to link the simple structural units of the polymer—the asymmetric monomers—into precisely ordered three-dimensional structures rather than into structures assembled more or less at random. The precise ordering of structure yields polymers with new and useful physical properties. The new stereoregular polypropylene polymers produced by our methods, and by similar methods successfully developed by others, have been in large-scale production in the U.S. since early this year, following the completion last year of three major plants. The polymers have been commercially available in Italy since 1957. Only last year our laboratory was successful in carrying stereospecific polymerization methods another step forward, suggesting that still-new varieties of stereoregular polymers may achieve practical importance before too many years have passed.

Our recent work has led to the synthesis of polymers that, when placed in solution, have the property of rotating the plane of polarization of a beam of plane-polarized light. They are said, therefore, to be optically active. It was Louis Pasteur who discovered, about 1850, that tartaric acid comes in two isomeric forms, one able to rotate polarized light to the right, the other able to rotate it to the left. A mixture of the two forms in equal amounts is called a racemic mixture. Since Pasteur's time it has been shown that compounds with optical activity are widely used in nature as the monomers of the polymeric constituents of living matter, for example proteins, cellulose and starch. To display optical activity an organic molecule must contain at least one asymmetric carbon atom, meaning a carbon linked to a different kind of atom (or group of atoms) through each of its four valence bonds [*see illustration below*]. For reasons difficult to explain (and perhaps not yet fully explained) the electron



OPTICAL ISOMERS OF ALANINE, one of the 20-odd amino acids that link up to form proteins, illustrate what is meant by an "asymmetric" carbon atom. The central carbon is asymmetric because it has attached to each of its four chemical bonds a different kind of atom or group of atoms. When in solution one configuration, called L(—)-alanine (*left*), rotates plane-polarized light to the left; its mirror image, D(+)-alanine (*right*), rotates polarized light to the right. Natural proteins are all built from L(—)-amino acids.



OPTICAL ISOMERS OF GLUCOPYRANOSE, a natural sugar, each contain five asymmetric carbon atoms (*starred*). Plants make chiefly *alpha*-D(+)-glucopyranose (*top*) and *beta*-D(+)-glucopyranose (*bottom*), which differ only at one carbon (*dark star*). The former polymerizes to form starch, latter to form cellulose (*see illustrations on opposite page*).

cloud around an asymmetric atom—which need not be carbon—causes polarized light to rotate.

A compound containing one asymmetric carbon atom can exist in two isomeric forms, called enantiomers; one is the mirror image of the other, as the right hand is of the left. An optically active compound is assigned to the dextro (D) or levo (L) series according to the position of its asymmetric carbon atom (or atoms) with respect to that in certain reference compounds. This classification is independent of the way the compound in question actually rotates polarized light. If the rotation is to the right, the compound is labeled (+); if to the left, (−).

For more than a century chemists have sought methods of synthesizing one particular isomer in preference to its optical twin. Ordinary methods of synthesis produce all possible optical isomers in equal abundance. One way to obtain an excess of a particular isomer is to employ optically active starting materials. Chemists have made only negligible progress, however, in achieving an "absolute asymmetric synthesis"—one that employs unselected starting materials. The idea that irradiation of the reactants with polarized light might favor one isomeric product over another has been tested without success.

No one has been able to explain why all natural proteins should be built up from L-series amino acids. Presumably the exactly equivalent D series would do just as well. A giant molecule containing a random mixture of L and D types, however, would lack the distinctive physical properties of normal proteins. It is the ordered repetition of molecules sharing a common symmetry that endows a giant molecule with crystalline properties. By "crystalline" is meant the ability of a molecule to pack together with others in orderly array. Crystallinity endows a polymer with strength and rigidity. In contrast, a polymer lacking an ordered structure is generally amorphous.

Although two enantiomers may have almost identical physical properties, the polymers formed from them may differ greatly. A remarkable example of this is found in starch and cellulose, which are made from two D-series sugars that differ in only one isomeric detail. Starch is a chainlike polymer made from *alpha*-D(+)-glucose; cellulose is a comparable chain made from *beta*-D(+)-glucose [*see illustrations at left and on opposite page*]. The slight differences between the two sugars give rise to different types

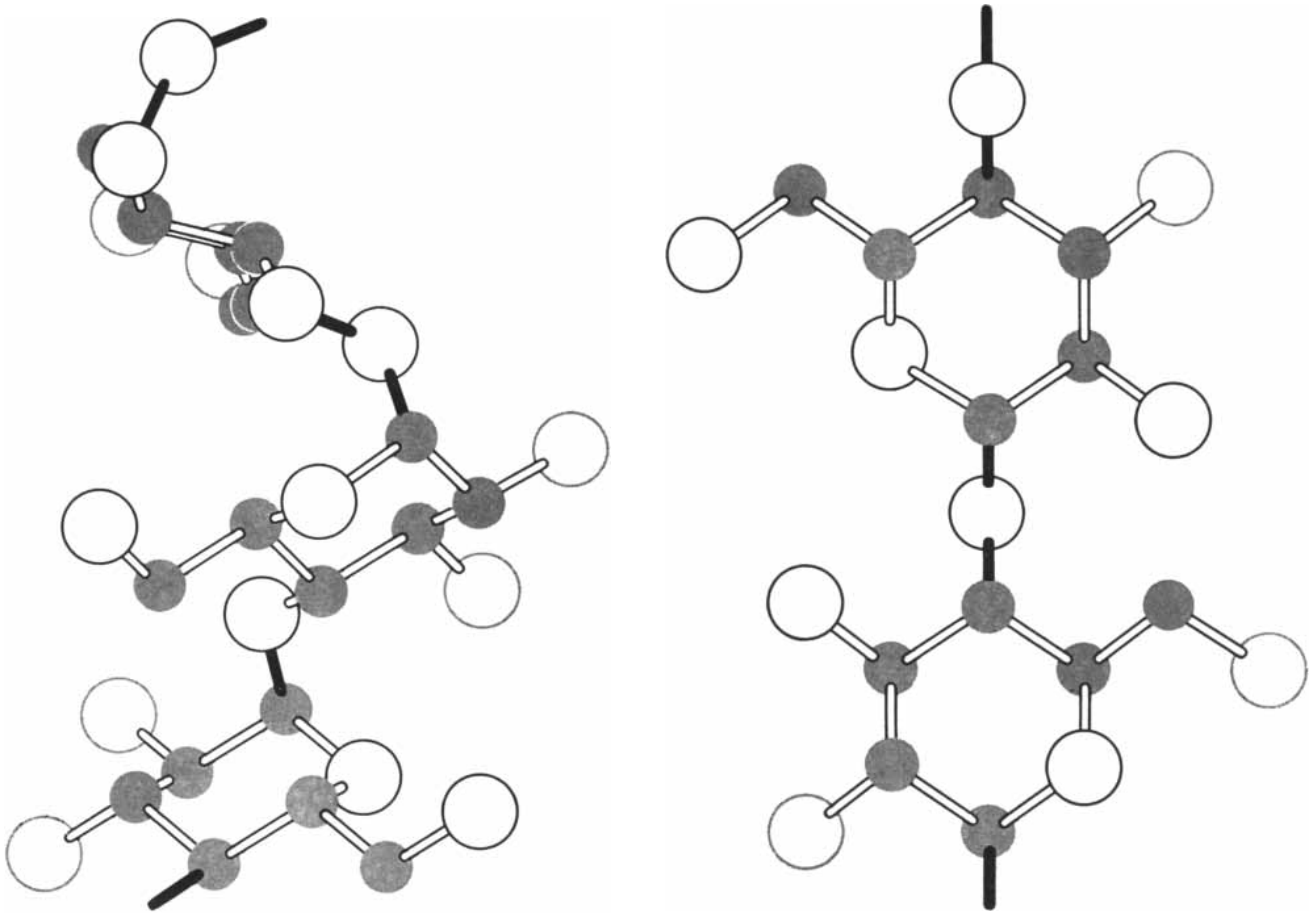
of chain and thus to profound differences in their polymers: starch can be digested by man and animals, cellulose cannot. It is apparent, therefore, that the ability to synthesize giant molecules from optically active organic compounds—and also to decompose them—is an important characteristic of living organisms.

One would like to know if life on other planets shows the same stereoisomeric preferences as life on earth. It is generally assumed that the preference of earth life for L-amino acids and D-sugars is a simple accident, tracing back, perhaps, to an accident of catalysis when life first began. If only accident is involved, there would seem to be a good chance that life elsewhere is built around amino acids and sugars having optical activities different from those preferred on earth. If space explorers ever discover plants or animals on another planet, it will be of some importance to learn the precise steric configuration of these organisms. An extraterrestrial plant that appeared to be edible would be totally unassimilable if it contained D-amino acids and L-glucose.

Our own efforts at asymmetric synthesis of polymers are a direct outgrowth of the work that led in 1954 to stereoregular polypropylene. It will be recalled that in 1954 polyethylene was already well known as the plastic material used in "squeeze" bottles. Ethylene (C_2H_4) is the simplest hydrocarbon containing a double chemical bond. When it polymerizes, the double bond breaks and provides two free connecting links to join with two other molecules of ethylene—one on each side—in which bonds have similarly been broken. In this fashion thousands of ethylene units can link up to form a long chain, which packs together well with other similar chains. The result is a crystalline polymer that is both strong and flexible but has a rather low melting point.

The propylene monomer (C_3H_6) is an ethylene molecule in which one hydrogen atom has been replaced by a methyl group (CH_3). Unlike the molecule of ethylene, the propylene molecule is structurally asymmetric. Consequently if propylene is allowed to polymerize, the resulting polymer can take various steric configurations. If the polymerization is "undirected," the methyl groups will fall at random along the chain, now on one side, now on the other. Such chains do not pack well together and the result is a rubbery, amorphous polymer of relatively low strength. We called this structure "atactic," meaning without order. We found that certain catalysts would direct the polymerization so that the methyl groups would all fall on one side of the chain or would alternate regularly from side to side; in both cases the resulting polymers are crystalline. The former chains we called "isotactic"; the latter, "syndiotactic" [*see illustrations on pages 36 and 39*].

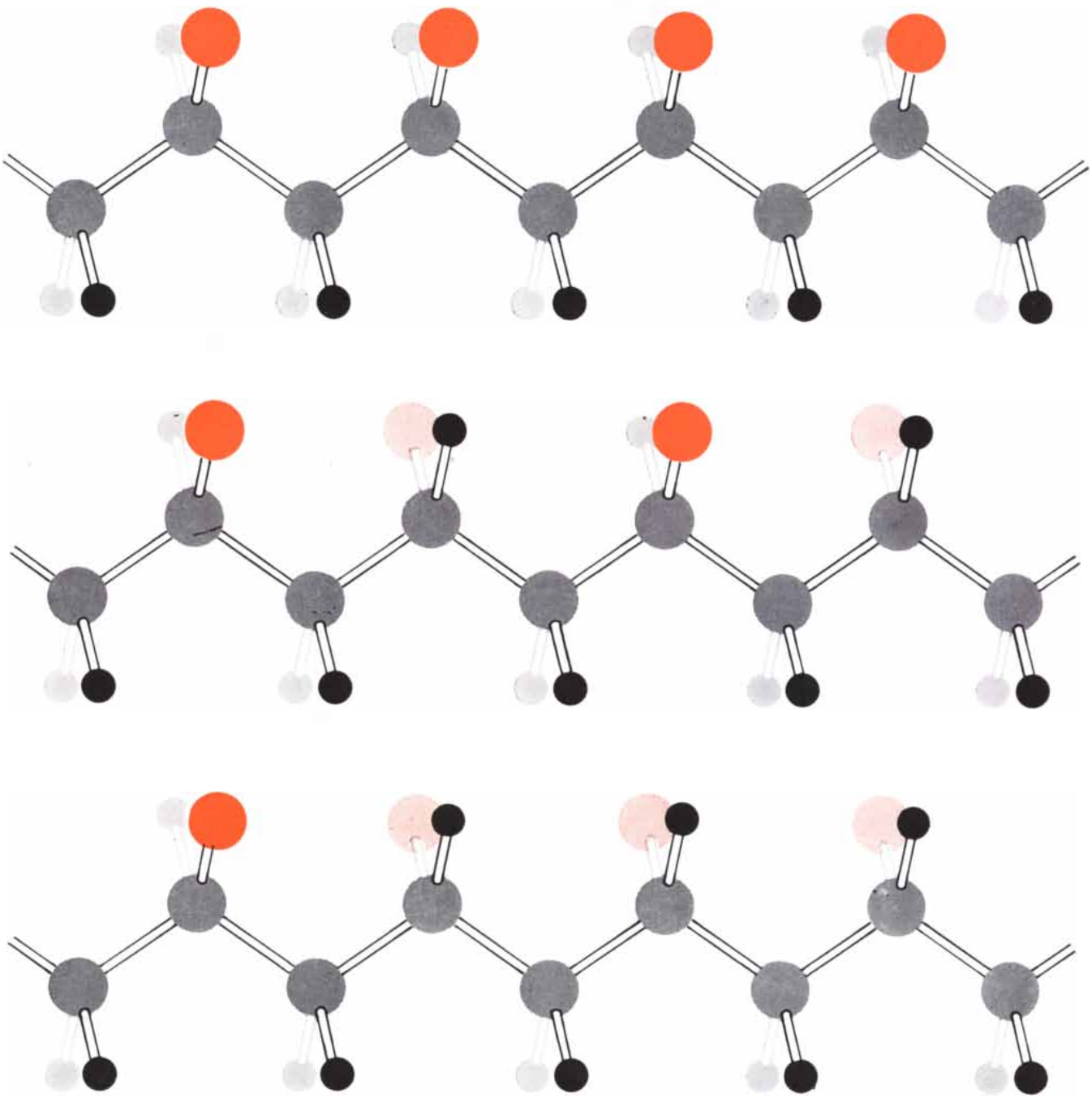
Isotactic polypropylene, because of its special structure, has a high melting point and yields a polymer of high crystallinity that is harder, tougher and



STARCH AND CELLULOSE (*left and right*) are giant molecules formed from *alpha*-D(+)-glucopyranose and *beta*-D(+)-glucopyranose respectively. In this illustration hydrogen atoms, shown in the monomers on the opposite page, have been omitted for clarity. Although the monomers have nearly identical physical properties, the giant molecules created from each are quite different.

more heat-resistant than polyethylene. As a textile fiber it is as strong as nylon and 30 per cent lighter in weight. It can also be produced in the form of a thin transparent film, as clear as cellophane and stronger if its polymer units are oriented by stretching. Extruded into pipes or molded into complex shapes, it can compete with metals in many applications.

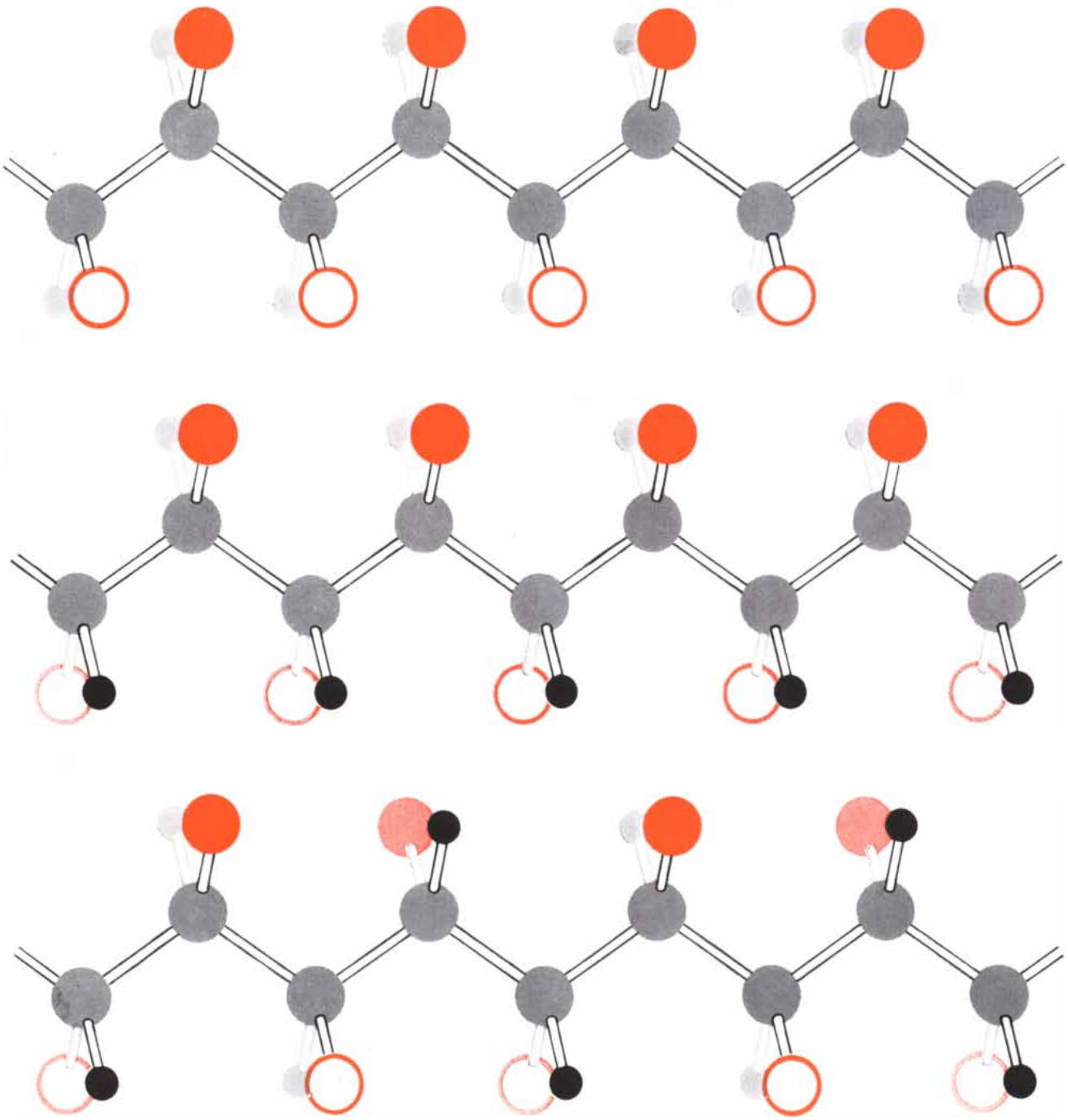
If ethylene is doubly substituted so that one hydrogen atom on each carbon is replaced with a different group of atoms, yielding a molecule with the type formula CHR:CHR′, stereospecific polymerization gives rise, as shown in the illustration on the opposite page, to three ordered configurations: threo-di-isotactic (R and R′ on the same side of the chain), erythro-di-isotactic (R and R′ on opposite sides) and di-syndiotactic (R and R′ alternating regularly from one side to the other). Polymers of each of these configurations, made in our laboratory,



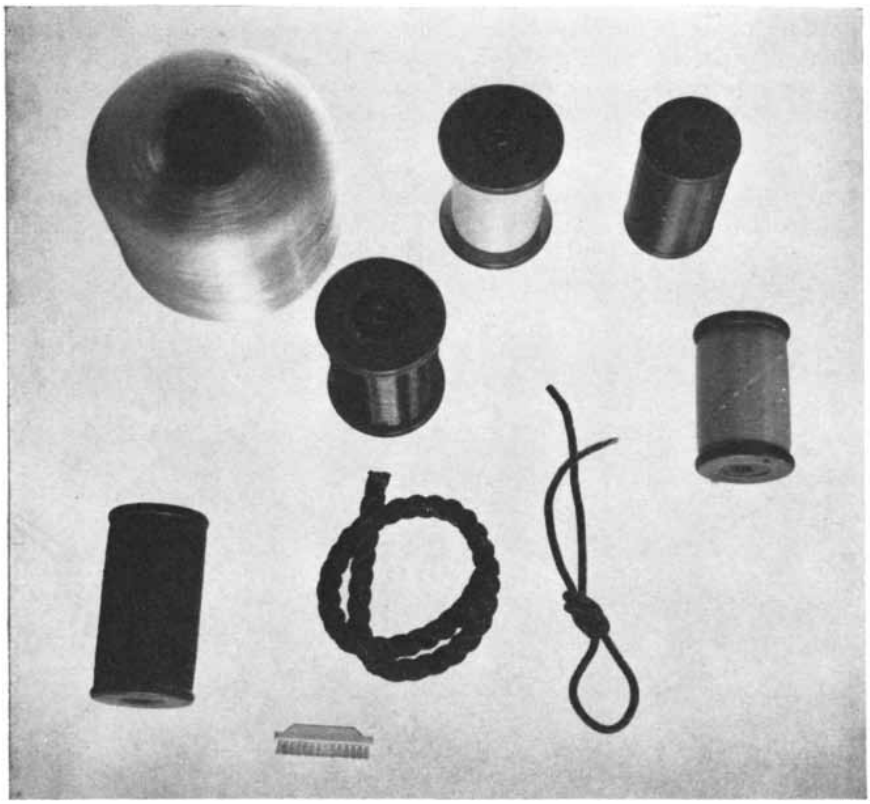
ORDERED AND DISORDERED POLYMERS can be produced when so-called vinylic (CH_2:CHR) monomeric units link up in head-to-tail succession. "R" (*colored ball*) may represent any group of atoms; thus if R is CH_3, the vinyl monomer is propylene and the polymer is polypropylene. The main chain of carbon atoms has been drawn as if flattened in a plane. (*Three-dimensional views appear on page 39.*) When R groups are all on one side of the chain (*top*), the polymer is called "isotactic." When R groups alternate from side to side (*middle*), the polymer is "syndiotactic." When R groups are disposed at random (*bottom*), the polymer is "atactic."

show a number of interesting properties. Their commercial value remains to be determined.

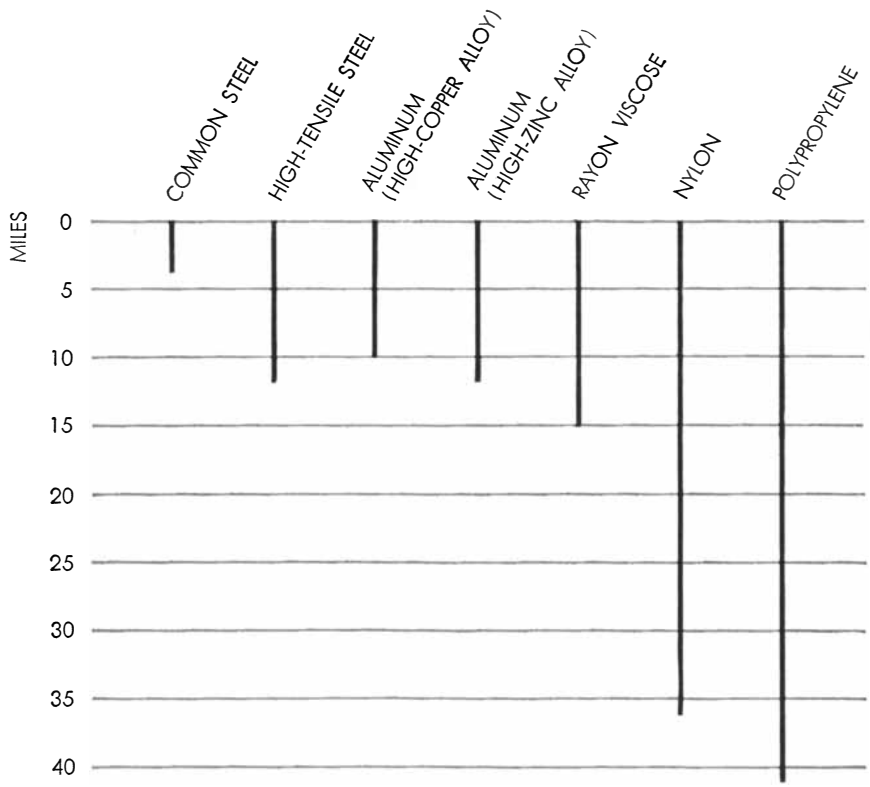
These various stereoregular polymers represented a small but definite step toward asymmetric synthesis in that each giant molecule is formed by long sequences of monomeric units having the same steric configuration. However, the giant molecules forming a crude vinyl isotactic polymer, such as isotactic polypropylene, do not display optical activity, primarily because inner compensations cancel out whatever slight optical activity might arise. It is true that in such polymers each carbon attached to a side group is asymmetric, but the asymmetry is very slight because it is due almost solely to difference in length and in configuration of the two portions of chain linked to two of its bonds. As we shall see, appreciable optical activity will occur in a polymer only when the asymmetry arises from strong nonuni-



MORE INTRICATE STEREO-ORDERING can arise when the vinyl monomer contains a different R group on each carbon, yielding a molecule of the form CHR :CHR′. New spatial arrangements are possible because the first carbon carries a hydrogen atom plus an R group, instead of two hydrogens, which are indistinguishable. When R and R′ are on the same side of the plane defined by the carbon chain (*top*), the polymer is threo-di-isotactic. When all the R groups are on one side and all the R′ groups on the other side (*middle*), the polymer is erythro-di-isotactic. When R and R′ alternate from side to side (*bottom*), the polymer is di-syndiotactic.



POLYPROPYLENE MONOFILAMENTS can be fabricated into a variety of forms. The strength of the polymer derives from its stereoregularity and high crystallinity. "Crystallinity" means that long-chain molecules of the polymer lie side by side in orderly fashion.



SELF-SUPPORTING LENGTHS OF VARIOUS FILAMENTS reflect, in a single value, a material's weight as well as its strength. The value is independent of diameter. Aluminum, although weaker than steel, can support as many miles of its own length. Polypropylene is almost as strong as nylon and 30 per cent lighter, hence its superiority by this measure.

formities of atomic configuration in the immediate vicinity of each of many carbon atoms.

So far we have not mentioned a common and important type of isomerism that is due simply to variations in three-dimensional structure and which is therefore called geometric isomerism. Geometric isomers arise in organic compounds that contain a double bond between two carbon atoms. When connected by a double bond, two carbon atoms are no longer free to rotate around a common axis, as they are when they are joined by a single bond. As a result it is possible to create isomers of different spatial geometry, depending on whether or not distinctive substituents attached to the two carbons are locked on the same side of the molecule, giving rise to the "*cis*" isomer, or on opposite sides, yielding the "*trans*" isomer.

In nature two well-known polymers, identical in chemical composition, are distinguished by their *cis* and *trans* geometric isomerism. *Cis*-1,4-polyisoprene is natural rubber, whereas *trans*-1,4-polyisoprene is gutta-percha [*see top illustration on page 40*]. The properties of the two substances are very different. Rubber, when vulcanized, is strong and elastic. Gutta-percha, vulcanized, becomes hard and tough rather than strong. It is often used as a covering for golf balls.

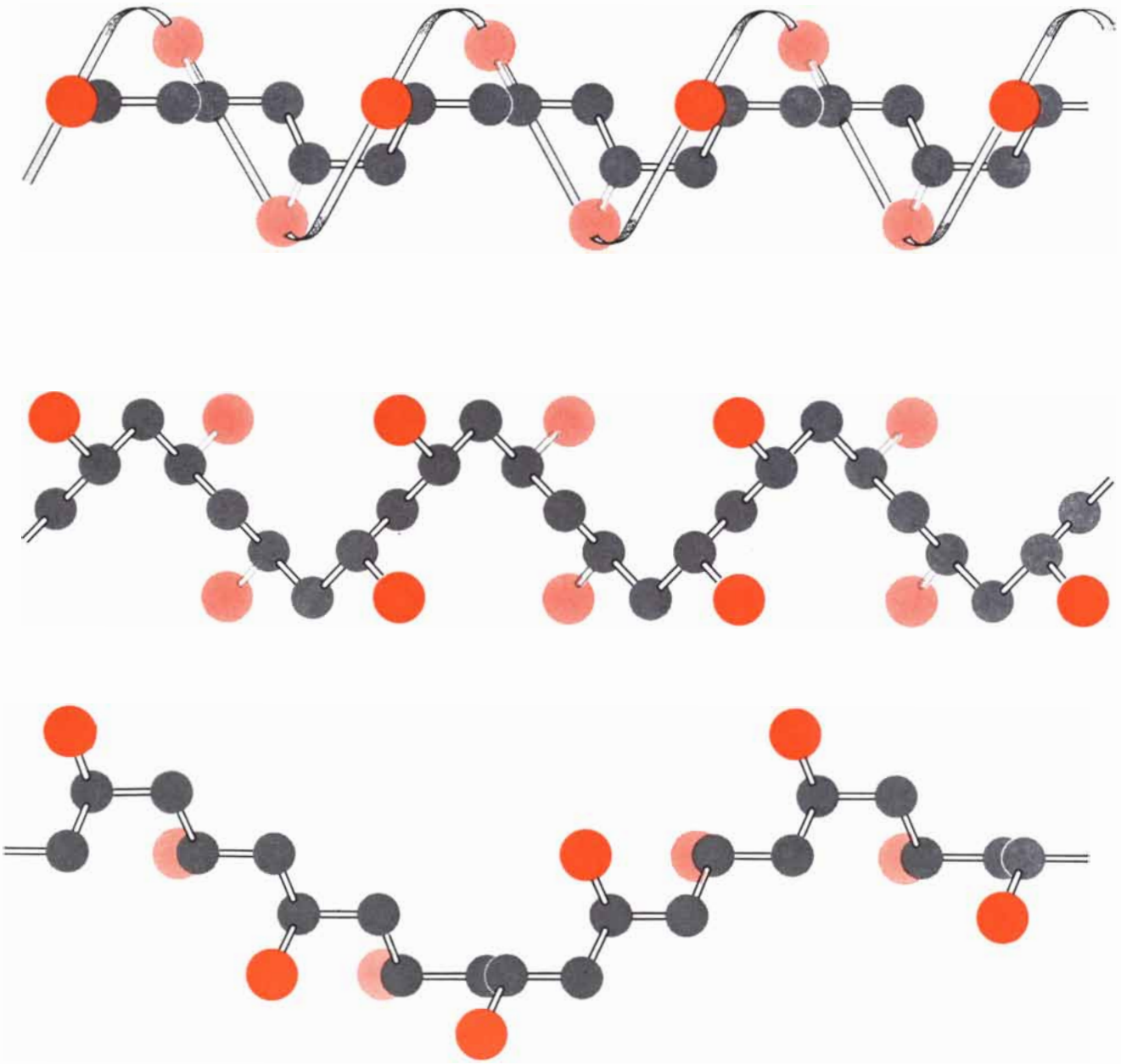
Early efforts to synthesize natural rubber failed because the monomer, isoprene (C_5H_8), would not link up in the required stereoregular form. In 1954, with new principles of stereospecific polymerization, a true synthetic rubber was synthesized in the U.S. and a true gutta-percha was created in our Milan laboratories. The polyisoprene synthetic rubber is now being produced commercially by at least two U.S. firms.

Our laboratory was the first to show that an excellent synthetic rubber is also produced by *cis*-1,4-polybutadiene. Cheaper than isoprene, butadiene (C_4H_6) has a single hydrogen atom where isoprene has a methyl group. Butadiene was commercially manufactured on a large scale in the U.S. during World War II as the principal ingredient in butadiene synthetic rubbers, which have been made in large volume ever since. The new stereoregular polymers of butadiene show elastic and dynamic properties quite similar to those of natural rubber and are far superior to those of the old butadiene synthetics, which have a nonuniform chemical composition and a disordered three-dimensional structure.

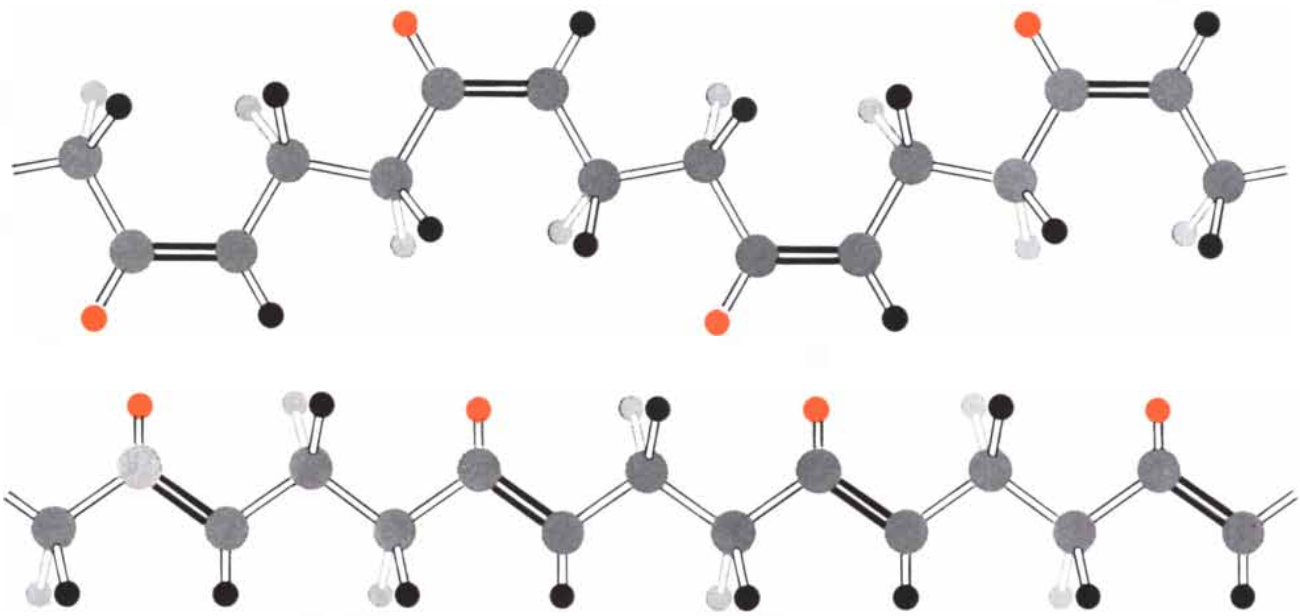
We have been able to produce synthetic rubbers containing more than 98 per cent of *cis*-1,4-polybutadiene, which even exceeds the steric purity of 97 to 98 per cent of *cis* units found in natural rubber. Automobile tires made from these high-purity polybutadienes compare very favorably with tires of natural rubber in durability, riding qualities and low heat build-up when operating at high speeds.

Out of this work with butadiene and related diolefins (molecules with two sets of double bonds) have come polymers demonstrating optical as well as geometric isomerism. Our approach to achieving optical isomerism has been to create polymers from derivatives of diolefins, such as butadiene, in which at least one hydrogen atom in each molecule has been replaced with more complex atomic substituents. When monomers of this sort are polymerized in a stereospecific way, the repetition of complex configurations produces strong local asymmetries in a large fraction of the carbon atoms. Each single giant molecule, if it could be extracted from the polymer and examined alone, should show optical activity. As normally produced, however, the polymer mix will contain equal numbers of isomeric molecules of opposite optical activity.

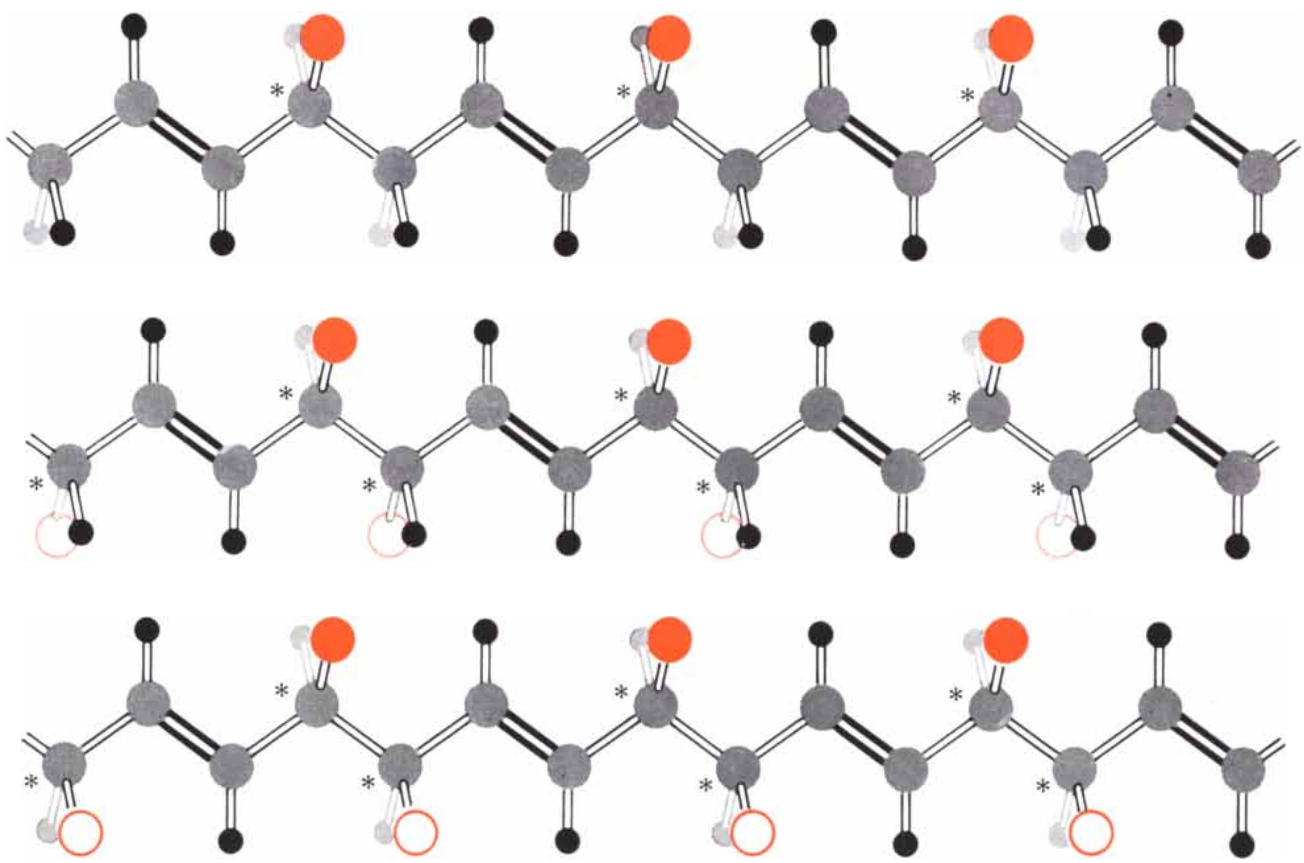
Our goal, therefore, was to find conditions that would favor the polymeriza-



THREE-DIMENSIONAL VIEWS OF POLYPROPYLENE correspond to the simplified views on page 36, except here hydrogen atoms are omitted. Colored balls represent methyl groups (CH_3). In isotactic polypropylene (*top*) the CH_3 groups define a helix (*gray ribbon*). In syndiotactic polypropylene (*middle*) structure is also regular. Atactic polypropylene (*bottom*) is nonregular in form.



RUBBER AND GUTTA-PERCHA (*top and bottom*) are geometric isomers built up from units of the same monomer, isoprene (C_5H_8). Rubber is *cis*-1,4-polyisoprene. The "*cis*" means that a methyl group (*color*) and a neighboring hydrogen (*black*) are on the same side of each pair of carbon atoms joined by a double bond. The "1,4" means that the four-carbon chain of the monomer is linked into the polymer through its first and fourth carbons. Gutta-percha is *trans*-1,4-polyisoprene, indicating that methyl groups and adjacent hydrogens lie across from each other. If the methyl groups in rubber are replaced by hydrogen atoms, the resulting polymer is *cis*-1,4-polybutadiene, a new and commercially promising synthetic with properties very similar to those of *cis*-1,4-polyisoprene.



OPTICALLY ACTIVE POLYMERS can be created from butadiene monomers containing substituents (*color*) for hydrogen either on the first carbon atom or on the first and fourth in the four-carbon chain of the monomer. The polymer of singly substituted butadiene (*top*) is of the *trans*-1,4-isotactic type. Polymers of doubly substituted butadiene can show erythro-di-isotactic succession (*middle*) or threo-di-isotactic succession (*bottom*). The asymmetric carbons are starred; each polymer can exist in the form of its mirror image.

tion of only one of the two optically active forms. The first successful asymmetric synthesis of this kind was achieved last year at the Politecnico di Milano with esters of sorbic acid.

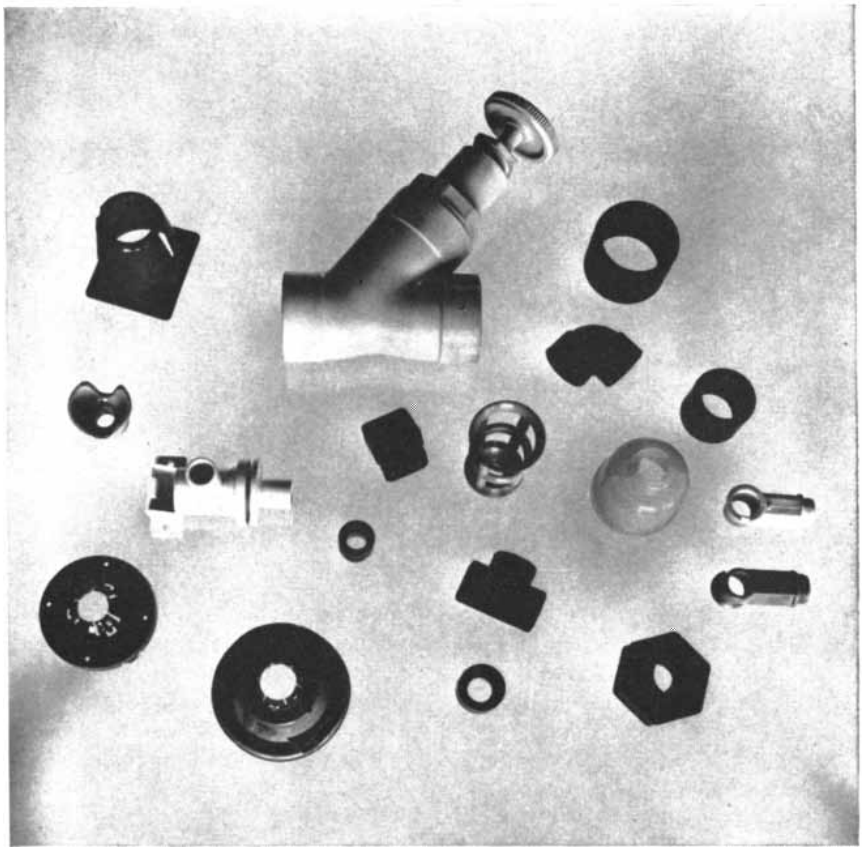
Sorbic acid itself can be regarded as a butadiene molecule that has been lengthened by a methyl (CH_3) group at one end and by a carboxyl (COOH) group at the other. Stereospecific polymerization of certain sorbic acid esters yields crystalline polymers having a "polytactic" structure: each monomer has three different sites of stereoisomerism—one of geometric type and two of optical type—which repeat regularly throughout the polymer.

In polymerizations carried out with a catalyst (butyllithium) that does not have in itself centers of optical asymmetry, there is nothing to establish at the outset a preference for one steric configuration over another. The result is a polymeric substance in which half the molecules have one configuration and half have another. Both molecules, however, are of the erythro-di-isotactic type [*see bottom illustration on opposite page*].

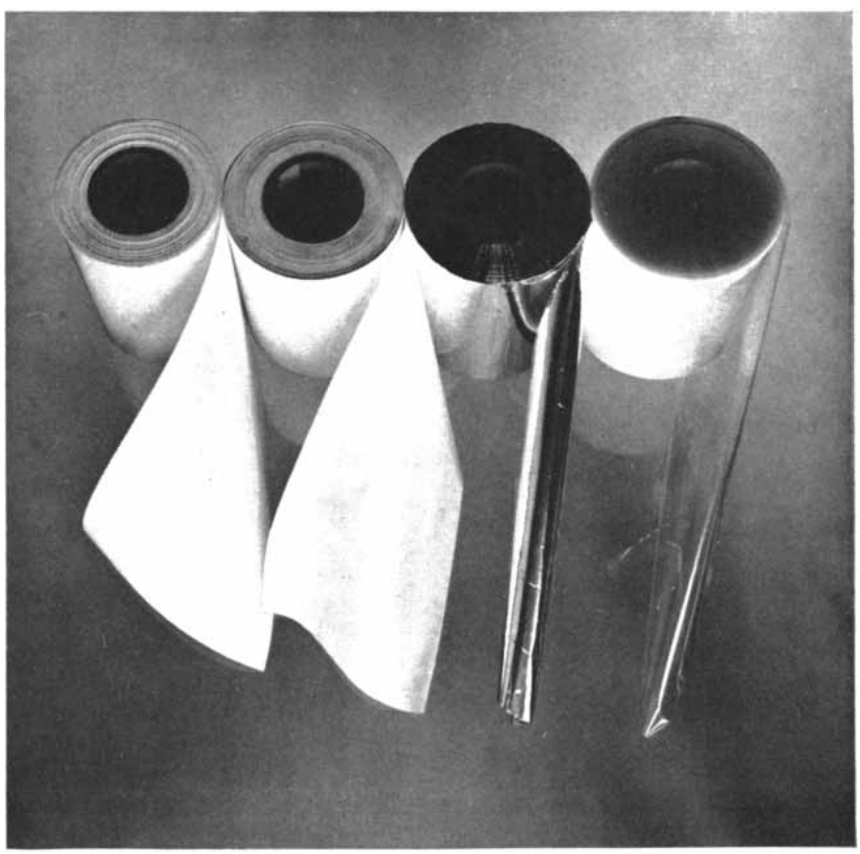
When a catalyst (isoamyllithium) that has a center of optical asymmetry was selected, the resulting molecules were preponderantly of one optical configuration. This was the first asymmetric synthesis of a giant molecule starting from a monomer that was not itself optically active. It is true, however, that the optically active macromolecules contain an optically active end group derived from the catalyst, which is partially consumed during the polymerization.

Subsequently we achieved asymmetric synthesis without consumption of pre-existing optically active reagents. The catalyst for this polymerization was a so-called organometallic compound that was bound to an optically active organic base. Although the base does not take part in the chemical reaction, it provides the steric guidance for the synthesis. (The catalyst is of ionic nature, meaning that the giant molecule grows outward from the catalyst like a growing hair. Oriented monomeric units are fed in at the base of the "hair" with the formation of an ionic bond that joins the end of the hair to the catalyst.)

This is not yet an "absolute" asymmetric synthesis inasmuch as some optical activity is required in the catalyst. The synthesis may suggest, nevertheless, a simplified model of the way nature carries out at least some stereospecific syntheses of optical isomers.



ARTICLES OF MOLDED POLYPROPYLENE yield tough parts and fittings coming into industrial use. In addition to strength the polymer has good heat and chemical resistance.



POLYPROPYLENE FILM resembles polyethylene but is stronger. The articles shown on this page and on page 38 are fabricated from polypropylene made by Montecatini of Italy.

CLEANING SYMBIOSIS

The invasion of the oceans by skin-diving biologists has led to the discovery that a surprisingly large number of marine organisms either live by cleaning other marine organisms or benefit by being cleaned

by Conrad Limbaugh

While skin diving in the cool water off the coast of southern California in the spring of 1949, I observed a brief and seemingly casual meeting between a small golden kelp perch (*Brachyistius frenatus*) and a walleye surfperch (*Hyperprosopon argenteum*) twice its size. The walleye had separated itself from a milling school of its fellows several yards away and was holding itself rigid with fins extended, its body pointed at an unnatural angle to the surface of the water. The three-inch kelp perch spent several minutes picking at the silver sides of the walleye with its pointed snout. Then the kelp perch darted into the golden leaves of a nearby kelp plant, and the walleye returned to lose itself in the activity of the school. At the time I recorded this event in my notes only as an interesting incident.

Since then my studies and the observations of others have convinced me that this was not an isolated episode. On the contrary, it was an instance of a constant and vital activity that occurs throughout the marine world: cleaning symbiosis. Certain species of marine animal have come to specialize in cleaning parasites and necrotic tissue from fishes that visit them. This mutually beneficial behavior promotes the well-being of the host fishes and provides food for those that do the cleaning.

The relationship between the cleaner and the cleaned is frequently so casual as to seem accidental, as in the encounter that first caught my attention. On the other hand, one finds in the Bahamas the highly organized relationship between the Pederson shrimp (*Periclimenes pedersoni*) and its numerous clients. The transparent body of this tiny animal is striped with white and spotted with violet, and its conspicuous antennae are considerably longer than its body. It establishes its station in quiet water where fishes congregate or frequently pass, always in association with the sea anemone *Bartholomea annulata,* usually clinging to it or occupying the same hole. When a fish approaches, the shrimp will whip its long antennae and sway its body back and forth. If the fish is interested, it will swim directly to the shrimp and stop an inch or two away. The fish usually presents its head or a gill cover for cleaning, but if it is bothered by something out of the ordinary, such as an injury near its tail, it presents itself tail first. The shrimp swims or crawls forward, climbs aboard and walks rapidly over the fish, checking irregularities, tugging at parasites with its claws and cleaning injured areas. The fish remains almost motionless during this inspection and allows the shrimp to make minor incisions in order to get at subcutaneous parasites. As the shrimp approaches the gill covers, the fish opens each one in turn and allows the shrimp to enter and forage among the gills. The shrimp is even permitted to enter and leave the fish's mouth cavity. Local fishes quickly learn the location of these shrimp. They line up or crowd around for their turn and often wait to be cleaned when the shrimp has retired into the hole beside the anemone.

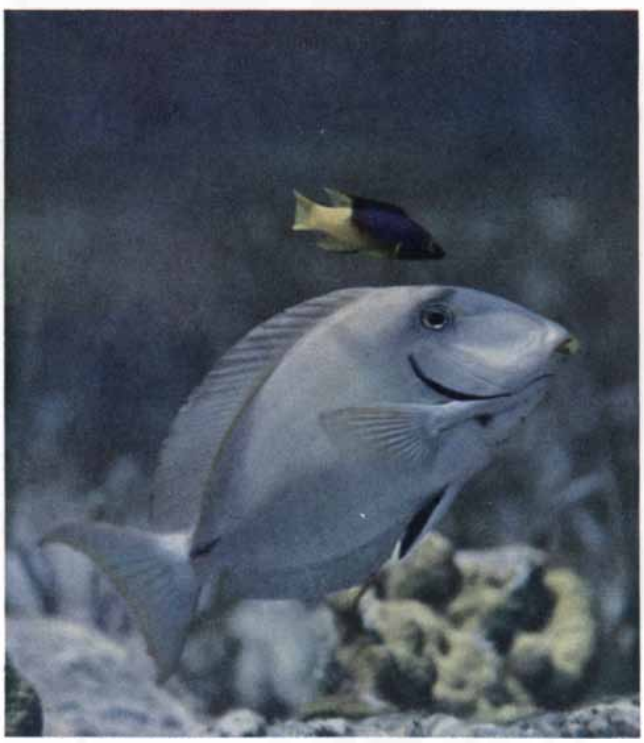
Such behavior has been considered a mere curiosity for many years. The literature contains scattered reports of cleaning symbiosis, including a few examples among land animals: the crocodile and the Egyptian plover, cattle and the egret, the rhinoceros and the tickbird. As early as 1892 the German biologist Franz von Wagner had suggested that the pseudoscorpion, a tiny relative of the spider that is frequently observed stealing a ride on larger insects, is actually engaged in removing parasitic mites from these insects. The U.S. biologist William Beebe in 1924 saw red crabs remove red ticks from sunbathing marine iguanas of the Galápagos Islands. While diving in the coral waters off Haiti four years later, Beebe also saw several small fishes of the wrasse family cleaning parrot fish. Mexican fishermen in the Gulf of California refer to a certain angelfish (*Holacanthus passer*) as *El Barbero*. They explain that this fish "grooms the other fishes" and so deserves its title as "The Barber."

Recognition of cleaning symbiosis and its implications has come only in recent years. The gear and the technique of skin diving have given marine biologists a new approach to the direct observation of undersea life. They have discovered numerous examples of cleaning behavior, enough to establish already that the behavior represents one of the primary relationships in the community of life in the sea. The known cleaners include some 26 species of fish, six species of shrimp and Beebe's crab. This number will undoubtedly increase when the many marine organisms now suspected of being cleaners have been studied more closely. It now seems that most other fishes seek out and depend on the service they render. The primary nature of the behavior is evident in the bright coloration and anatomical specialization that distinguish many cleaners. It appears that cleaning symbiosis may help to explain the range of species and the make-up of populations found in particular habitats, the patterns of local movement and migration and the natural control of disease in many fishes.

The importance of cleaning in the ecology of the waters off southern California became more and more apparent to me during the early 1950's as I accumulated observations of cleaners at work. My notes are particularly concerned with

FOUR CLEANING RELATIONSHIPS are depicted in this drawing by Rudolf Freund. In each the cleaner is in color. At top left a señorita (*Oxyjulis californica*) cleans a group of blacksmiths (*Chromis punctipinnis*). At top right are a butterfly fish (*Chaetodon nigrirostris*) and two Mexican goatfish (*Pseudupeneus dentatus*); in center, two neon gobies (*Elecatinus oceanops*) and a Nassau grouper (*Epinephelus striatus*); at bottom, a Spanish hogfish (*Bodianus rufus*) in the mouth of a barracuda (*Sphyraena barracuda*).

CALIFORNIA MORAY EEL (*Gymnothorax mordax*) has its external parasites removed by four California cleaning shrimps (*Hippolysmata californica*). At upper left is a fifth shrimp. This photograph and the one at right below were made by Ron Church.



SPANISH HOGFISH (*top*) in process of cleaning ocean surgeon (*Acanthurus bahianus*) was photographed by author in Bahamas.

LIONFISH (*Pterois volitans*) is host to a very much smaller cleaning wrasse (*purple fish in center*) of undetermined species.

the performance of the golden-brown wrasse (*Oxyjulis californica*), commonly called the señorita. This cigar-shaped fish is abundant in these waters and well known to fishermen as a bait-stealer.

Certain fishes, such as the opaleye (*Girella nigricans*), the topsmelt (*Atherinops affinis*) and the blacksmith (*Chromis punctipinnis*), crowd so densely about a señorita that it is impossible to see the cleaning activity. When I first saw these dense clouds, often with several hundred fish swarming around a single cleaner, I thought they were spawning aggregations. As the clouds dispersed at my approach, however, I repeatedly observed a señorita retreating into the cover of the rocks and seaweed nearby. Often the host fishes, unaware of my approach, would rush and stop in front of the retreating señorita, temporarily blocking its path. In less dense schools I was able to observe the señorita in the act of nibbling parasites from the flanks of a host fish. While being cleaned blacksmiths would remain motionless in the most awkward positions—on their sides, head up, head down or even upside down.

The material cleaned from fishes by the señorita and other cleaners has not been thoroughly studied. Among the organisms I have noted in the stomach contents of cleaners are copepods and isopods: minute parasitic crustaceans that attach themselves to the scales and integument of fishes. I have also found bacteria, and on several occasions I have seen señoritas in the act of nibbling away a white, fluffy growth that streamed as a milky cloud from the gills of infected fishes. Especially in the spring and summer months off California and farther south in the warmer waters off Mexico, many fishes display this infection; it ranges from an occasional dot of white to large ulcerated sores rimmed with white. Carl H. Oppenheimer, now at the University of Miami, has shown that this is a bacterial disease by infecting healthy individuals with material taken from diseased fishes.

Judging by the diversity of its clientele, the señorita is well known as a cleaner to many members of the marine community. Among the species that seek out its services I have counted pelagic (deep ocean) fishes as well as the numerous species that populate the kelp beds nearer shore. The black sea bass (*Stereolepis gigas*) and the even larger ocean sunfish (*Mola mola*) seem to come purposely to the outer edge of the kelp beds, where they attract large numbers of señoritas, which flock around them to pick off their parasites. I have also observed the señorita at work on the bat ray (*Holorhinus californicus*), showing that the symbiosis embraces the cartilaginous as well as the bony fishes.

Since first recognizing cleaning behavior in these southern California fishes, I have studied it in numerous places down the Pacific Coast of Mexico, in the Gulf of California, in the Bahamas and in the Virgin Islands. Observations such as mine have been paralleled in the literature by other skin-diving biologists and by underwater photographers. From 1952 to 1955 Vern and Harry Pederson made motion pictures in the Bahamas of cleaning behavior in a number of species of fish and in the violet-spotted shrimp that bears their name. In 1953 the German skin diver Hans Hass suggested that the pilot fish associated with manta rays ate the parasites of their hosts. Irenäus Eibl-Eibesfeldt, a German biologist, published notes in 1954 on cleaning behavior he had witnessed in fishes in Bahamian waters; he expressed the belief that it is common in the oceans of the world. In the Hawaiian and Society islands John E. Randall of the University of Miami identified as cleaners four fishes of the genus *Labroides,* two of which were new species.

A few generalizations about cleaning symbiosis may now be attempted. In the first place, the phenomenon appears to be more highly developed in clear tropical waters than in cooler regions of the seas. The tropical cleaner species are more numerous and include the young of the gray angelfish (*Pomacanthus aureus*), the butterfly fish (*Chaetodon*), gobies (*Elecatinus*) and several wrasses such as the Spanish hogfish (*Bodianus rufus*) and the members of the genus *Labroides.* Even distantly related species have analogous structures for cleaning, such as pointed snouts and tweezer-like teeth; this suggests convergent evolution toward specialization in the cleaning function. In the tropical seas the cleaning fish are generally brightly colored and patterned in sharp contrast to their backgrounds; it appears that most fishes that stand out in their environment are cleaners. Since cleaning fishes must be conspicuous, it is logical that they should have evolved toward maximum contrast with their surroundings. (The parasites on which they feed have evolved toward a maximum of protective coloration, matching the color of their hosts, and are usually invisible to the human observer of cleaning behavior.) In general these fishes are not gregarious and live solitarily or in pairs. In Temperate Zone waters, on the other hand, the cleaners are not so brightly colored or so contrastingly marked. They tend to be gregarious, to the point of living in schools, and are more numerous, though the number of species is smaller.

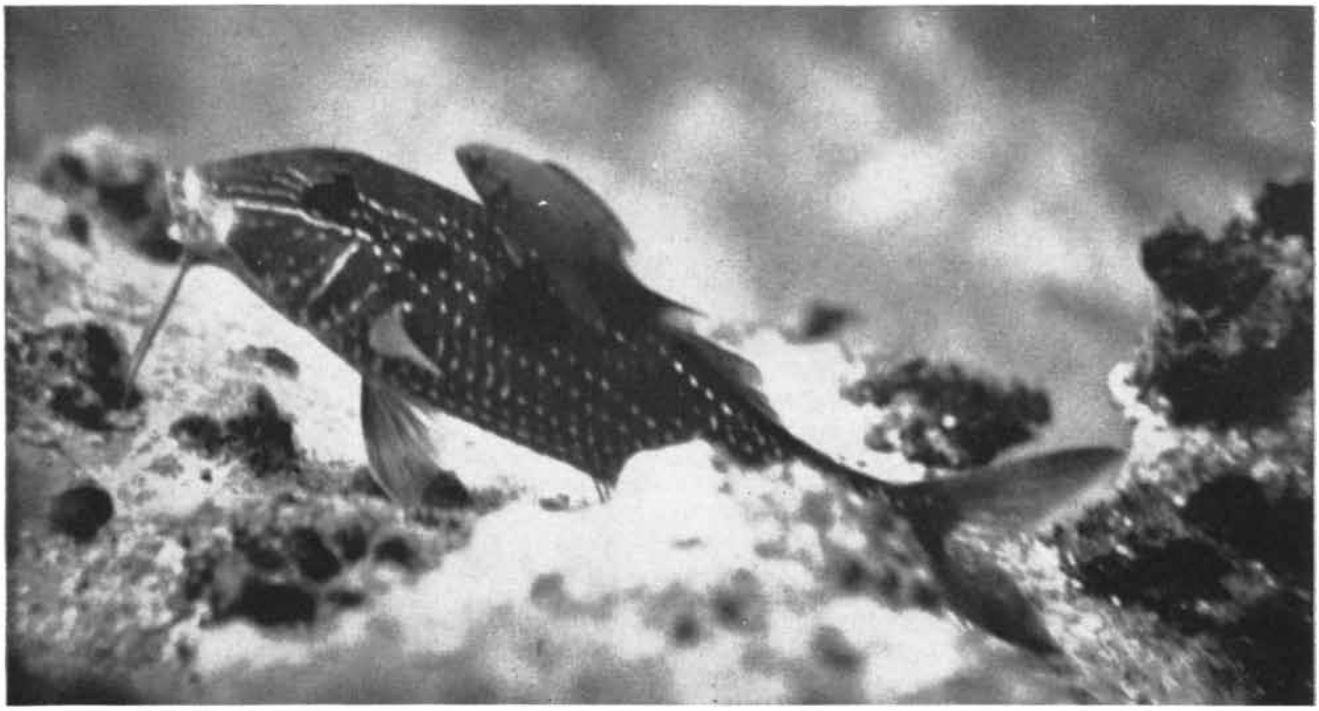
The cleaning behavior of the tropical forms is correspondingly more complex than that of the Temperate Zone species. Whereas the latter simply surround or follow a fish in order to clean it, the tropical cleaners put on displays not unlike those shown in courtship by some male fishes. They rush forward, turn sideways and then retreat, repeating the ritual until a fish is attracted into position to be cleaned. Frequently they sense the presence of a fish before a human observer can, and they hasten to take up their station before the fish arrives to be cleaned.

Some species clean only in their juvenile stage; none of them appears to depend exclusively on the habit for its food. Again, however, the tropical species come closer to being "full time" cleaners. One consequence of their higher degree of specialization is that they enjoy considerable immunity from predators. In an extensive investigation of the food habits of California kelp fishes I never found a señorita, a close cousin of the numerous cleaning wrasses of the tropics, in the stomach contents of other fishes. I have seen it safely enter the open mouth of the kelp bass, a fish that normally feeds on señorita-size fishes. On the other hand, the kelp perch, a more typical Temperate Zone cleaner, frequently turns up in the stomachs of fishes that it cleans. The immunity of certain cleaners is so well established that other fishes have come to mimic them in color and conformation and so share their immunity. Some mimics reverse the process and prey on the fish that mistake them for cleaners!

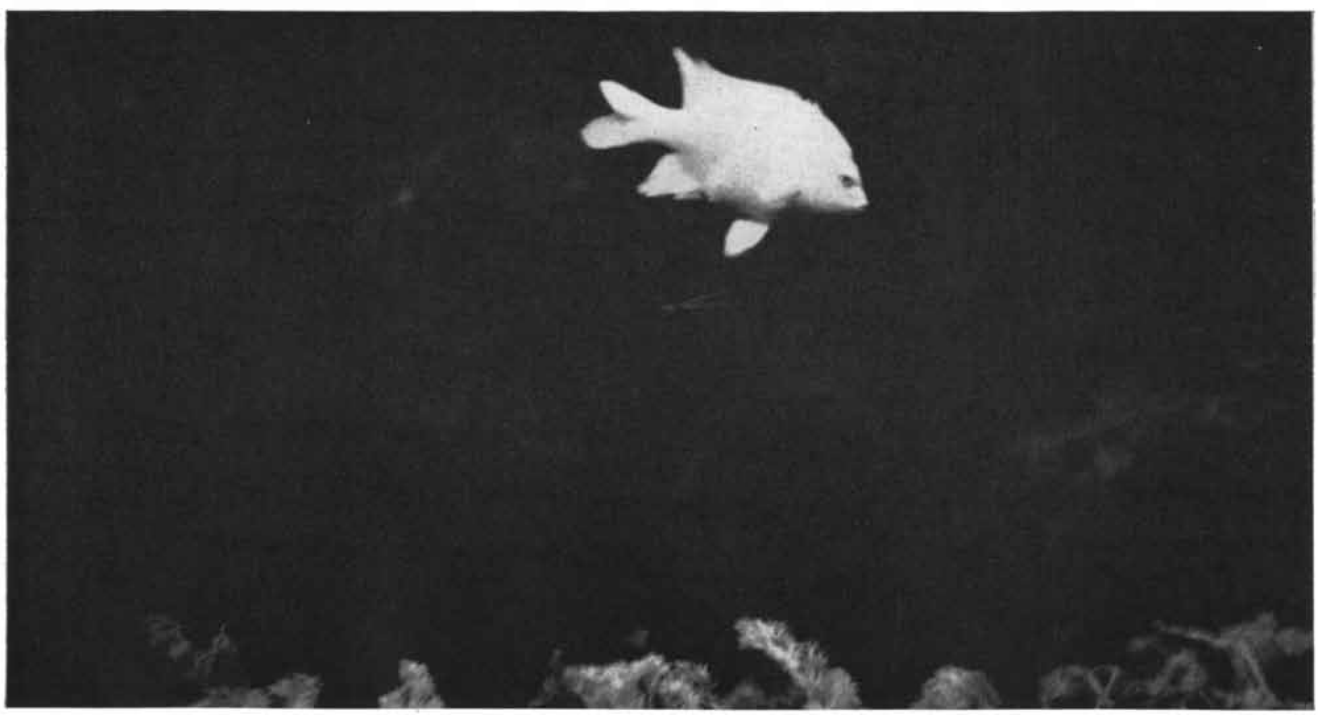
The same generalizations may be made in contrasting the cleaning shrimps of the Tropical and Temperate zones. Only one of the six known species occurs outside the tropics; this is the California cleaning shrimp (*Hippolysmata californica*). It is a highly gregarious and wandering animal, at the other pole of behavior from the tropical species as represented by the solitary and sedentary Pederson shrimp of the Bahamian waters. The California cleaning shrimp does not have the coloration and marking to make it stand out from its environment. So far as I have been able to determine, it does not display itself to attract fishes. These California shrimps wander abroad in troops numbering in the hundreds, feeding on the bottom at night and re-

tiring to cover during the day. They act as cleaners when they come upon an animal, say a lobster, in need of cleaning or when a fish, perhaps a moray eel, swims into the crevice where they have found shelter. They will crawl rapidly over the entire outside surface of the animal, cleaning away everything removable, including decaying tissue. A lobster that has been worked over by a team of these shrimps comes out with a clean shell; a human diver's hand will receive the same treatment. Fishes do not seem to be bothered by these rough attentions, although the moray may occasionally jerk its head as if annoyed.

In some cases the shrimps may enter the mouth of the moray to get at parasites there, but not without risk; the stomachs of morays have yielded a considerable number of these shrimps. In



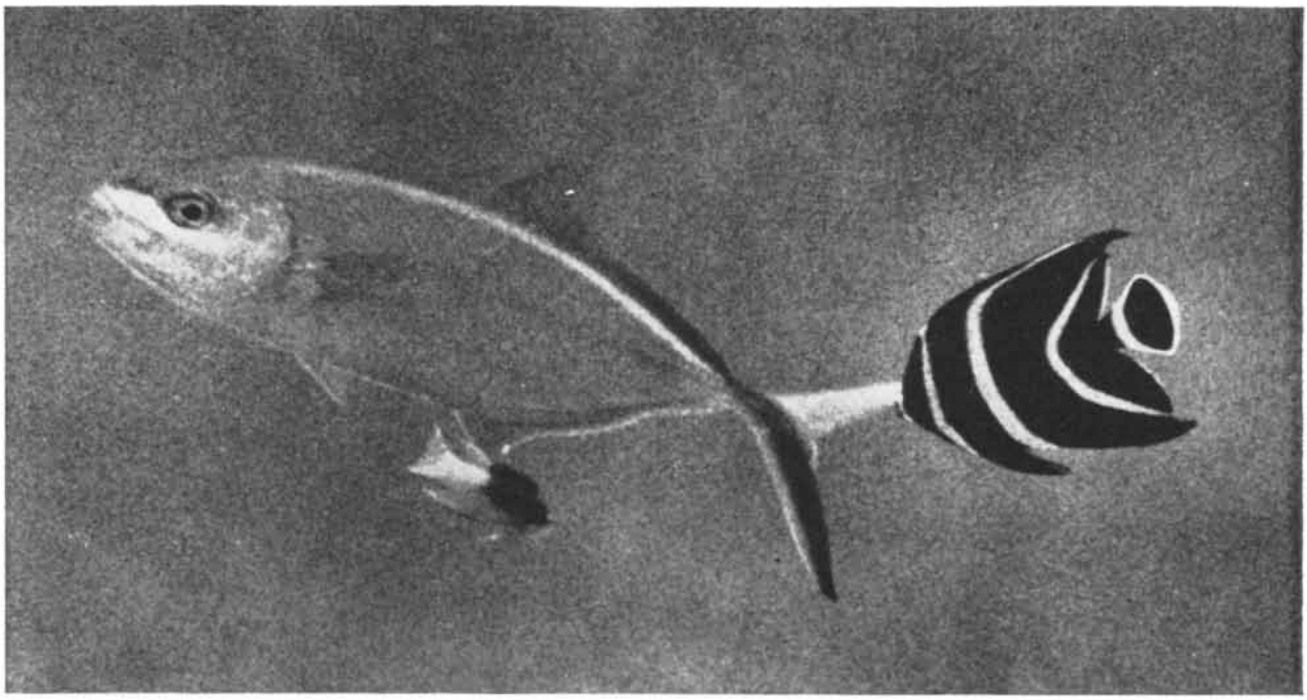
SPOTTED GOATFISH (*Pseudupeneus maculatus*) is host to the smaller Spanish hogfish. The hogfish is found in the tropical waters from Bermuda and Florida to Rio de Janeiro, in the Gulf of Mexico and around Ascension and St. Helena islands in the South Atlantic.



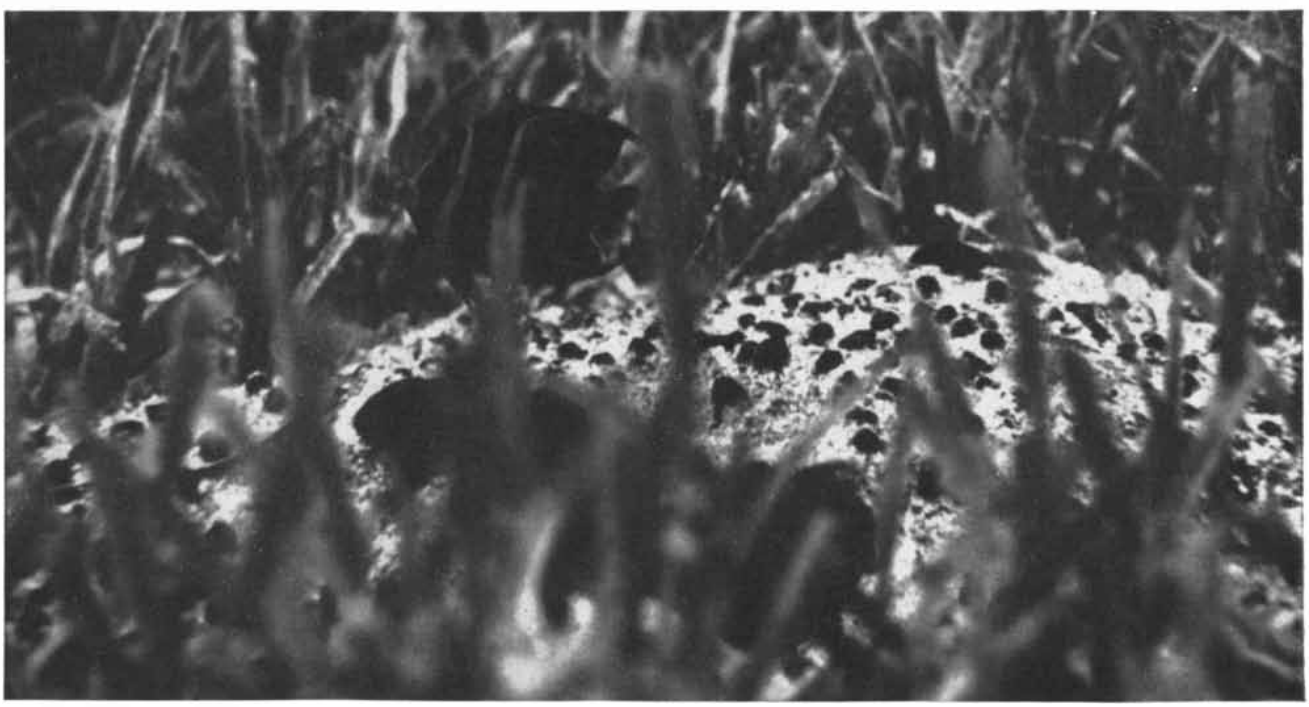
GARIBALDI (*Hypsypops rubicunda*) at top holds itself at an unnatural angle while being cleaned by a señorita. The latter, which is found in temperate waters from central California to central Lower California, cleans more than a dozen species of fish.

contrast, the tropical cleaning shrimps, all of them more exclusively specialized as cleaners, seem to have the same immunity from predation as the tropical cleaning fishes. With their bright colors, their fixed stations and their elaborate display behavior, they are plainly advertised to the community as cleaners and attract hosts rather than predators. It is easy to visualize the evolutionary path by which the more complex cleaning symbiosis may have developed from the imperfect cleaner-host relationships such as that of the California shrimp.

In the summer of 1955, in the Gulf of California near Guaymas, I noted that cleaning behavior appeared to be concentrated at rocky points: each point was manned by two butterfly fish and one angelfish. I assumed that the concentration of other fishes arose from the



JUVENILE GRAY ANGELFISH (*Pomacanthus aureus*) at right cleans external parasites from the tail of a bar jack (*Caranx ruber*). Below the jack is another cleaner, the Spanish hogfish. This photograph and those on the opposite page were made by the author.

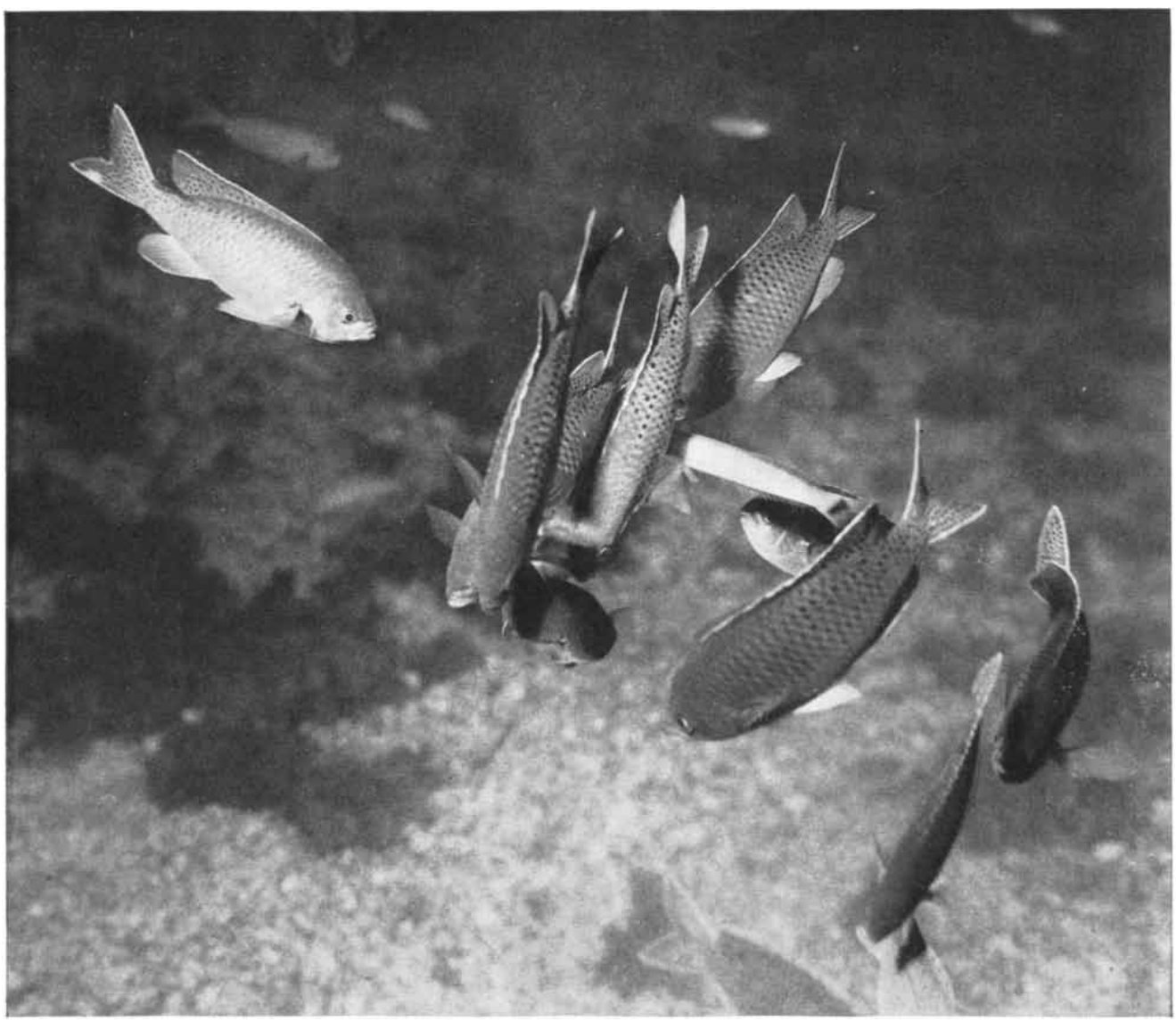


"CLEANING STATION," consisting of a sponge (*light area with small, dark protuberances*) surrounded by turtle grass, is manned by a juvenile gray angelfish. The station, located off New Providence Island in the Bahamas, was photographed by the author's wife.

fact that these points constitute the intersection of the communities of fishes on each side. In 1958 Randall, reporting on his studies of the cleaning wrasses in the Society Islands, observed that fishes came from comparatively long distances to the sites occupied by the cleaners, not just from the immediate community. The Pederson brothers made the same observation in the Bahamas, reporting that the cleaners congregate in regular "cleaning stations" in the coral reefs and attract host fishes from large areas.

Subsequent studies have confirmed these observations. The various species of cleaning fish and shrimp tend to cluster in particular ecological situations: at coral heads, depressions in the bottom, ship wreckage or the edge of kelp beds. Their presence in these localities accounts in great part for the large assemblages of other fishes that are so frequently seen there. Even a small cleaning station in the tropics may process a large number of fish in the course of a day. I saw up to 300 fish cleaned at one station in the Bahamas during one six-hour daylight period. Some of the fishes pass from station to station and return many times during the day; those that could be identified by visible marks, such as infection spots, returned day after day at regular time intervals. Altogether it seemed that many of the fishes spent as much time at cleaning stations as they did in feeding.

At cleaning stations inhabited by thousands of cleaning organisms, cleaning symbiosis must assume great numerical significance in determining the distribution and concentration of marine populations. In my opinion, it is the presence of the señorita and the kelp perch that brings the deep-water coastal and pelagic fishes inshore to the edge of the kelp beds on the California coast. Most concentrations of reef fishes may similarly be understood to be cleaning stations. Cleaning symbiosis would therefore account for the existence of such well-known California sport-fishing grounds as the rocky points of Santa Catalina Island, the area around the sunken ship *Valiant* off the shore of Catalina, the La Jolla kelp beds and submarine



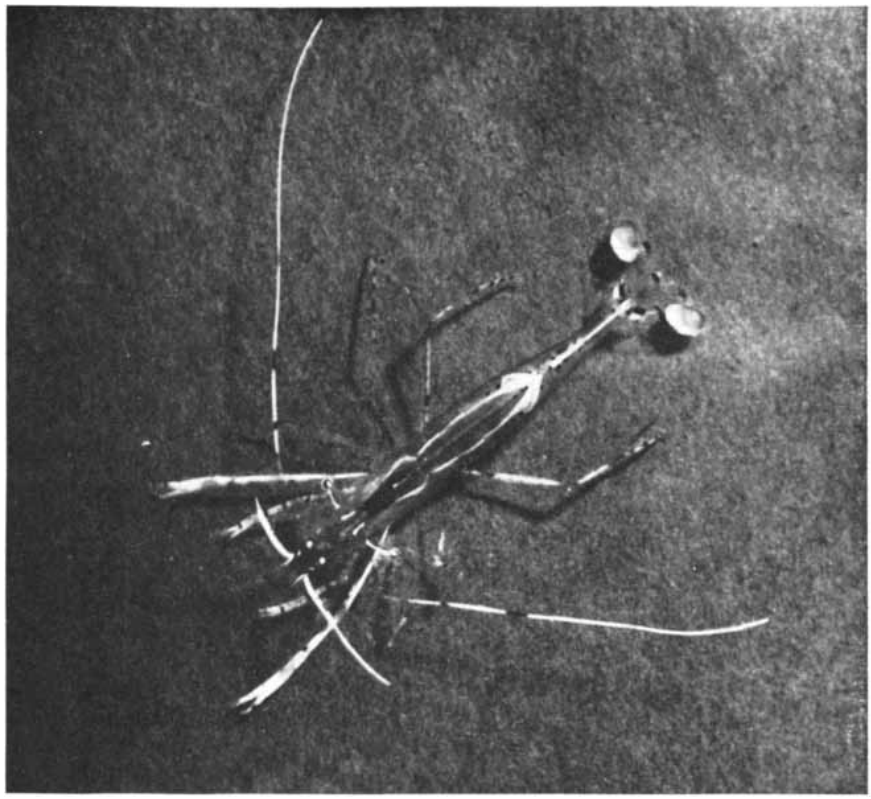
BLACKSMITHS IN GROUP waiting to be cleaned by a single señorita (*slender fish in nearly horizontal position at right center*) assume various positions. This photograph was made by Charles H. Turner of the State of California Department of Fish and Game.

canyon and the Coronado Islands.

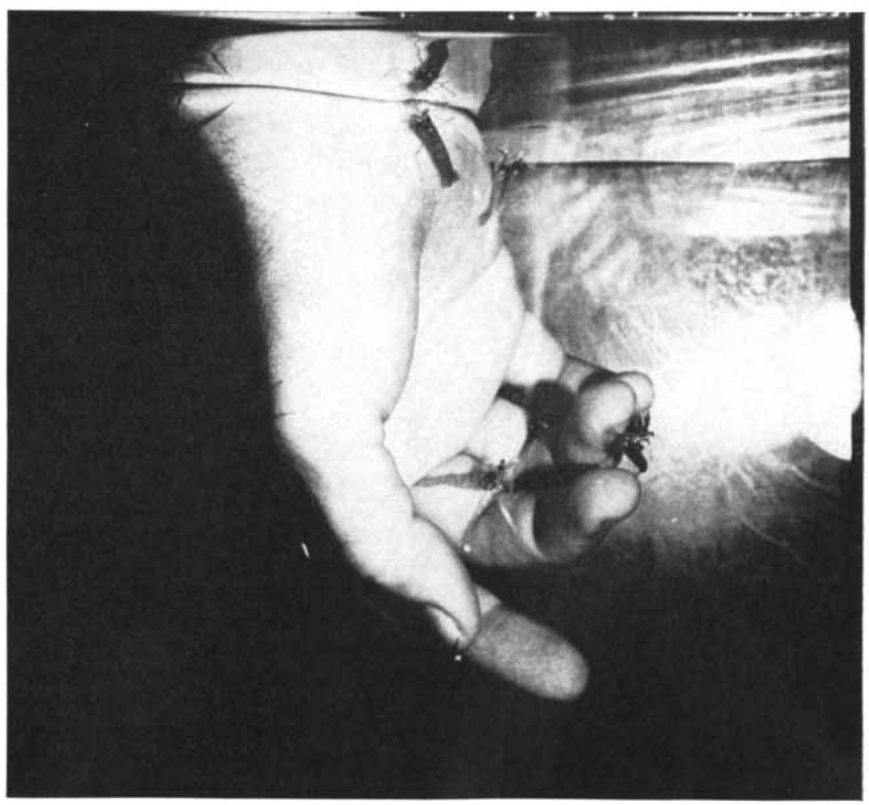
These generalizations of course call for further observation and perhaps experimental study. In a modest field experiment in the Bahamas I once removed all the known cleaning organisms from two small, isolated reefs where fish seemed particularly abundant. Within a few days the number of fish was drastically reduced; within two weeks almost all except the territorial fishes had disappeared.

This experiment also demonstrated the importance of cleaning symbiosis in maintaining the health of the marine population. Many of the fish remaining developed fuzzy white blotches, swelling, ulcerated sores and frayed fins. Admittedly the experiment was a gross one and not well controlled, but the observed contrast with the fish populations of the nearby coral heads was very striking. Certainly it appeared that the ailments occurred because of the absence of cleaning organisms. This impression was strengthened when a number of local fishes that had been maintained in an aquarium were found to be developing bacterial infections. I placed a cleaner shrimp in the aquarium, and it went to work at once to clean the infected fishes.

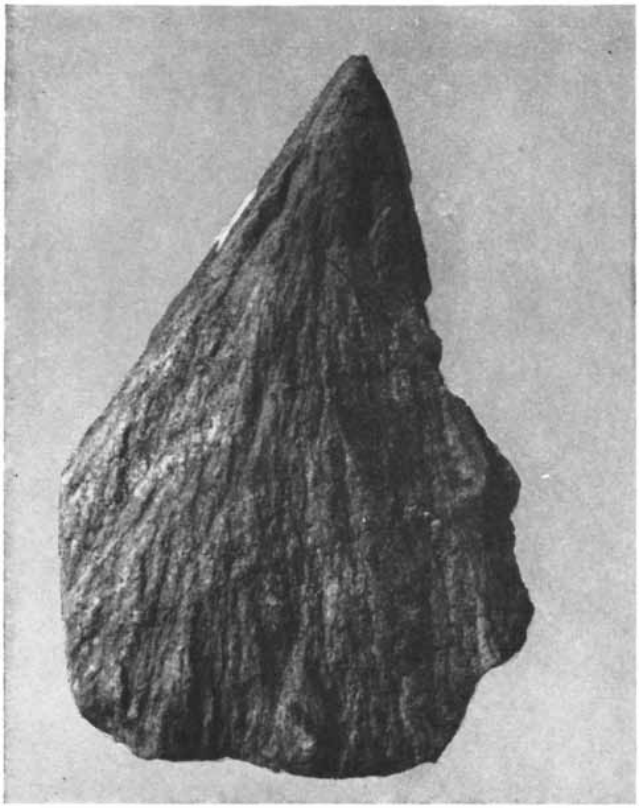
Symbiotic cleaning has some important biological implications. From the viewpoint of evolution it provides a remarkable instance of morphological and behavioral adaptation. Ecologically speaking, cleaners must be regarded as key organisms in the assembling of the species that compose the populations of various marine habitats. Cleaning raises a great many questions for students of animal behavior; it would be interesting to know what mechanism prevents ordinarily voracious fishes from devouring the little cleaners. In zoogeography the cleaning relationships may provide the limiting factor in the dispersal of various species. In parasitology the relationship between the cleaning activities on the one hand and host-parasite relations on the other needs investigation. The beneficial economic effect of cleaners on commercially important marine organisms must be considerable in some areas. The modern marine-fisheries biologist must now consider cleaners in any thorough work dealing with life history and fish population studies. From the standpoint of the philosophy of biology, the extent of cleaning behavior in the ocean emphasizes the role of co-operation in nature as opposed to the tooth-and-claw struggle for existence.



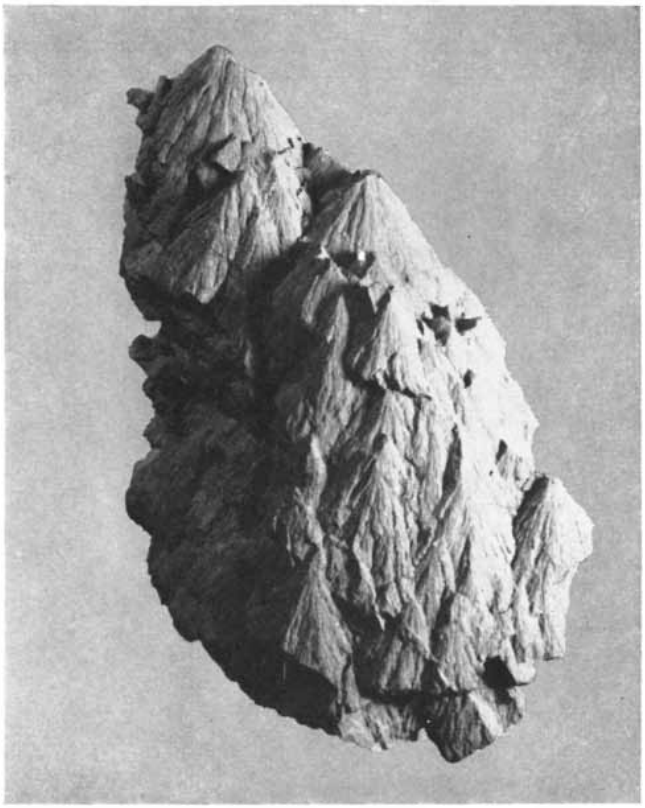
PEDERSON CLEANING SHRIMP (*Periclimenes pedersoni*) attracts hosts by waving its antennae, which are longer than its body. Shell-like objects (*upper right*) are shrimp's uropods, or "flippers." Photograph was made by F. M. Bayer of Smithsonian Institution.



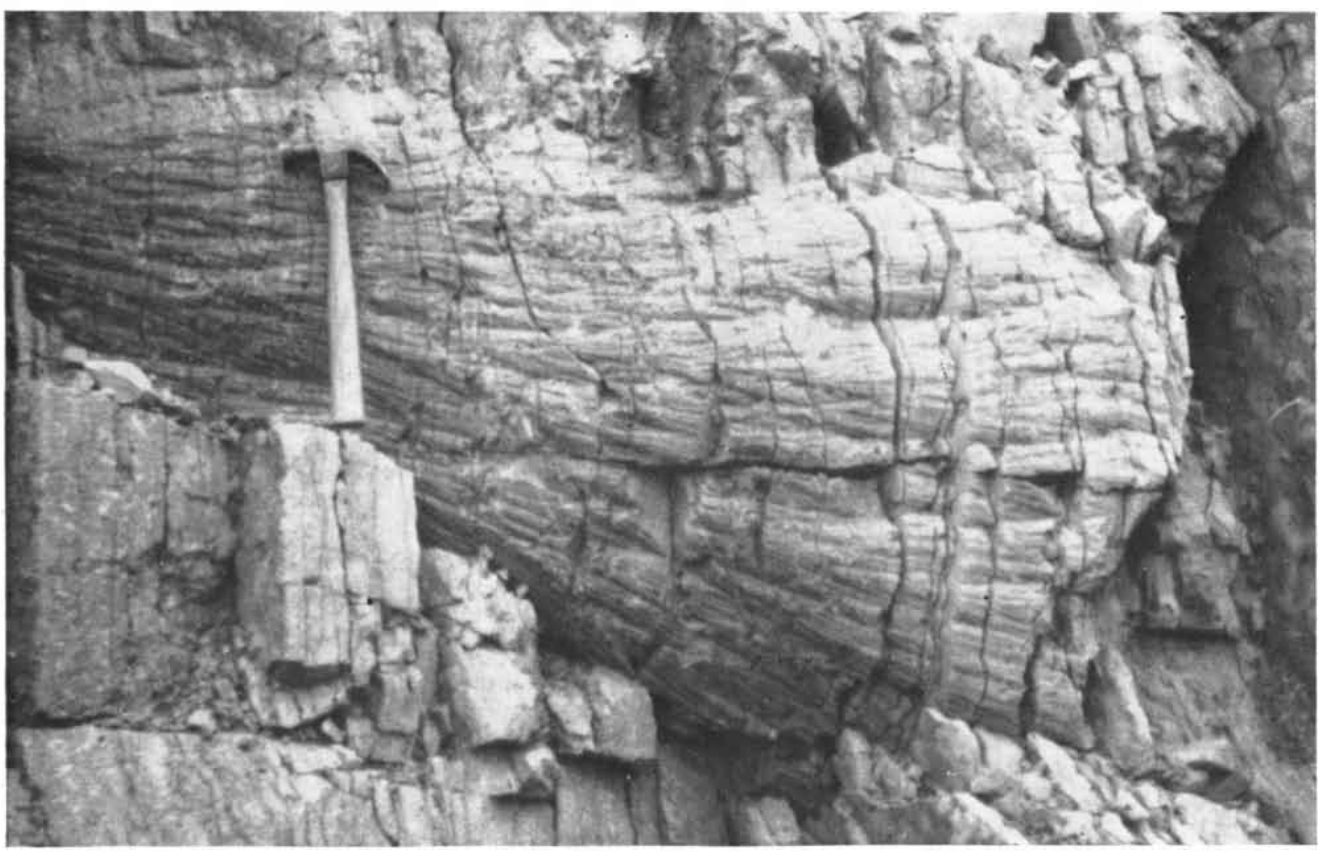
CALIFORNIA CLEANING SHRIMPS "clean" the author's hand, even to picking at his fingernails. These shrimps clean everything that is removable from the exterior of a host.



SHATTER CONE four inches high is one of many in igneous rock of the Vredefort Ring in South Africa, a structure that is probably the remains of the largest meteorite crater known on earth.



NEST OF CONES in dolomite, a type of limestone, is from Wells Creek Basin structure in Tennessee. This group is 11 inches high. Shock pressures generated by meteorite impact create such cones.



GIANT SHATTER CONE, over four feet long, is shown in place at the Kentland limestone quarry in Indiana. These cones found among jumbled rocks in a flat, geologically undeformed terrain indicate that the quarry is an ancient meteorite-impact site.

ASTROBLEMES

This newly coined word refers to ancient scars left in the earth's crust by huge meteorites. The evidence for such impacts is largely the high-pressure mineral coesite and "shatter cones" in the rocks

by Robert S. Dietz

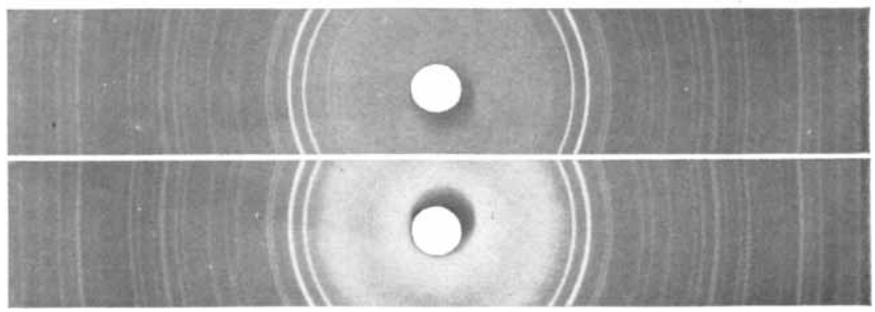
It is an awesome experience to stand on the rim of Barringer Crater in Arizona and reflect on the cosmic cataclysm that opened up this gaping hole, three-quarters of a mile across and 600 feet deep, in the crust of the earth. The Hopi Indians are said to retain the legend that one of their gods descended here from the sky in fiery grandeur. White sheepherders who came upon the crater a century ago found numerous lumps of metal lying about and intuitively concluded that a star had fallen at the site. Upon later analysis the lumps of metal proved indeed to be fragments of nickel-iron meteorite. Studies at the site have now established beyond doubt that the crater records the impact of a large meteorite that plunged to earth some 25,000 years ago. Barringer Crater is the first of an increasing number of geological structures to be recognized as the scars of an agelong and still continuing bombardment of the earth by rubble from elsewhere in the solar system.

An extraterrestrial explanation of terrestrial events finds a readier acceptance today than it did in the past. One persuasive body of evidence supporting the meteoritic origin of Barringer Crater and craters like it is represented by the pockmarked face of the moon. As long ago as 1895 G. K. Gilbert, the most distinguished U.S. geologist of his time, advanced the hypothesis that the craters of the moon had been caused by the impact of meteorites. His explanation of these lunar features stands little changed even today. Yet after a visit to Barringer Crater, Gilbert read a philosophical paper entitled "The Origin of Hypotheses" to the Geological Society of America in Washington, in which he argued that the crater had a purely terrestrial origin—in a volcanic explosion—and dismissed the notion of a meteorite fall. Gilbert's authority was such that it took more than 30 years to reverse his judgment. But the sciences progress not so much by the discovery of new truth as they do by the correction of old error. Overwhelming evidence was forthcoming by 1928, and Barringer Crater was firmly identified as the site where a large meteorite had struck.

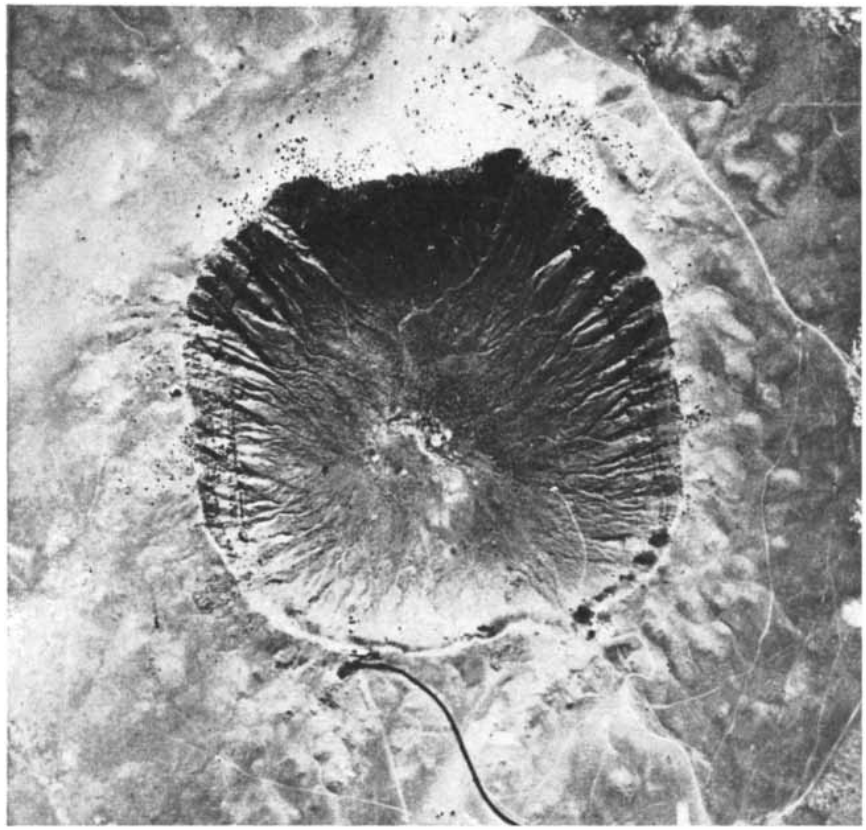
Acceptance of this prototype terrestrial meteorite crater opened the way for speedy recognition of others. In 1933 L. J. Spencer of the British Museum listed eight more, all of which have withstood closer inspection. Among them is the great Ashanti Crater (Lake Bosumtwi) in Ghana, which has a diameter of six miles. More recently discovered is the two-mile New Quebec Crater in subarctic Canada [see "The Canadian Meteor Crater," by V. B. Meen; SCIENTIFIC AMERICAN, May, 1951]. Four craters in Australia have also been identified as scars of meteorite falls.

The list of 14 well-certified terrestrial meteorite craters is impressive, but the record of bombardment preserved on the face of the moon plainly suggests that the list should be longer. At the conservatively estimated rate of one great fall every 10,000 years, some 50,000 giant meteorites must have struck the earth during the past 500 million years. Where are the craters they made? The answer is that on the earth's surface such craters are ephemeral features. Tectonic processes alter their round shapes, erosion wears away their rims and sedimentation fills them up; gradually they disappear as recognizable features in the terrain. On the airless, waterless and tectonically inactive surface of the moon, meteorite craters have remained unchanged from the most distant past except through the impact of later meteorites. The craters that remain clearly visible on earth today must all have been created by impacts during the last million years.

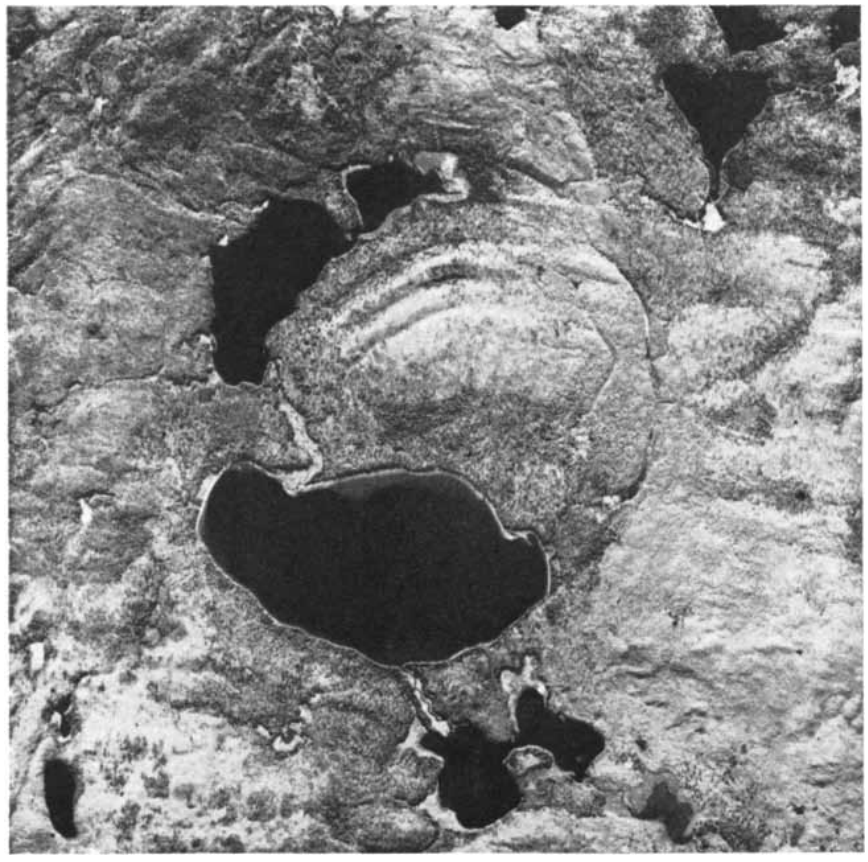
To lengthen the list of terrestrial meteorite craters one must now look for less obvious signs. A few "fossil" craters, scarcely discernible on the ground, have shown up in aerial photographs, appearing as faint circular features [see "Fossil Meteorite Craters," by C. S. Beals; SCIENTIFIC AMERICAN, July, 1958]. Geological maps of surface and subterranean rock formations have revealed still other



X-RAY-DIFFRACTION PATTERNS of synthetic coesite (*top*) and natural coesite found at Barringer Crater in Arizona are virtually identical. Coesite is a silica formed at high pressure. Diffraction patterns were made by E. C. T. Chao of the U.S. Geological Survey.



BARRINGER CRATER, also known as Meteor Crater, was made about 25,000 years ago by a meteorite impact. It is three-quarters of a mile across. Natural coesite was first found here.



BRENT CRATER in central Ontario is a shallow depression two miles across, first detected in an aerial photograph. It is a fossil crater approximately 500 million years old.

circular features, which geologists in the past have generally attributed to volcanic explosions. It now appears that many of these are the "root" structures of ancient meteorite craters. For those that prove to be obliterated craters made by a meteorite or the head of a comet I have proposed the term "astrobleme," from the Greek words for "star" and "wound."

Of course the discovery of the main body or of remnants of a meteorite embedded in the rocks would clearly identify an astrobleme. Gilbert looked for such evidence at Barringer Crater; because he could not detect the magnetic anomaly that would have indicated a buried mass of meteoritic iron, he was led to his negative conclusion. It is now known, however, that one can hardly expect to recover meteorite fragments from an astrobleme. The meteorite partly vaporizes on impact and the remaining fragments quickly weather away. Comet heads are largely composed of ices of water, methane and ammonia, and so they would leave little evidence.

But there is another kind of evidence that should persist. A meteorite large enough to cause an astrobleme enters the earth's atmosphere with the same high velocity as a small meteorite—at an average speed of some 10 miles per second. Because of its size, a big meteorite loses little of its enormous energy to deceleration by the atmosphere. The shock that it generates upon impact must therefore transcend that of any other earthly explosion, natural or man-made. It can be calculated that such impacts produce pressures of millions of atmospheres. (One atmosphere is about 15 pounds per square inch.) Volcanic explosions, in contrast, involve pressures of hundreds of atmospheres. Therefore at the site of a suspected astrobleme one should look for evidence of sudden, extremely intense shock waves.

In recent years two conclusive pieces of evidence for shock waves of this kind have been recognized: (1) curious conical fracture patterns in rocks known as shatter cones, and (2) a form of silica, called coesite, created under extremely high pressure. One or both of these products of the action of intense shock waves on rock have now been discovered at a dozen sites previously attributed to volcanic events. The map of the world will never be marked with as many identified meteorite craters and astroblemes as the moon, but it is beginning to show enough of them to support Gilbert's contention that most of the 30,000 craters on the visible side of the moon were made by meteorites.

Shatter cones are conical fragments of rock characterized by striations that radiate from the apex. Such cones vary in size from a fraction of an inch up to many feet, depending largely on the thickness of the stratum deformed as a unit. Their conformation suggests that the parent rock was subjected to a sudden shearing stress so intense that the splintering of the rock ignored the natural lines of fracture weakness. Moreover, a shatter cone breaks up into smaller shatter cones when struck with a hammer, showing that the pattern of striations forms interlacing cones within the rock. Fine-grained, homogeneous rocks such as limestone or sandstone appear to favor their development, but they form in any type of rock. Shatter cones were first discovered at the beginning of this century in the Steinheim Basin in southern Germany, the site of an immense natural explosion. The Germans called them *Strahlenkalk* (*Strahlen,* rays; *kalk,* lime) and regarded them as being products of the same volcanic explosion to which they attributed the formation of the basin.

I first became interested in shatter cones nearly two decades ago when I was at the University of Illinois. The operators of a big limestone quarry at nearby Kentland, Ind., had uncovered the aftermath of some ancient cataclysm. Splintered, crushed and jumbled rock strata about 400 million years old lay in the midst of a flat terrain that showed no signs of folding or other tectonic processes. Geologists invoked a deep-seated volcanic steam explosion to explain the condition of the rocks, but the minerals and clays one would expect to find associated with such an event did not appear in the quarry. Shatter cones, however, abounded; they ranged from an inch to six feet in length. The cones were nearly all oriented at right angles to the sedimentary strata and pointed upward. If the blast had not jumbled the strata, all the apexes of the shatter cones would have been pointing to the zenith. Thus it appeared that the impulse that had shattered them came not from below, as in a volcanic explosion, but from above, as in the shock of a giant meteorite impact. It seemed to me also that in nature only the impact of a meteorite could supply the *brisance*, or shattering effect, necessary to form shatter cones.

My supposition that shatter cones must be the product of such intense shock rested largely on intuition and faith. To some observers the cones appeared to be merely "slickensides"—striated fragments produced when rock shears along faults. But the striations in slickensides are always parallel, whereas in shatter cones they flare out in radiating bundles from the apex of the cone. Others supposed that these shatter cones were a variety of cone-in-cone, a structure commonly found in limestone. But at Kentland shatter cones are present in sandstone and shale.

Proof of the shock origin of shatter cones came first from experiments with shaped charges. This technique for focusing the energy liberated by a given weight of explosive produces intense shock waves when used with ex-

HOLLEFORD CRATER, a slight depression a mile and a half in diameter in Ontario farmland, is a fossil crater, eroded and filled with sediments. A meteorite impact created it some 500 million years ago. It was also discovered in an aerial photograph.

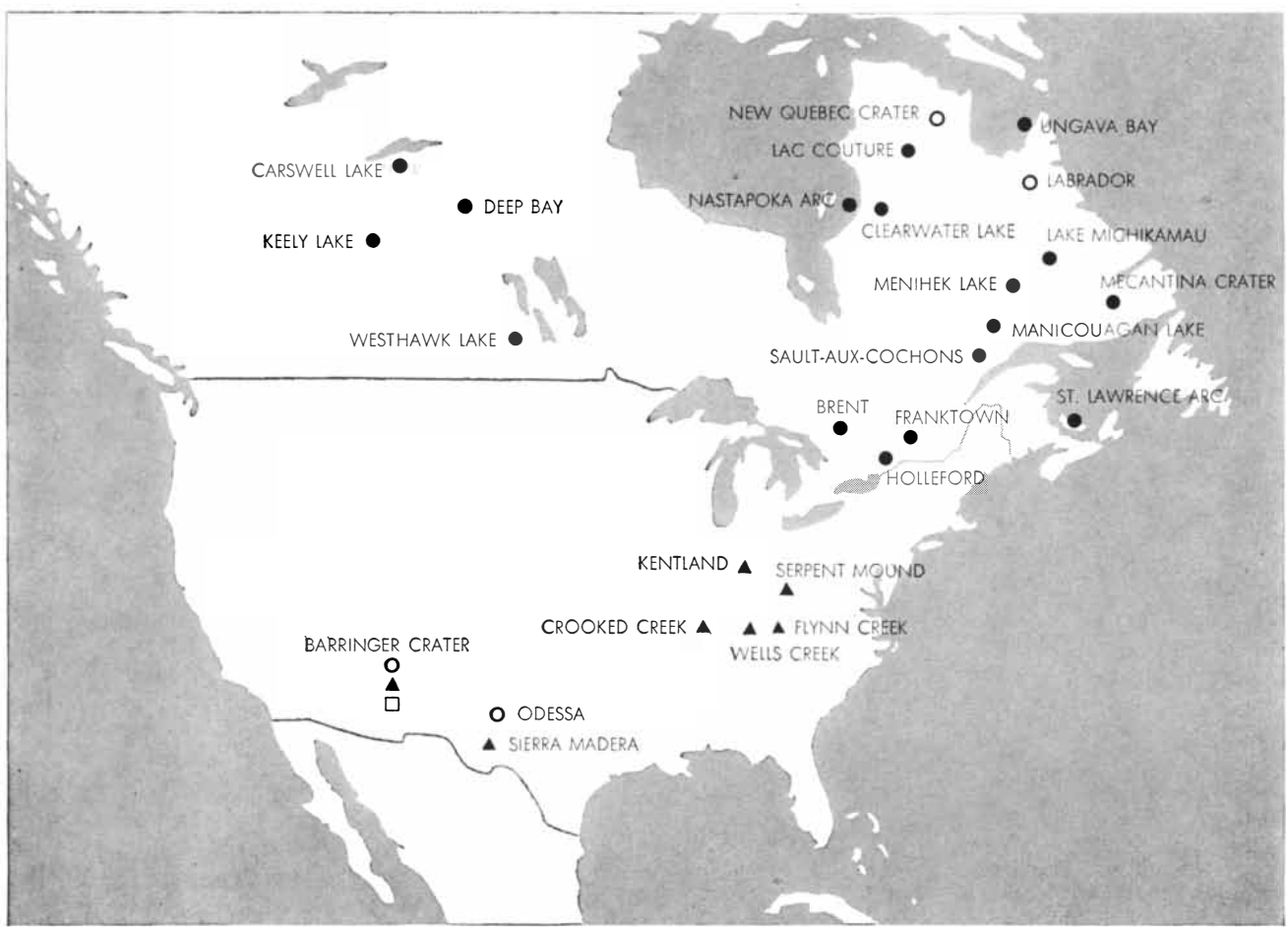
plosives that have great shattering power. In limestone shaped charges produced shatter cones closely similar to those found in nature. A heaving explosive, such as TNT, sometimes produces a rude sort of cone but one without striations. In 1960 Donald Gault and Eugene Shoemaker of the U.S. Geological Survey achieved an even closer simulation of a meteorite collision with the earth. They fired small pellets from a gas gun at the ultrahigh speed of 18,000 feet per second into limestone and produced minute but perfect shatter cones.

A search of the literature showed that shatter cones had been discovered in several other interesting structures. In 1933 Walter Bucher of Columbia University had reported finding them in the center of the Wells Creek Basin in Tennessee, a site similar to the Steinheim Basin. Herbert E. Hendriks of Cornell College in Iowa had described shatter cones from the middle of the Crooked Creek structure in Missouri; in dissent from the standard volcanic explanation for this site, he put it among those caused by meteorite impacts. Particularly interesting was the report of shatter cones from the great Ashanti Crater, a structure young enough to have been identified on other grounds as a true meteorite crater.

In Texas, not far from the MacDonald Observatory of the University of Texas, there is a chaotic circular structure known as the Sierra Madera that has attracted the interest of geologists for many years. On the strength of its resemblance to oil-bearing domed structures, prospectors have drilled two deep test wells there. In 1936 J. D. Boon and Claude C. Albritton of Southern Methodist University listed the Sierra Madera as a possible impact structure, involving rocks about 250 million years old. Two years ago, on a visit to the MacDonald Observatory, I seized the opportunity to visit the site and was rewarded with the discovery of shatter cones in the dolomite and limestone near the bull's-eye of the structure. The cones had previously gone unnoticed in spite of the active interest in the site; it seems that even exposed shatter cones are not observed unless one is searching for them.

With this new stimulus I began to seek shatter cones at other places in the U.S. thought to be the sites of natural explosions. I soon found them at the Serpent Mound structure in southern Ohio and also at the Flynn Creek structure in eastern Tennessee, which C. W. Wilson, Jr., of Vanderbilt University had long believed to be an impact site. Apparently these two structures may now be regarded as astroblemes along with the Sierra Madera.

The most obvious place to look for the cones, of course, is Barringer Crater. Attempts to find them there were at first unsuccessful. This negative finding was discouraging but not conclusive. A shock wave attenuates with the sixth power of the distance from the impact point. Except in the most gigantic meteorite craters one must expect that most of the cones will be concentrated at the center and may be buried deep under the floor where only careful drilling can expose them. Nonetheless, E. C. T. Chao of the



METEORITE IMPACT SITES in North America, including craters, fossil craters and probable astroblemes, are widely scattered. The Quaternary craters were made during the past million years. The other sites are much older and the craters have disappeared.

U.S. Geological Survey recently discovered a small shatter-coned fragment of sandstone in the fallout debris on the south slope of Barringer Crater.

Shatter cones provide the conclusive evidence for the identification of the most spectacular of all astroblemes, the peerless Vredefort Ring in the Transvaal of South Africa. Practically nothing of the original crater remains, but geological study has revealed a worn-down "dome" of granite 26 miles in diameter surrounded by an upturned and even partially overturned collar of Pre-Cambrian rock (the Pre-Cambrian era ended some 600 million years ago). A great ring syncline (the trough of a fold in the rocks) surrounds the collar, making the entire deformation 130 miles in diameter. Geologists have traditionally attributed this huge structure to a long sequence of tectonic events. A few months ago I asked Robert Hargraves of the University of the Witwatersrand to search for shatter cones. He found them in abundance and showed also that if the rocks were returned to their original positions, the cones would all point inward toward the center of the ring.

Upon reconstruction, the event that produced this structure emerges beyond doubt as the greatest terrestrial explosion of which there is any clear geological record. Apparently an asteroid a mile or so in diameter plunged into the earth from the southwest, for the structure is overturned somewhat to the northeast. The huge object drilled into the earth and released enormous shock forces, causing a gigantic upheaval. Strata nine miles thick peeled back like a flower spreading its petals to the sun, opening a crater 30 miles in diameter and 10 miles deep. The shock must have reached with shattering force down through the entire 30-mile thickness of the earth's crust. Shock pressures of many millions of atmospheres spread through the collar, forming scattered pockets of pseudotachylite (fused rock) like raisins in raisin bread. Rock that had lined the cavity was melted and injected into the rock walls as great dikes of fused rock (of a type called enstatitic granophyre) 100 feet across and several miles long. Except for these rocks, which remained molten until the shock had passed, the collar rocks are intensely and wonderfully shattered, and it is in these that the shatter cones abound.

This grand-scale event took place at least 250 million years ago, because sediments laid down since then cover part of the astrobleme. Its energy must have been comparable to that of the im-

EUROPEAN AND AFRICAN SITES include Steinheim Basin, where shatter cones were first found; the Ries Kessel, where coesite has been found; and the Ashanti Crater in Ghana.

AUSTRALIAN SITES are all craters less than a million years old. They are located in the arid regions of the continent, where the processes of erosion and sedimentation are very slow.

pacts that produced the magnificent rayed craters Tycho and Copernicus on the moon. The Vredefort blast was a million times larger than the 1883 Krakatoa volcanic explosion in the East Indies and probably several thousand times larger than the greatest possible earthquake. In the terminology of nuclear explosions it was at least a 1.5-million-megaton event (one megaton is equivalent to the force exerted by the explosion of a million tons of TNT). By comparison the meteorite impact that produced Barringer Crater was a mere five-megaton explosion.

Although the Vredefort impact would seem to have been large enough to have generated secondary volcanic phenomena, the rocks hold no record of such a reaction. The disturbance did, however, bring into play the longer-term forces of isostasy, which make for equilibrium in the crust of the earth. Isostatic processes pushed the bottom of the crater up into its maw so that the collar now surrounds a thrust-up plug of early Pre-Cambrian granite. The eroded structure of today is neither a crater nor a fossil crater. The term "astrobleme" best describes it. The Vredefort Ring shows that tectonics, isostasy, erosion and sedimentation all conspire to give meteorite impact sites on the earth an appearance quite different from those on the moon.

Coesite, the second shock-wave product that may serve to identify an astrobleme, has been sought and found so far at only five sites. Unlike the shatter cone, which was known in nature for decades before it was duplicated in the laboratory, the first known coesite came out of the laboratory in 1953. The mineral is named for Loring Coes, Jr., of the Norton Company in Worcester, Mass., who made it in an apparatus that produces pressures exceeding 20,000 atmospheres. Such pressures occur within the earth only at depths greater than 40 miles. Just as diamond and graphite are forms of pure carbon, so coesite and quartz are different forms of silica. There are many other silicas such as opal, chalcedony, geyserite, tridymite, cristobalite, lechatelierite and diatomaceous earth. Coesite is the superdense and high-pressure form of silica and may be defined as the "diamond" of the family.

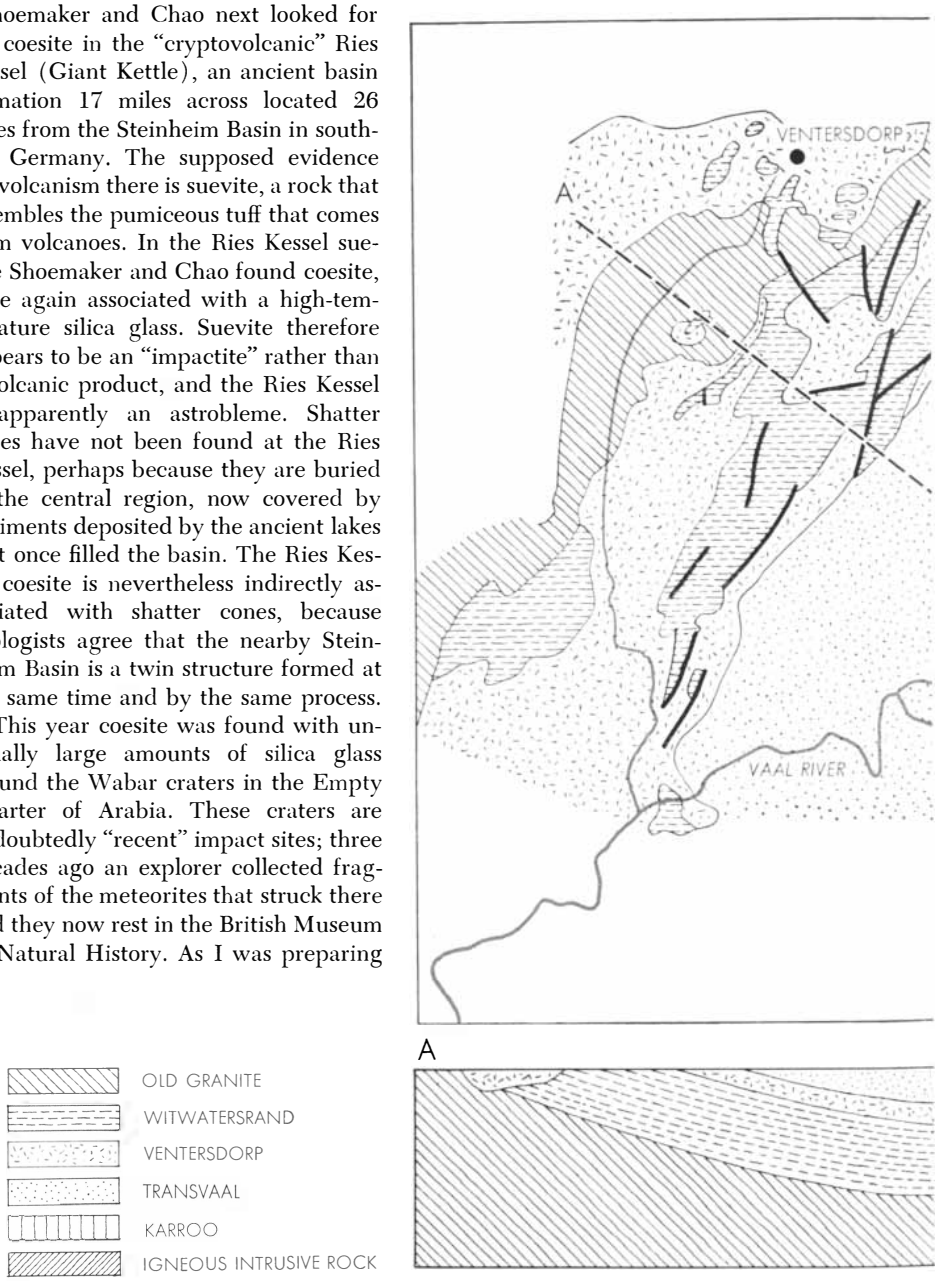
Soon after its creation in the laboratory, coesite was sought in nature. Because diamonds are created by pressures deep within the earth and carried to the surface in "explosion pipes," investigators reasoned that the diamond pipes might also carry coesite. The South African diamond pipes, however, yielded none. Some condition for its formation may not have been fulfilled. Perhaps silica was absent; at best the diamond fields are quite poor in the mineral.

It happens that minute diamonds of the carbonado type have long been known to be present in the highly shocked meteoritic fragments from Barringer Crater. This circumstance prompted Shoemaker, Chao and B. M. Madsen of the U.S. Geological Survey to search the highly sheared and fused sandstone at Barringer Crater for coesite. Last year they found minute crystals of it in intimate association with lechatelierite, or silica glass.

Shoemaker and Chao next looked for coesite in the "cryptovolcanic" Ries Kessel (Giant Kettle), an ancient basin formation 17 miles across located 26 miles from the Steinheim Basin in southern Germany. The supposed evidence for volcanism there is suevite, a rock that resembles the pumiceous tuff that comes from volcanoes. In the Ries Kessel suevite Shoemaker and Chao found coesite, once again associated with a high-temperature silica glass. Suevite therefore appears to be an "impactite" rather than a volcanic product, and the Ries Kessel is apparently an astrobleme. Shatter cones have not been found at the Ries Kessel, perhaps because they are buried in the central region, now covered by sediments deposited by the ancient lakes that once filled the basin. The Ries Kessel coesite is nevertheless indirectly associated with shatter cones, because geologists agree that the nearby Steinheim Basin is a twin structure formed at the same time and by the same process.

This year coesite was found with unusually large amounts of silica glass around the Wabar craters in the Empty Quarter of Arabia. These craters are undoubtedly "recent" impact sites; three decades ago an explorer collected fragments of the meteorites that struck there and they now rest in the British Museum of Natural History. As I was preparing this article, coesite was found in suevite-like rock at the Ashanti Crater. Still another coesite locality is the Teapot Ess Crater at the Nevada Proving Grounds of the Atomic Energy Commission, where the mineral was created by an atomic blast. The quick discovery of this mineral at these five sites is encouraging, particularly because the suspected sample must be transported from the field to the laboratory for examination by X-ray diffraction.

The search for coesite and shatter cones is now to be extended to other

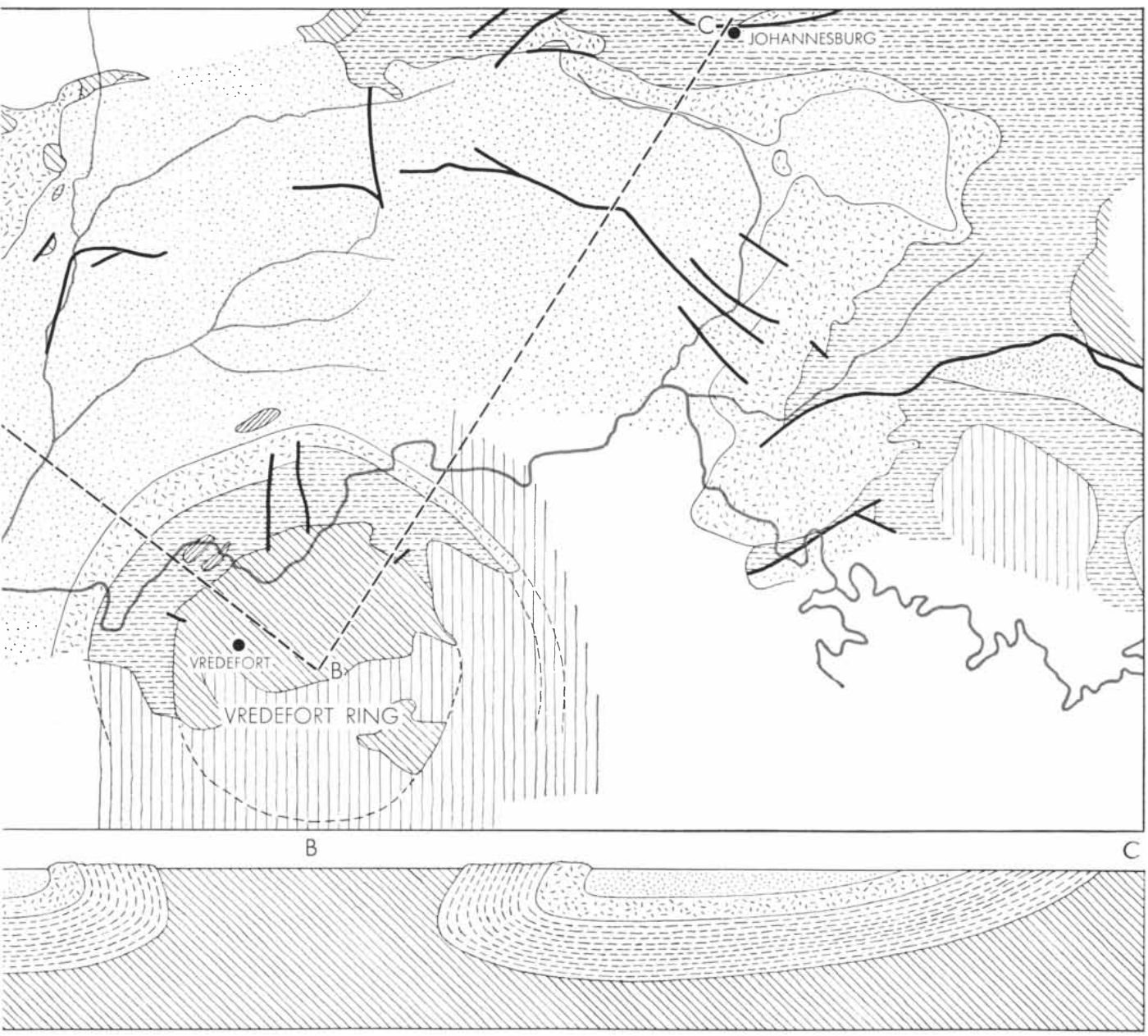


VREDEFORT RING in South Africa is depicted from above (*top*) and in cross section taken along broken line ABC. The diagrams cover an area 140 miles across. In the center of the ring is a plug of granite, partly covered by Karroo sediments laid down after the meteor-

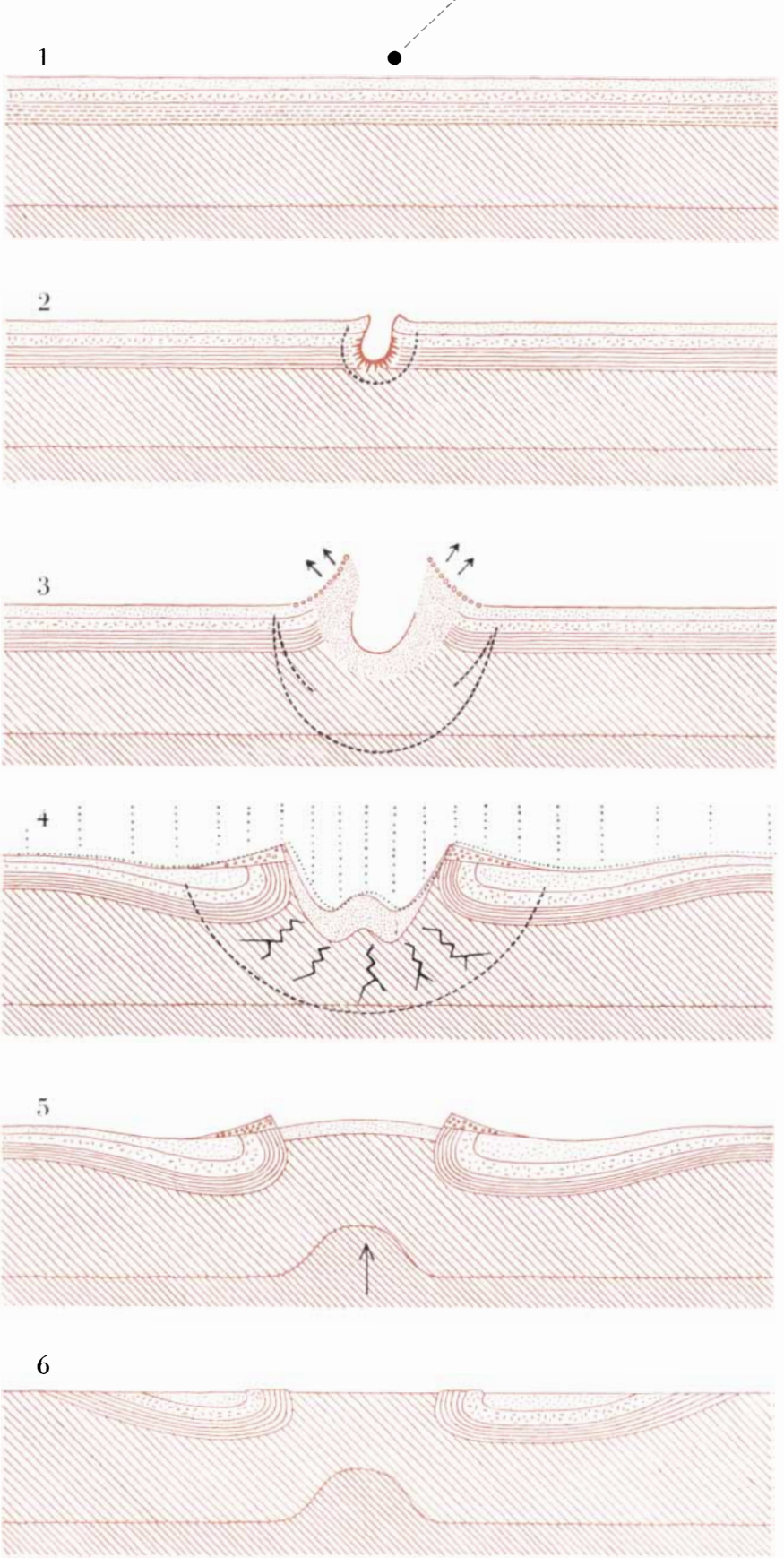
putative astroblemes, including the fossil craters of Canada. Meanwhile, as geologists become familiar with the shatter cones, they will be able to recognize astroblemes even in sites deformed by later tectonic upheavals. If the location of the center of the impact is obscured at these sites, it may be difficult to find the shatter cones. But where the bull's-eye can be identified the shatter cones can be brought up in drill cores, as they have been at the Kentland and Wells Creek sites.

The creation of coesite and of minute diamonds by meteorite impact opens up the new field of "impact metamorphism." Meteorite impacts are natural "experiments" in ultrahigh pressures on a scale that can never be equaled in the laboratory. Doubtless geologists will soon unearth other pressure minerals through the study of astroblemes.

One puzzling mineral that is evidently the product of impact metamorphism is the tektite. Small masses of silica glass containing metallic oxides, tektites are strewed widely over several regions of the world and are known from rock strata as old as 40 million years. Chao has recently found minute nickel-iron meteorite spherules embedded in some tektites, proving that tektites are not the result of lightning, volcanism or other purely terrestrial events. Some investigators argue that they may have been splashed upward from meteorite impacts on the earth and are scattered at long distances from ground zero. I am among those who find evidence, in the molding and shaping of their surfaces, for the idea that tektites were ejected earthward from the moon's surface by meteorite



ite impact. It is surrounded by a collar of upturned and overturned rock strata. Around them lies a great ring syncline, much of it under the Transvaal stratum. At its outer edges, strata of the collar appear again. Heavy black lines are faults. Blank areas are regions for which data were not available. Tectonic processes, sedimentation and erosion have destroyed the original gigantic crater.



FORMATION OF VREDEFORT RING is shown in this sequence. An asteroid a mile in diameter (*1*) strikes the earth (*2*), liquefies and turns partly to gas. Shock wave (***broken lines***) spreads out. At maximum crater development (*3*) the meteorite is a thin lining of the crater; debris flies off, rock strata peel back and shock wave spreads further, to be reflected back. Soon rocks recoil (*4*) to form a dome in the crater. Fallout settles slowly. Later viscous rock of earth's mantle pushes solid granite up into maw to form a plug (*5*). The ring structure today (*6*) has been badly eroded but roots of ring remain as hills.

falls and that they were shaped into their droplike form in their fiery passage through the earth's atmosphere.

During the 20th century two great impact events have occurred, both in Siberia. One, at Tunguska, was probably the fall of a comet head. The other, at Sikhote-Alin in 1947, was the fall of a very large meteorite that disintegrated in mid-air, leaving more than 100 craters on the ground. The two events show that bombardment from space continues even today.

Like the Siberian events, all known meteorite impacts have occurred on land. But with the largest part of the earth's surface covered by water, it is inevitable that the majority of meteorites must have fallen into the sea. Delving into historical records, N. H. Heck of the U.S. Coast and Geodetic Survey has compiled a list of 270 tsunamis (so-called tidal waves) since 479 B.C. Earthquakes doubtlessly generated most of them, but a few could certainly have resulted from meteorites. The effects of a really large impact, like those that leave astroblemes, are terrifying to contemplate. A giant meteorite falling into the middle of the Atlantic Ocean could generate a wave 20,000 feet high that would overwhelm vast areas of the continents surrounding the ocean, sweeping over the entire eastern seaboard of the U.S. and across the Appalachians.

From modern theory on the origin of the solar system and study of the lunar craters, it seems that the major meteorite bombardment of the moon—and so of the earth—must have taken place three billion years or more ago, during the first half of the life span of the earth-moon system. Radioactive dating gives the oldest rocks of the continents an age of about three billion years. The tectonic and meteorological processes that molded the present surfaces of the earth must therefore have obliterated the scars of the early period, still so much in evidence on the moon. But the earth should retain a geological record of cosmic damage comparable to that indicated by the youngest of the lunar craters. These craters have associated ray systems—lanes of debris radiating from the center of impact. (The ray systems of older craters were presumably erased by "weathering" due to radiation and by later meteorite falls.) The near side of the moon displays about 130 of these in an area roughly equivalent to that of North America. So it seems reasonable to expect geologists someday to find something like that many astroblemes dotted across the continent.

Kodak reports on:

a movie processor that keeps pace with the projector... anthracene: decent, pure, purest, hyper-pure... a robot for speechmakers

A familiar force

Here is a picture of the basic amplifier used in photography.

This amplifier can provide a gain of 10^9. There is a genie in the bottle. Familiarity with him breeds not contempt but admiration. We know him very well.

Once upon a time, as when working out for the merit badge in photography, it was customary to summon the genie by retiring to a little darkroom and pouring him out of his bottle into a white enameled tray. No longer does he demand such ceremonious treatment.

Our wet friend is now content to work unseen inside a handsome gray box like this, responding to pushbuttons. His very fluidity has been replaced by a kind of viscosity which need little concern the client, who merely inserts a probe into a disposable cartridge. When the work is done, the genie uses his private exit to the sewer.

This newly announced *Eastman Viscomat Processor* does 36 feet of 16mm film per minute. Not entirely by coincidence, this happens to be the rate at which film runs through a projector. The film spends about one minute in the processor. It emerges processed to standard commercial quality, ready to project. It can be stopped for seconds or daysand restarted without loss of quality. Were we not so touchy about processing quality, the gadget would have been on the market long before this. But since we are also film-makers by trade and want to keep our faith in photography, we refuse to be party to sloppiness in film-handling.

For a pamphlet about the Eastman Viscomat Processor, write Eastman Kodak Company, Motion Picture Film Department, Rochester 4, N. Y. A new booklet about where it comes from may prove even more worthwhile. This one is broad in scope, as hinted by the title, "Kodak, a Force in Being." It undertakes an inventory of the capabilities we have exhibited for creative collaboration with other organizations, not only in photography but also in optics, mechanisms, electronics, and infrared. We hope it will strike you as a sober self-appraisal—prejudiced perhaps, but realistic. Request a copy from Eastman Kodak Company, Government Contracts Department, Rochester 4, N. Y.

Infiltrated by solid-staters

An oldtimer from the coal pits has been cleaned up with a vengeance, to the accompaniment of long thoughts about "purity" in organic chemistry. (The word is becoming almost useless as a good, all-purpose shibboleth.) You can now buy *Anthracene* as Eastman H480 for $1200 per kilogram.

The prefix "H" stands for hyper-pure. Replace the "H" by "P" for Practical, and the price drops to $6.70 per kg. Leave off prefixes and you get the Eastman Grade at $10.85 for 100g. This is defined as "essentially free from isomers, homologs, and impurities." That "essentially" leaves a little essential room for maneuver. If say 99% of the organic molecules in a bottle are of identical species, most organic chemists would consent to labeling it essentially pure.

But now there has sprung up a breed of organic chemists who work in solid-state physics. To them a substance that is only 99% pure is like a pail of garbage. Some of them are even to be found in the Kodak Research Laboratories, which is (or are) where Eastman Organic Chemicals are made. At their behest was Eastman H480 made.

For the solid-staters it was only the beginning. They recrystallized it from toluene, got rid of the toluene by a special technique, and zone-refined a dozen times or so. Then by Bridgeman technique in a two-zone furnace they made a large single crystal of the hyper-hyper-pure anthracene. They sandwiched little slices of the crystal between transparent electrodes, applied voltage, and illuminated with an air spark of microsecond duration and very high intensity. They compared current vs. time oscillograms for illumination of the positive side with those for illumination of the negative side. The curves told how long an electron or a hole could drift in the crystal lattice between being set loose by the flash and being trapped by an irregularity or impurity in the lattice. Both electrons and holes showed lifetimes of about 200 microseconds. It is very unusual to have long-lived electrons and holes in the same organic photoconductor. Not only is this very interesting, but long lifetimes permit accurate measurements of the mobility of electrons and holes.

What is happening to organic chemistry?

Whatever is happening, we are continuing the sale of some 3900 Eastman Organic Chemicals from Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company). Write for a copy of List No. 42.

Multiply thyself

Should the thrill wear thin of skittering here and there over the map to show slides and speak your spiel, send out a box of slides, a *Kodak Cavalcade Projector*, a decent tape recorder, and a *Kodak Cavalcade Programmer* that ties them together in a presentation so alive that your own living presence will scarcely be missed. The time saved could be devoted to new efforts—raw material for slides yet unborn. In return for forgoing the pleasure of your company as entertainer, society gets more out of you as investigator.

The Kodak Cavalcade Programmer is used by a speaker to pre-package his presentation in solitude so as to maximize its cogency and minimize dependence on others for accuracy and effectiveness. The microphone from the tape recorder is plugged into the programmer instead of the recorder itself. The magazine of the Cavalcade Projector is loaded with the slides. The speaker starts his speech. At the instant when he wants the first slide to come on, he presses the button. This records a 6.5-kc beep on the tape. Now he is seeing exactly what the audience will be seeing at this point in the discourse. Pertinent points about it may well occur to him that might not occur when speaking with his back to the picture and his gaze fixed on some vindictive-looking character in the fourth row. When he wants the next slide he presses the button again; without further human intercession the beep will change the slide at that instant every time. And so on for the allotted time. The "erase" feature of tape, a benign presence denied to those who speak in the flesh, is always comfortingly there during the recording session.

Write for the name of a nearby dealer to: Eastman Kodak Company, Apparatus and Optical Division, Rochester 4, N. Y.

Prices subject to change without notice.

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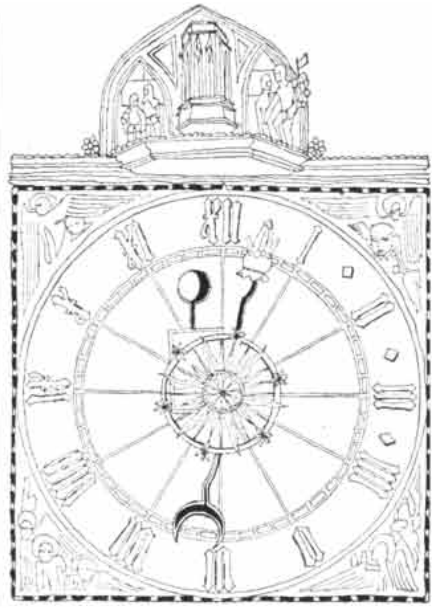
SCIENCE AND



N-bomb?

With negotiations on a nuclear-test ban stalled in Geneva, it was suggested in a number of quarters last month that the U.S. resume nuclear-weapons testing. Representative Chet Holifield of California, long a member of the Joint Congressional Committee on Atomic Energy, said the U.S. "should relieve itself" of the voluntary moratorium and start tests as soon as possible. Among the results that might be achieved he mentioned lighter warheads for missiles, better small-yield weapons and improved safety features. In addition, he declared, "concepts are now being considered by our scientists which could be as revolutionary as the H-bomb in 1949.

Holifield did not identify the concepts, but there was speculation in the press that a major one is the "neutron bomb," said to have been the "clean bomb" originally proposed by Edward Teller and his associates at the University of California Radiation Laboratory. In a recent speech Senator Thomas J. Dodd of Connecticut described the bomb as follows: "The neutron bomb could be produced by tailoring the energy of a fusion explosion so that instead of heat and blast, its primary product would be a burst of neutrons. Such a burst would operate as a kind of death ray. It would do next to no physical damage, it would result in no contamination, but it would immediately destroy all life in the target area. This, of course, would make it an ideal battlefield weapon. It would, in fact, make it a far more effective battlefield weapon than any now in existence." As for the possibility of making such a device, Dodd remarked: "Today I doubt there is a single nuclear physicist of repute who would challenge the neutron bomb from the standpoint of scientific feasibility."

According to *The New York Times*, information "pieced together" from hints "dropped over the last four years" indicates that the neutron bomb would be essentially a small hydrogen bomb in which the fusion reaction is somehow set off without a fission explosion. The fusion process releases neutrons with an energy of about 14 million electron volts. These fast neutrons have a small probability of being absorbed by atomic nuclei; hence they have high penetrating power and induce correspondingly little radioactivity in the materials, per unit of depth, through which they pass. They do, however, produce a number of high-speed secondary particles, particularly protons, by colliding with atomic nuclei. The secondary particles are responsible for the lethal effect of the neutron beam.

"There are still several unanswered technical questions about how the bomb would be built," said the *Times*. "Probably the most important is how the scientists plan to achieve the temperatures . . . necessary to ignite the thermonuclear reaction without the fission trigger." Some physicists of repute also have raised questions: whether a fissionless trigger, which so far has eluded the substantial research program in thermonuclear power, can be developed in weapons testing; whether the fusion reaction can be "tailored" to increase the output of neutrons relative to heat; whether radioactivity induced by neutrons, although much less than that from a fission bomb, would not still constitute substantial contamination; and whether resumption of testing will not help the U.S.S.R. more than the U.S.

Powerful Projects

Two long-debated, hundred-million-dollar projects, give or take a few million, recently got a go-ahead from the Joint Congressional Committee on Atomic Energy. One is a two-mile-long linear electron accelerator at Stanford University; the other, the conversion of the new nuclear reactor at Hanford, Wash., to produce useful power as well as plutonium.

THE CITIZEN

The Stanford machine, first proposed in 1957, is to consist of an evacuated underground pipe two miles long, through which 240 klystron tubes will accelerate electrons to an energy of 22 billion electron volts (Bev). By later quadrupling the number of klystrons, the designers expect to reach 45 Bev. A linear accelerator appears to be the only type that can produce electron energies comparable to the 25 to 30 Bev developed by today's largest proton machines, the synchrotrons at the Brookhaven National Laboratory and at the European Organization for Nuclear Research (C.E.R.N.) in Geneva. Electrons pushed above 10 Bev in a circular track lose excessive amounts of energy by radiation.

Congress put up $3 million last year for preliminary development work. The accelerator is expected to cost $114 million in all and to require six years to build.

The Hanford project has been before Congress since 1958. In that year $120 million was appropriated to build a plutonium-producing reactor and—against the Eisenhower Administration's wishes—$25 million was added to make possible future conversion of the reactor to produce electricity for the Bonneville Power Administration as well. The economic feasibility of such power production, complicated by the issue of public-versus-private power, was debated and studied for several years. Following the completion of surveys by the Federal Power Commission and the Atomic Energy Commission this year, the Administration requested, and the Joint Committee has now recommended, the spending of $95 million to install the generating facilities. The reactor proper is scheduled for completion in 1962 and the power equipment in 1964.

In Lieu of Ability

The National Science Foundation has revoked a fellowship granted to a graduate student at the University of Illinois who had been convicted of contempt of Congress. In February, 1958, Edward L. Yellin invoked the First Amendment to the U.S. Constitution in support of his refusal to answer questions put to him by the House Committee on Un-American Activities. His conviction in March, 1960, has been upheld by the

Circuit Court of Appeals, and his plea for a review by the U.S. Supreme Court is pending before that court.

According to Alan T. Waterman, director of the National Science Foundation, the staff of the foundation had no knowledge of Yellin's difficulties when the fellowship was awarded in March of this year. In response to inquiries by the House Committee, Waterman first declared that the fellowship had been awarded to Yellin "solely on the basis of ability" in accord with the foundation's statutory charter. Then, in an appearance before the House Committee on Science and Astronautics in June, Waterman testified that Yellin's papers had been turned over to the Department of Justice for a determination of whether Yellin had sworn falsely to the affidavit of loyalty and allegiance appended to his application. A week later Waterman advised Yellin by telegraph that, "after a full review of all the facts . . . including the possibility that you may not be able to pursue your studies without interruption during the fellowship tenure," his fellowship had been revoked.

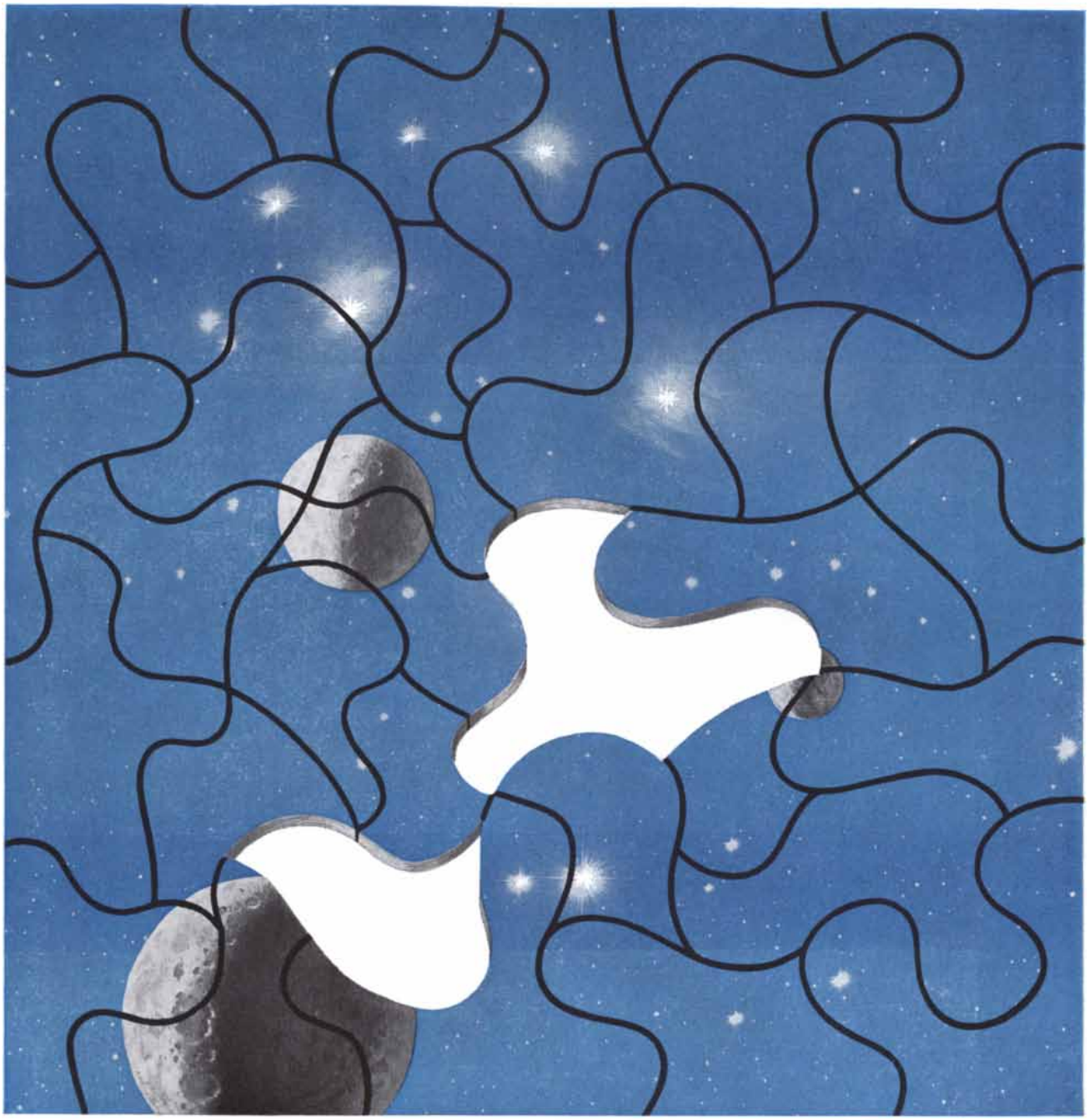
Congressman Overton Brooks of Louisiana, chairman of the Committee on Science and Astronautics, thereupon introduced a bill to amend the National Science Foundation Act "striking out 'solely on the basis of ability'... and inserting in lieu thereof 'on the basis of character, ability, and loyalty' " and requiring a fellowship applicant in the future to swear under oath "whether he has ever been a member of, or supported, any organization cited by the Attorney General as subversive" and whether he has ever been arrested, charged or held for any crime "other than minor traffic violations."

Fermi Award

The Atomic Energy Commission has named Hans A. Bethe as the winner of the Enrico Fermi Award for 1961. The award, consisting of a medal, a citation and a cash prize of $50,000, will be presented in December in recognition of Bethe's "contributions to nuclear and theoretical physics, to peaceful uses of atomic energy and to the security of the U.S." Bethe is professor of physics at Cornell University.

Genetic Stampings

A crucial piece has fallen into place in the jigsaw puzzle of genetics. Biochemists at New York University, St. Louis University and the University of



SOLVING PUZZLES IN SPACE

Man will soon step into space. But he must know more about radiation belts, the solar system, and other phenomena before he can travel to these alien worlds.

There are several solutions to this celestial jigsaw puzzle. Explorer satellites. Telescopes. Radar astronomy, where microwave energy is bounced against objects in space, to reveal their nature.

Varian klystrons make important contributions to radar astronomy. Two VA-842 tubes will power the world's largest radar telescope, in Puerto Rico. And a VA-800C klystron drives a JPL* transmitter at Goldstone, Calif., seeking out the secrets of Venus. To know more of Varian's power klystron capability, write Tube Division.

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*Jet Propulsion Laboratory, a NASA research and development facility operated by the California Institute of Technology.

Chicago have shown that deoxyribonucleic acid (DNA), the genetic material, can control the synthesis of a complementary molecule of ribonucleic acid (RNA) in the test tube.

The picture of genetic action that has been emerging over the past few years shows the master plan for the building of cell proteins stored in the nucleus in DNA. Proteins are manufactured outside the nucleus, in bodies called ribosomes, on templates of RNA. Recently evidence has been accumulating that manufacturing instructions are carried from genes to ribosomes by a "messenger" RNA stamped out by the DNA itself [see "Science and the Citizen," July]. Now Jerard Hurwitz at N.Y.U., Audrey Stevens at St. Louis and Samuel Weiss at Chicago have isolated the process outside the cell.

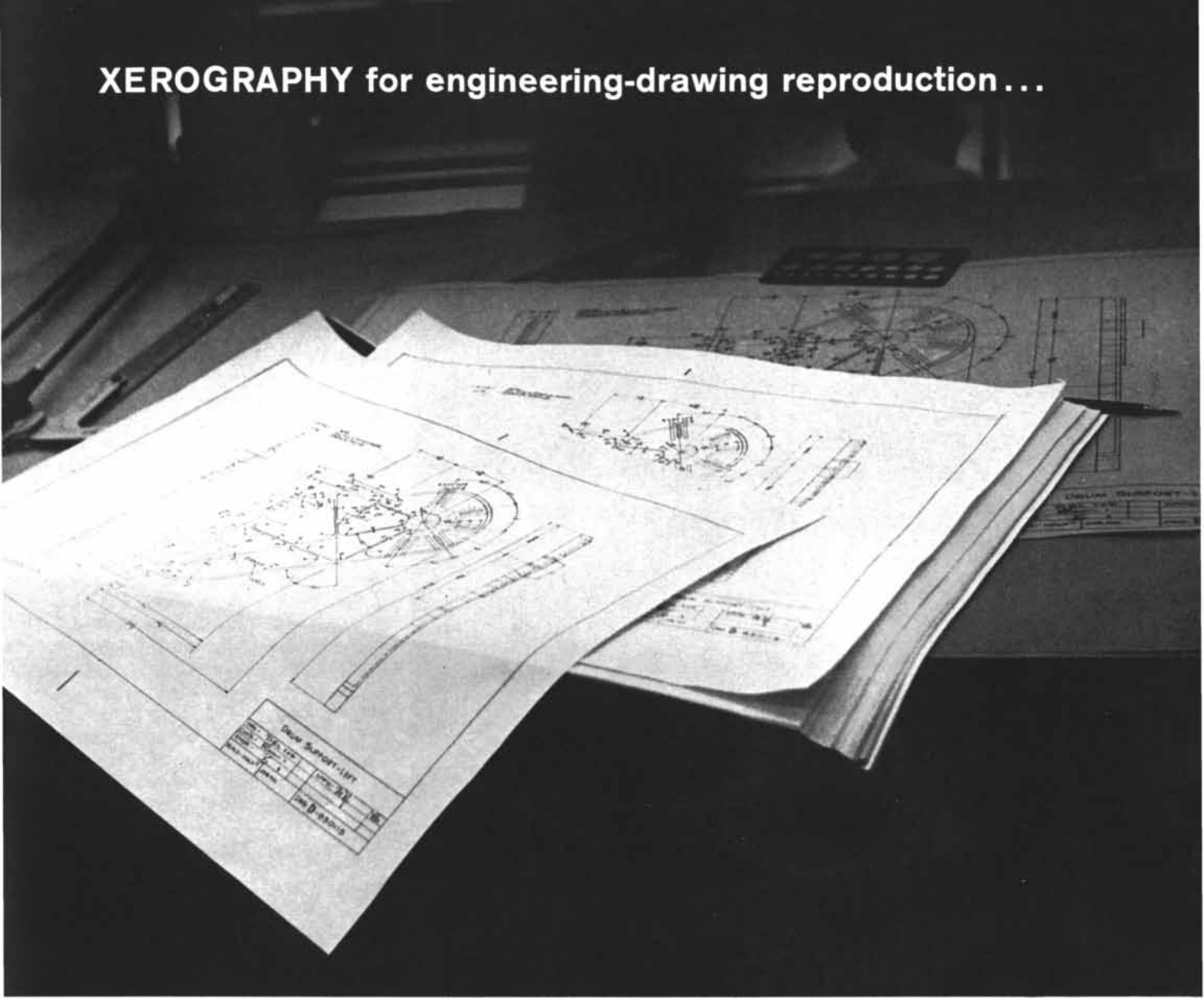
The workers have extracted from bacteria an enzyme that assembles the long, chainlike molecules of RNA out of the "bases" that make up the links, but only when DNA is added to the preparation. The process seems to bear out the famous model of DNA proposed by J. D. Watson and F. H. C. Crick, which calls for a specific relation between the bases in a DNA strand and those in the complementary RNA strand it assembles. In the test-tube synthesis the same enzyme makes different types of RNA if different types of DNA are added, and the RNA corresponds to the DNA. That is, the two molecules are composed of equivalent bases. Moreover, a DNA-like polymer containing only two of the usual four bases usually present in DNA (adenine and thymine) leads to a two-base RNA, made of adenine and uracil, again in agreement with the prediction of the model.

Hurwitz and Miss Stevens have reported their experiments in *Biochemical and Biophysical Research Communications*. Weiss described his in the *Proceedings of the National Academy of Sciences*.

Dust Catcher

The first careful inspection of the outer edge of the earth's atmosphere indicates that it is much dustier than had been supposed. The inspection was carried out in June with an Aerobee-Hi rocket, fired from White Sands, N.M., and equipped with eight leaves that opened and closed like the petals on the Venus's-flytrap plant.

At an altitude of 47 miles the leaves opened, exposing some plastic films and electron microscope slides. Micrometeorites that struck the films at high speed



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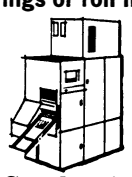
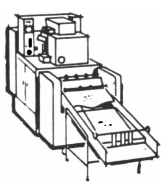
Volume reproduction from original drawings or roll microfilm: Just push a button on the Copyflo® continuous printer for sharp, dry, ready-to-use prints (on ordinary paper, vellum, or offset paper masters up to 12″ wide). Prints are made at the rate of 20 linear feet a minute. Copyflo printers reduce, enlarge, or copy size-to-size from original drawings or roll microfilm (16 or 35mm).



Reproduction from card-mounted microfilm: The Copyflo 24C continuous printer and the exciting new 1824 Printer automatically produce dry, positive prints on ordinary paper, vellum, or offset paper masters from 35mm card-mounted microfilm. The Copyflo 24C produces ready-to-use prints (up to 24″x 36″) at the rate of 20 linear feet a minute! The new low-cost 1824 Printer, for small volume users or large, decentralized users, produces prints from 8½″ x 11″ to 18″ x 24″.



Get all the Facts! Write: XEROX CORPORATION (formerly Haloid Xerox Inc.), 61-371X Haloid Street, Rochester 3, N. Y. Branch offices in principal U.S. and Canadian cities. Overseas: Rank-Xerox Ltd.

XEROX
CORPORATION

vaporized but left a record of their impact in the form of microscopic cavities in the film. The slides were designed to capture samples of micrometeorite dust—chiefly particles less than a micron (a thousandth of a millimeter) in diameter. These survived the impact because of their low kinetic energy. The leaves remained open as the rocket soared to a height of 102 miles and closed at 65 miles on the way down. The nose cone was recovered, wrapped in plastic to prevent contamination by surface dust and shipped to the Air Force Cambridge Research Laboratories at Bedford, Mass., for examination.

Preliminary study of the films and slides shows that, during the four minutes the leaves were open, they were struck by an average of 10 particles per square centimeter per second. This rate is many times greater than had been anticipated from data gathered by rockets with acoustic micrometeorite detectors. Most of the particles recorded or captured by the film and slide detectors were less than three microns in diameter, the lower limit for acoustic detectors. The largest captured particle found so far, according to Robert K. Soberman, Air Force worker in charge of the project, measures only .3 micron in diameter. How far out the dust belt may extend has yet to be determined.

Two-minded Monkeys

Monkeys that behave as though they had two separate and independent brains are opening "promising new approaches to the study of cerebral organization." So says R. W. Sperry, psychobiologist at the California Institute of Technology, in a recent article in *Science*. Sperry and his associates produce the unusual behavior by severing the nerves that connect the hemispheres of the monkeys' brains and then giving the animals special training.

The "twin brain" technique is a product of an investigation, begun by Sperry nearly 10 years ago, into the functions of the corpus callosum, a large bundle of nerve fibers joining the right and left hemispheres of the brain. From its structure and location, the callosal bundle (particularly prominent in man) was assumed to integrate the activities of the cerebral hemispheres, each of which can carry out most of the functions of the brain on its own. Strangely, however, cutting the callosal fibers, as was occasionally done in epilepsy patients, seemed to make little difference in behavior.

Working with cats and monkeys, Sperry and his students finally proved

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that the corpus callosum ties the hemispheres together, functionally as well as structurally, by cutting not only the corpus callosum but also the optic chiasm (where the optic fibers cross over) in such a way that the left hemisphere receives visual information from the left eye only and the right hemisphere only from the right. A normal animal taught through one eye to perform a task involving visual discrimination can perform it using the other eye. Treated animals retain the ability for tasks learned before surgery but not for those learned afterward. Moreover, the split-brain animal can be taught contradictory discrimination tasks with each eye.

In one series of experiments C. B. Trevarthen, a member of Sperry's group, placed the monkeys in a training box equipped with polarized light filters to make a stimulus object look different to the two eyes. Thus while the animal learned in one hemisphere that it could get a reward by pushing a lever marked with a circle but not one marked with a cross, it learned the reverse in the other hemisphere. Many split-brain monkeys were taught the two tasks during the same training period by switching back and forth between the two eyes. They learned both tasks as quickly as an ordinary monkey learns just one.

The behavior of divided-brain monkeys is otherwise quite normal. They encounter no special difficulties because of having two "masters," partly because both halves of the brain receive much the same visual and auditory stimulation when the animal is outside the training box. When the animal is made to choose between two tasks—one learned by the right hemisphere and the other by the left—there is only slight hesitancy over which to do. First one hemisphere takes command and does what it learned; then the other gets a turn.

Big Blast, Little Bang

A conical shock tube in which five pounds of explosive can duplicate the blast waves generated by a 75-ton charge of TNT fired in the open has been developed at the Naval Ordnance Laboratory. William S. Filler designed it as the preliminary model of a tube that will duplicate the blast effects of nuclear explosions.

The device is a massive steel tube 180 feet long with an inside diameter of six inches at the smaller end and 30 inches at the larger. The charge is fired at the small end in a firing block fashioned from a retired six-inch naval gun. The large end of the tube is closed by a

See the "Atomic Energy in Action" Exhibit at the new Union Carbide Building in New York

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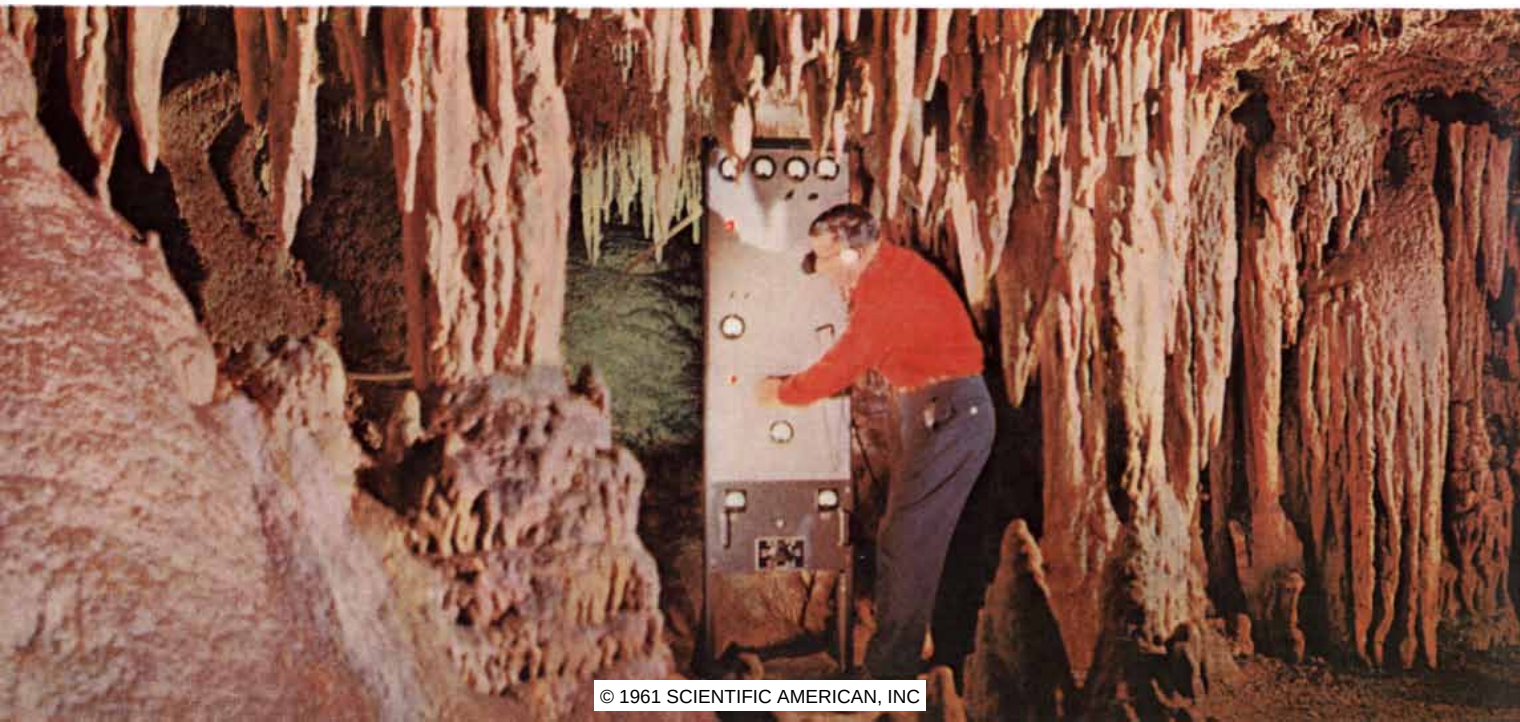


heavy metal cap. The arrangement multiplies the pressure of the blast wave some 25,000 times by confining the entire force of the explosion to the small segment of a sphere represented by the inside of the tube. Capping the tube makes the device practically noiseless.

The shock tube was developed to provide the Navy with a means of studying nuclear-blast effects on ship structures while the nuclear-test ban is in force. It promises to be simpler, cheaper and, because no radiation is generated by the test explosions, safer than conventional nuclear testing. The full-sized tube, for simulating nuclear explosions, would be 2,000 feet long. A 1,000-pound charge, Filler calculates, should simulate a nuclear explosion equivalent to the blast from thousands of tons of TNT.

New Moons?

A Polish astronomer has discovered two cloudlike objects that appear to be natural satellites of the earth. They lie in the same orbit as the moon and just at a point where an 18th-century mathematical analysis predicted they might be found. K. Kordylewski of the Cracow Observatory located the satellites near the so-called L_5 point, named for the French mathematician and astronomer Joseph Louis Lagrange.

In 1772 Lagrange calculated that there are five points of gravitational equilibrium around a pair of massive bodies. Three of these correspond to crests of a hill and represent an unstable equilibrium. Two, L_4 and L_5, are gravitational pits; a small body in either position tends to stay there. In the case where one of the massive bodies revolves around the other, L_4 and L_5 lie on the orbit, respectively 60 degrees ahead of and behind the revolving body.

In 1904 a small mass was found oscillating around the L_4 point of the sun-Jupiter system. It was one of the Trojan asteroids, of which 11 others have since been identified, some at L_4 and others at the L_5 point behind Jupiter.

Kordylewski decided to look for similar objects in the earth-moon system. After several years of searching he photographed, last March and April, two faint clouds circling the earth at the L_5 point behind the moon. He announced his discovery in a circular of the International Astronomical Union. The satellites appear to be collections of meteoritic material. Kordylewski suggests that similar satellites may be found at the L_4 point ahead of the moon, which will next be in position for observation from the earth beginning in September.

The Reproduction of Sound

In the design of systems to record and replay complex sounds the acoustical engineer seeks not to re-create sounds exactly but to satisfy the peculiar requirements of the ear and brain

by Edward E. David, Jr.

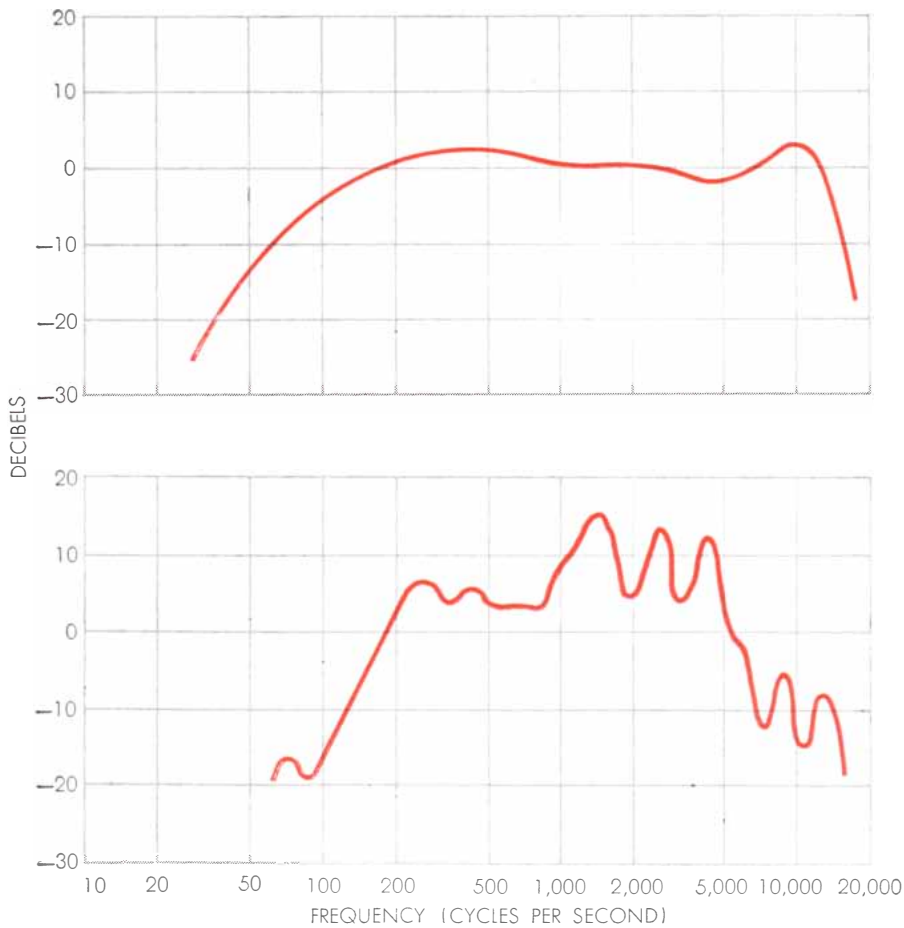
Does a falling tree make a noise when no one is nearby to hear it? This famous question, propounded by the British philosopher Bishop Berkeley, points up a fundamental duality in the concept of sound. A physicist would doubtless answer yes; the crash produces a spreading disturbance in the air—in other words, a wave of sound. A psychologist might say that the disturbance does not become sound until it is perceived.

The acoustical engineer has a foot in each camp. In manipulating sound physically—storing it, transmitting it, projecting it—his eventual aim is to deliver a wave that, in falling on a listener's ears, produces a sensation resembling as closely as possible the sensation that the waves from the original acoustical event would have produced. Fortunately, subjective duplication does not require physical duplication. The human auditory sense is deaf to many gross distortions and omissions. What cannot be perceived need not be preserved. Therefore the engineer does not have to try to duplicate every detail of the original waves when reproducing them. That would be a hopelessly complicated task.

On the other hand, the hearing apparatus is surprisingly sensitive to certain effects. And human preferences often depend as much on experience as on present sensation. The distinction between auditory necessity and irrelevance and the subtle connection between the physics and the aesthetics of sound pervade all of acoustical technology.

Modern sound engineers are expert at turning physical means to psychological ends. Under some conditions even experienced listeners cannot distinguish between the sound produced by the best reproduction systems and that of the original performance. Nevertheless, there is still room for improvement in certain of the standard components. Engineers are only now beginning to learn to use sound systems to tailor the acoustics of rooms, concert halls and theaters. Here too the physical-psychological duality is the key.

Physically sound is created by vibrating bodies that set up traveling condensations and rarefactions in the air or other material around them [*see illustrations on page 74*]. A tuning fork sets up condensations and rarefactions that blend smoothly into each other. Such a sound is a pure, or monochromatic, tone. The spacing between condensations determines the number reaching the ear each second, since they all travel at the same speed in a given medium. When this number, or frequency, lies between



FREQUENCY RESPONSE determines the fidelity of a sound-reproduction system. In a system with good frequency response (*curve at top left*), the piano note middle C (*recorded*

20 and about 16,000 per second, the normal young adult listener can hear the tone. The physical frequency of the tone determines its subjective pitch. The greater the frequency, the higher the pitch. The lowest note on a piano corresponds to the pitch of a 27.5 cycle-per-second tuning fork, whereas the highest corresponds to a frequency of 4,186 cycles per second.

A second subjective characteristic of the tone—its loudness—depends on the physical intensity of the condensations and rarefactions, that is, on the degree of compression and expansion of the air. (The relative intensity of two sound waves is measured in a unit called the decibel. If a particular wave is arbitrarily chosen to represent zero decibels, then a wave at 10 decibels is 10 times as intense, one at 20 decibels 100 times as intense, one at −10 decibels a 10th as intense, and so on.)

Sound Waves

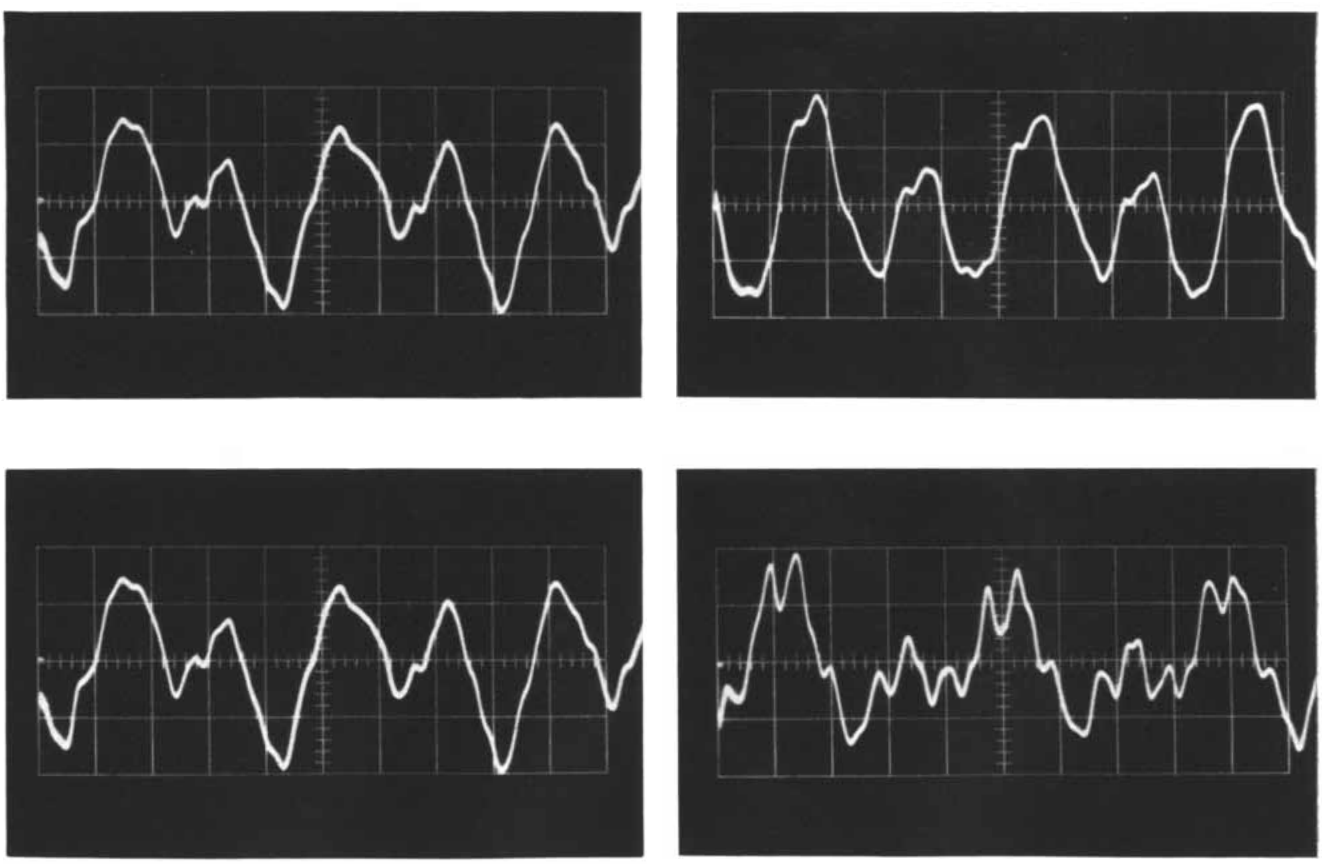
For the purpose of picturing or analyzing sound waves, the direct representation of condensations and rarefactions is not very helpful. It is more convenient to plot a curve showing variations in air pressure, the crests corresponding to points of maximum condensation and the troughs to points of maximum rarefaction. When a pure tone is plotted this way, the curve turns out to be the familiar sine wave.

In practice, of course, practically none of the sounds we hear are pure tones. If the waves were visible, they would not look like the regular processions of compressions shown in the diagrams but would vary from place to place in both spacing and intensity. The pressure curve would no longer be a simple sine wave but would actually have a complex shape.

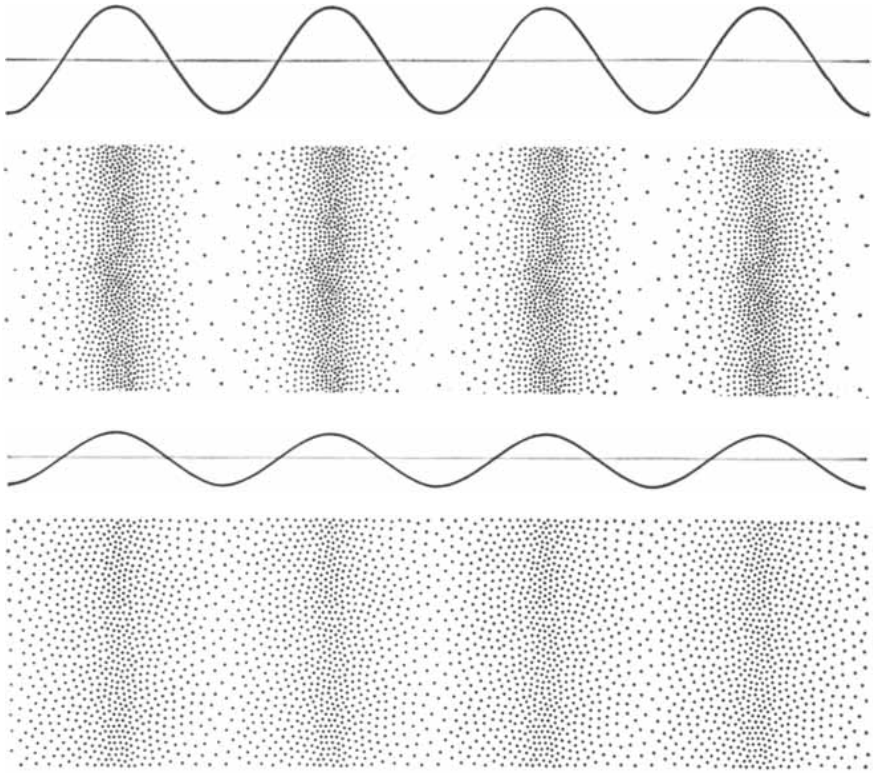
Some 150 years ago the French mathematician Jean Baptiste Joseph Fourier discovered that such shapes, even when extremely complicated, can be formed by adding together various sine waves [*see illustration on page 75*]. This fact implies that every sound, whether a musical note or a discordant noise, is a combination of pure tones. In musical notes the lowest tone establishes the pitch. The remaining sine-wave components, or harmonics, determine the quality, or "tone color." The difference in quality between a French horn and a trumpet, say, when both are sounding the same note, depends on the relative intensities of the harmonics produced by each instrument.

About 50 years later Hermann von Helmholtz found that the subjective quality of a sound depends almost not at all on the relative phases of its harmonics. As the drawings on page 75 show, shifts in phase among sine-wave components can drastically alter the shape of a resultant curve. Yet the ear almost totally disregards the change. It tends to hear each harmonic as a separate tone, combining them without regard to phase. This is a lucky circumstance; it is an exacting and expensive task to build electrical and acoustical circuits that preserve the relative phases of the components in a wave.

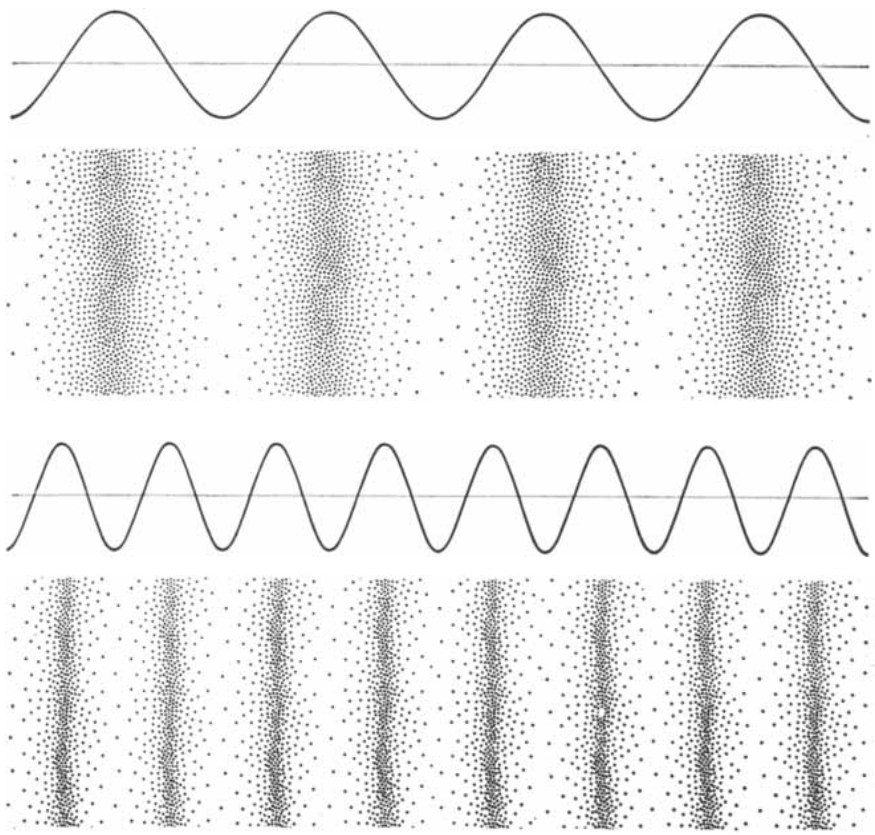
An ideal acoustical system, then, would deliver to the listener a wave containing all the sine waves that were in the original wave, and only those. Their relative intensities would be strictly preserved, but not necessarily their relative



***in oscillograph at top center*) is reproduced with high fidelity (*oscillograph at top right*). In a system with poor frequency response (*curve at bottom left*), the same note (*bottom center*) is reproduced with low fidelity, *i.e.*, considerable distortion (*bottom right*).**



INTENSITY of sound waves (*sine curves*) in air (*dots*) depends on the degree of condensation (*closely spaced dots*) and rarefaction (*widely spaced dots*). Degree of condensation and rarefaction in wave at top is approximately twice that in the wave at bottom.



FREQUENCY of sound waves (*sine curves*), measured in cycles per second, is the number of condensations or rarefactions that pass a given point in one second. The frequency of the wave at bottom is twice that of the wave at top. Both waves are equal in amplitude.

phases. Needless to say, there are no ideal systems.

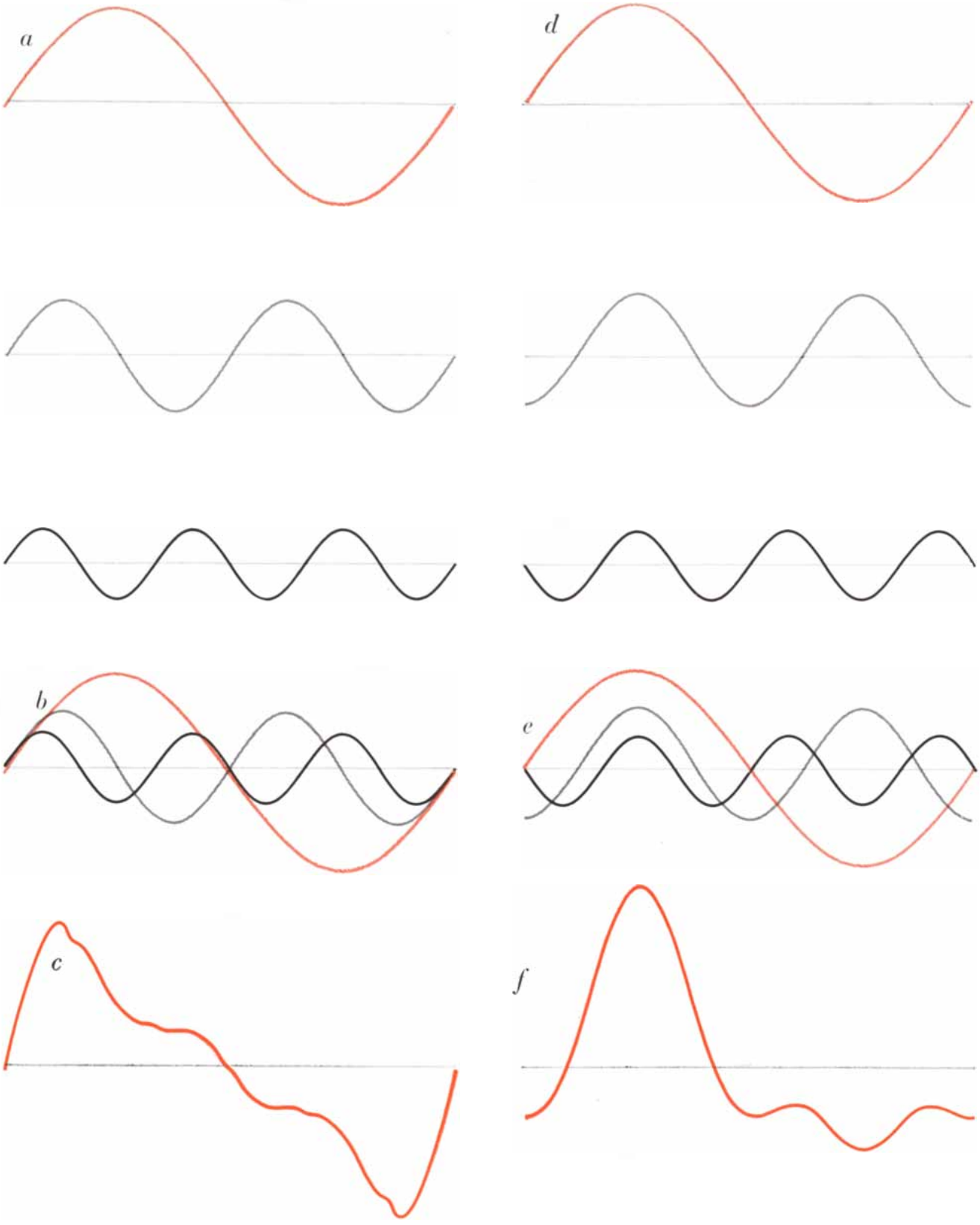
How do they fall short? They may degrade sounds in two general ways. First, an imperfect frequency response may overemphasize the intensities of some sine waves in the input while depressing or eliminating others. Second, new sine waves, not contained originally in the input, may appear at the output if a system changes the input wave shape. This effect is known as nonlinear distortion.

A system with poor frequency response imposes its own characteristic tone color on any sound passing through it. Cutting off low frequencies gives a thin, shrill sound; high frequencies, a muffled sound. Complex, uneven responses produce distortions that are harder to describe but easy to recognize. The added tone color remains constant, whereas the tone color of the desired sound—for example, orchestral music—is continually changing. Listening to such a system is like looking at a movie through an imperfect pane of glass that distorts all images in the same way. To reproduce tone color with high fidelity a sound system must have a "flat" response, varying no more than three or four decibels, for frequencies from about 30 to 15,000 cycles per second.

Although people are growing accustomed to high-fidelity reproduction and are coming more and more to demand it, particularly in phonographs, they can be, and often are, satisfied with much less. It is not hard to make an unconscious correction for a constant distortion. A listener willingly accepts a tone quality from a car radio or pocket-size portable radio that he would not tolerate from a phonograph. The frequency response of the telephone hardly extends below 200 or above 3,600 cycles per second. To be sure, no one would choose to listen to music over such a system, yet in spite of the lack of low and very high frequencies it serves well for personal voice communication.

Similarly, added components of sound will be discounted if they are not too loud and if they are steady. A little hum from an amplifier or hiss from a record surface can be ignored. Even a mixture of two entirely dissimilar types of sound may be admissible, as in the case of speech and background music. Each has its own tempo, pitch, frequency spectrum and intensity, and the listener has no trouble keeping the two apart.

The most objectionable change that a reproduction system can impose on a sound is to introduce extraneous com-

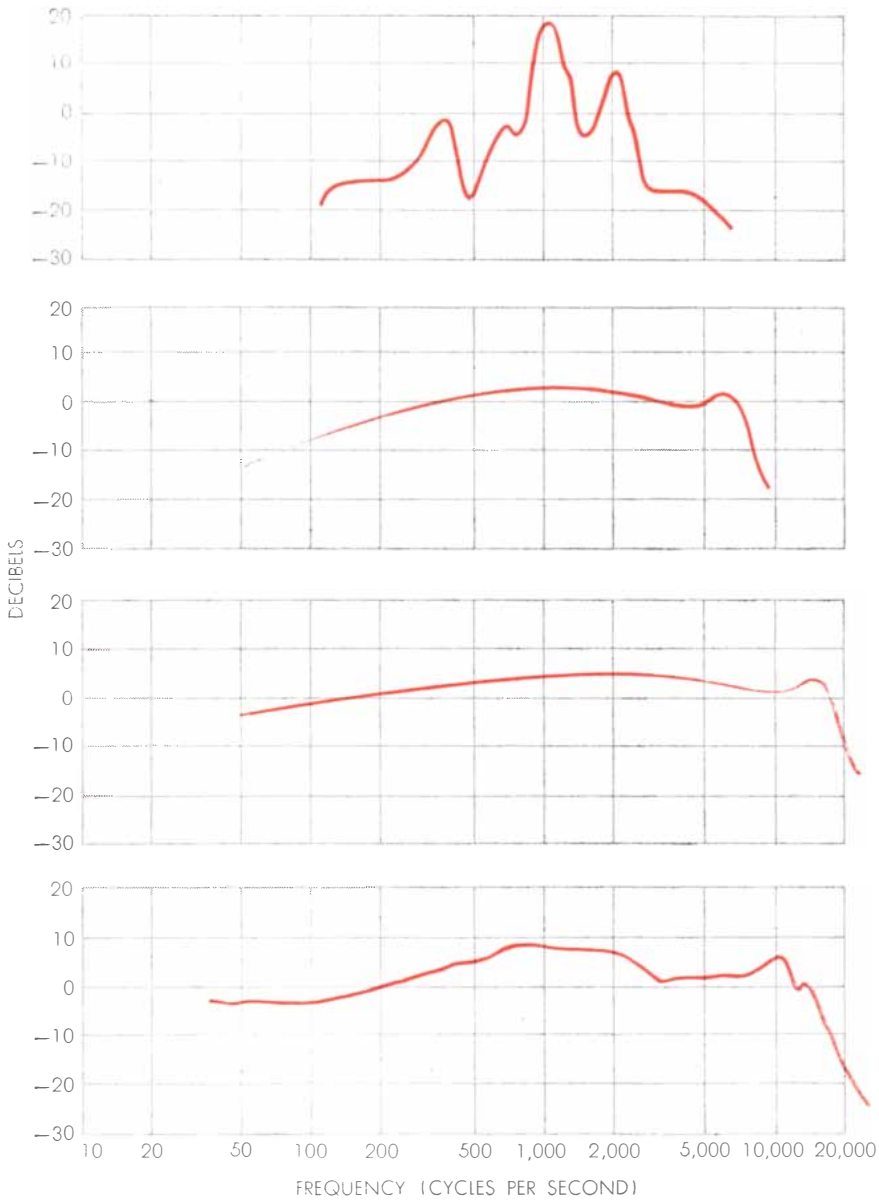


MUSICAL NOTE can be represented by a complex curve (*c*) that is a combination of pure tones: a fundamental (*sine curve at top in* "*a*") and one or more overtones (*two lower curves in* "*a*"), which are heard simultaneously (*b*). When the phases of these tones are shifted with respect to one another ("*d*" *and* "*e*"), the complex curve representing the note is greatly changed (*f*). The ear largely ignores this change, however, and the note produced sounds almost exactly like the previous one (*c*), when there was no phase shift.

ponents with a rhythm of variation similar to that of the original sound. This nonlinear distortion occurs most commonly when the original sound becomes too intense for the capabilities of the system. In physical terms, the input waves are larger than can be duplicated by some component of the reproduction device. As they pass through, their tops are clipped off and they come out flattened. Such flat-topped wave shapes are, as Fourier showed, composed of sine waves, but many components that were not in the original sound are required to produce the shape. In other words, when the reproduction equipment is driven too hard, it adds new components to the sound wave.

The effect is not constant. Once the intensity limits have been reached, the greater the intensity of a wave, the more it is flattened. Therefore nonlinear distortion varies with the intensity of the input sound. In an orchestral piece, for instance, the intensity changes from note to note, and the fluctuating distortion becomes entwined with the music.

In the late 1940's Harry F. Olson of the RCA Laboratories tested the effects of nonlinear distortion on over-all subjective reaction to reproduced sound. He played music to a group of listeners through a sound system with a variable frequency response and variable nonlinear distortion. The wider the range of frequencies reproduced, the less nonlinear distortion the subjects would tolerate. For instance, with the system adjusted to pass only the frequencies between 50 and 5,000 cycles per second, they put up with three times the distortion they would accept when the response was extended to 15,000 cycles per second. This subjective interaction between frequency range and nonlinear distortion constantly plagues the sound engineer. He may take great pains to extend the frequency range of his equipment only to find that he has revealed previously unnoticed faults in the apparatus or recordings.



PERFORMANCE of modern sound-reproduction systems, as measured by frequency response (*colored curves*), has been greatly improved over that of earlier systems. The early mechanical recorders (*top*) responded very unevenly to a narrow range of frequencies. The Maxfield-Harrison recorder of 1925 (*second from top*) showed a smoother response to a still narrow frequency range. Except for the loudspeaker (*bottom*), components in modern systems (*third from top*) show an almost "flat" response up to at least 15,000 cycles per second.

The Origins of Sound Reproduction

The modern technology of sound reproduction is rooted in the work of three American inventors: Alexander Graham Bell, Thomas Edison and the late Lee De Forest. In 1876 Bell's telephone showed that the vibrations of a sound wave could be picked up by a diaphragm and then reconverted to sound by making it set up vibrations in a second diaphragm in an earphone. A decade later Edison's gramophone demonstrated that the vibrations could be permanently stored in the form of a "hill and dale" track cut into a smooth surface. In 1906 De Forest built the audion, a three-element vacuum tube that can amplify electrical signals.

It was almost 20 years more before the three innovations were brought together. The first sound-storage systems were entirely mechanical. The tiny forces in the condensations and rarefactions of sound waves were transmitted by means of a diaphragm and a series of levers to a needle-like stylus, which cut a track in a wax cylinder or disk. The energy came entirely from the sound wave. To obtain enough power for cutting the wax, sound had to be funneled into the diaphragm with a large horn. In reproduction all the energy for the loudspeaker diaphragm was supplied by the needle that retraced the up-and-down track of the record.

The greatest problem that the early acoustical engineer faced was simply to make the sound loud enough. Part of the solution was to design a mechanical system that resonated strongly to a narrow band of frequencies. The result was a narrow and spectacularly uneven response that had, in addition, a generous dose of nonlinear distortion [*see top graph at left*]. Little wonder that early gramophone music sounded more like a

product of the device than of the performing instruments.

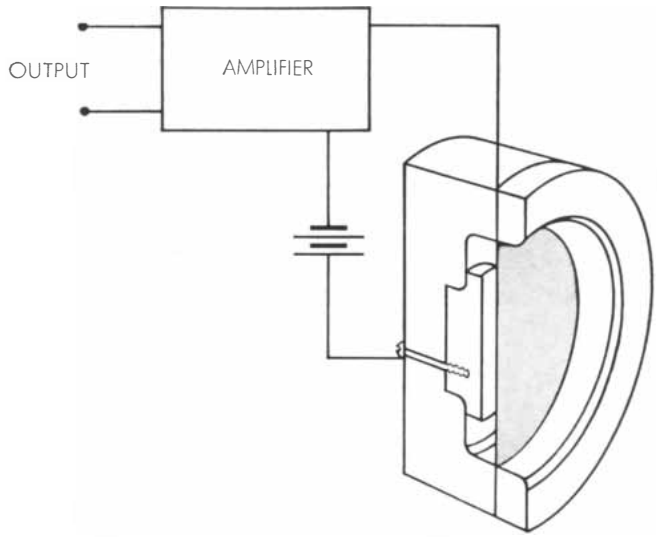
In 1925 Joseph P. Maxfield and Henry C. Harrison of the Western Electric Company took advantage of what was already at hand to create a new technology. They hooked up a microphone and an amplifier to drive an electrically actuated recording stylus and were at once able to improve dramatically on the frequency response of the mechanical recorder. As soon as their "electrical transcriptions" were available it became worthwhile to build an electronic reproducer, with electromechanical pickup, amplifier and loudspeaker.

Maxfield and Harrison's electromechanical recorder is based on a magnetic principle. A tiny slug of iron is suspended between the poles of a permanent magnet with a wire coil wound around it [*see illustration at bottom left on next page*]. The slug is attached to one end of a shaft and the stylus to the other. Fluctuating current supplied to the coil varies the magnetism acting on the slug, making the slug rock back and forth against the force of a retaining spring. The stylus moves from side to side in response to the current in the coil. Thus the sound track is cut laterally rather than up and down. The same device can recover an electrical signal from the sound track. Motion of the stylus tip causes a varying magnetic field, inducing a corresponding voltage in the coil.

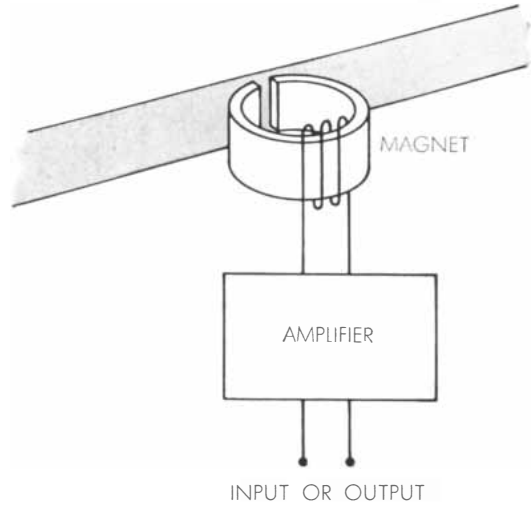
With power no longer a concern, engineers could now turn to the problem of fidelity. The easiest part of the job turned out to be the electronics. In a few years they learned to make amplifiers that far outperformed the other parts of the system. Today it is no trick to build an amplifier that is, within the capabilities of the human ear, nearly perfect. Modern electromechanical recorders and pickups have also been brought to a high level of performance. Present limitations are set by the storage medium itself and the "transducers," which convert between electricity and sound.

Disk, Wire and Tape

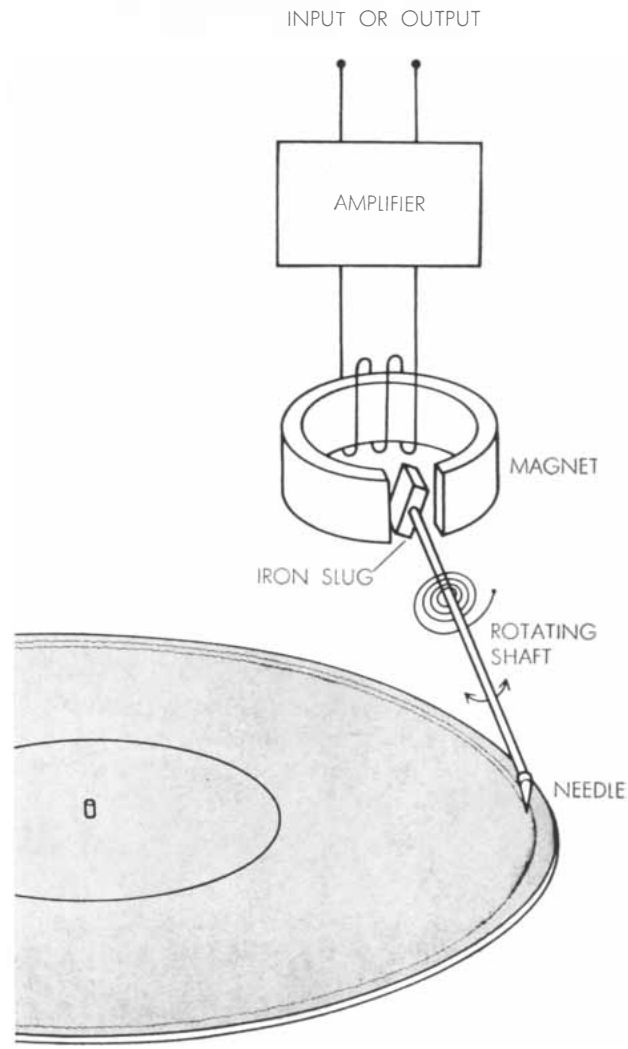
Everyone is aware of the enormous superiority of present disk recordings over those of even 10 years ago. Today's best records are fine indeed but they are still noticeably far from ideal. Their chief drawback is nonlinear distortion from several causes. Some of these are economic. For instance, frugal duplicating procedures may set limits on the fidelity of the reproduced grooves. Other limits are inherent, for instance distortions introduced by the curvature of the



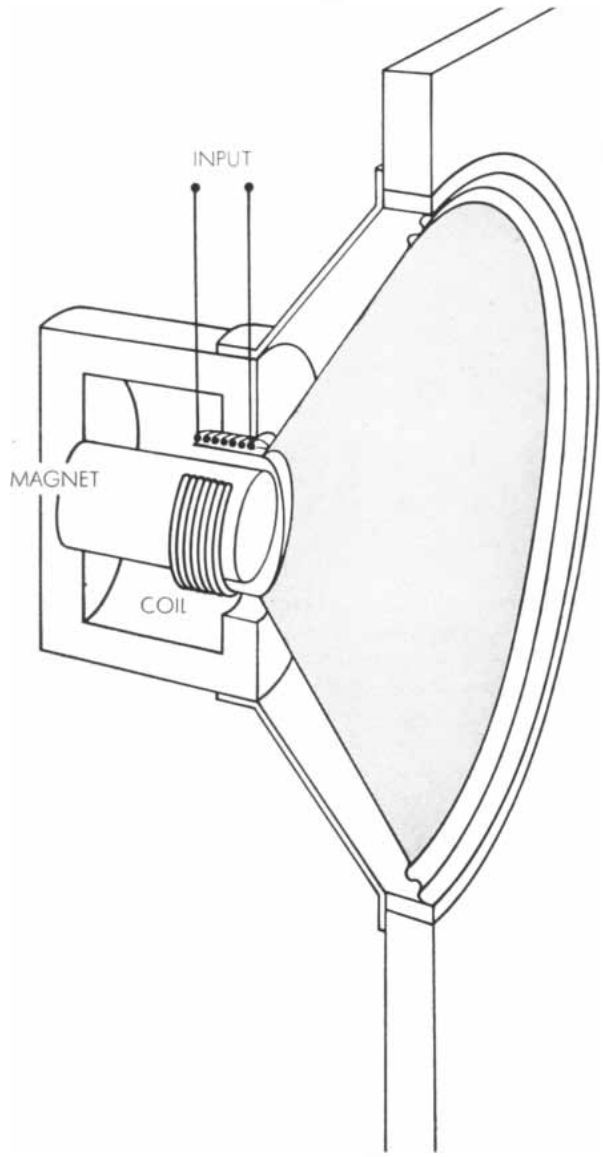
CONDENSER MICROPHONE converts sound into an electrical output. Diaphragm (*shaded area*) in front of condenser plate moves in response to sound waves, varying the gap and thus the output.



TAPE RECORDING-HEAD AND PICKUP are identical in principle. In recording, magnetization of tape (*shaded area*) varies with electrical input; in playback, output varies with magnetization.



DISK RECORDING-HEAD AND PICKUP also are identical in principle. In recording, input determines needle movement as grooves are cut. In playback, needle movement determines output.



LOUDSPEAKER consists of a magnet and a wire coil attached to a paper or fabric cone (*shaded area*). The coil moves in response to the input. Corresponding motion of cone produces sound.

sound track. Then there is the question of durability in use. Great care is necessary if the track is not to be worn out of shape, adding new, unwanted sine waves.

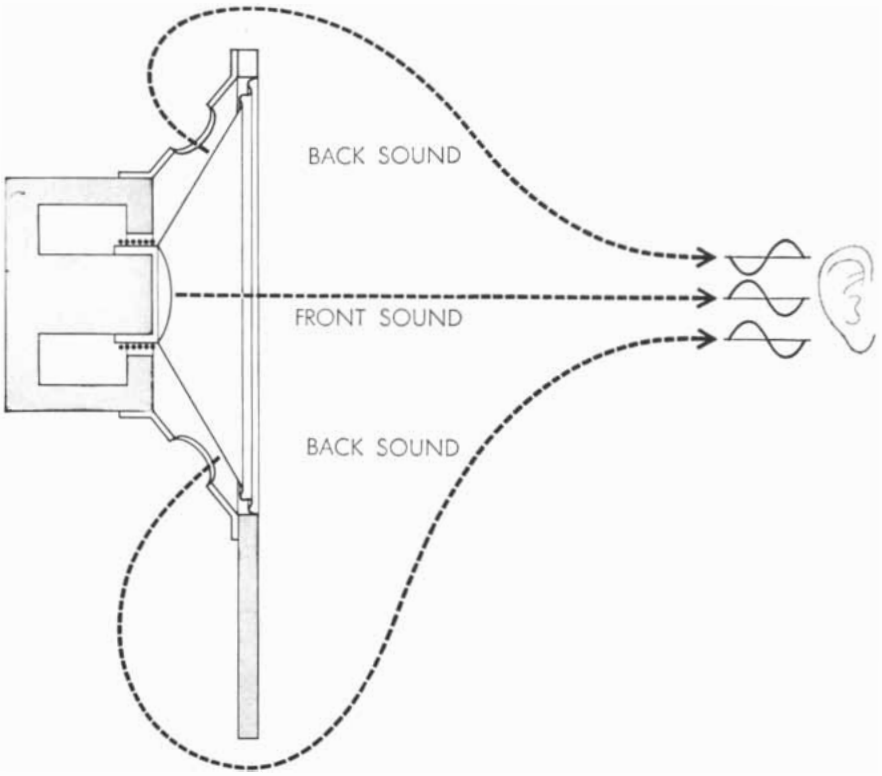
Another shortcoming of the disk is its inability to accommodate anywhere near the full range of intensity in orchestral music. The limits are set at the upper end by the overload point, at which the recorder and pickup begin to respond in a nonlinear manner; at the lower end, by the surface noise inherent in the disk material. The best records have a range of about 40 decibels from the noise level to the overload level (an intensity ratio of 10,000 to 1). At a live performance of a symphony the sound level may extend over 80 decibels. To reduce nonlinear distortion the sound engineer usually cuts the volume of the louder passages before their vibrations reach the stylus. If all the other parts of a system are as good as they can be, the disk record will set the limit on the fidelity.

For the storage of sound, magnetic tape recording was an advance nearly as revolutionary as the coming of electrical recording. As long ago as 1898 Valdemar Poulsen—the "Danish Edison"—discovered how to record sound magnetically. He sent the varying current from a microphone through the coils of an electromagnet and passed a steel wire across the poles. Successive portions of the wire were magnetized with a strength corresponding to the changing strength of the current. When the wire was moved past the poles of a second electromagnet, the changing field induced a varying current in the coil. Sending the current through a headphone reproduced the sound.

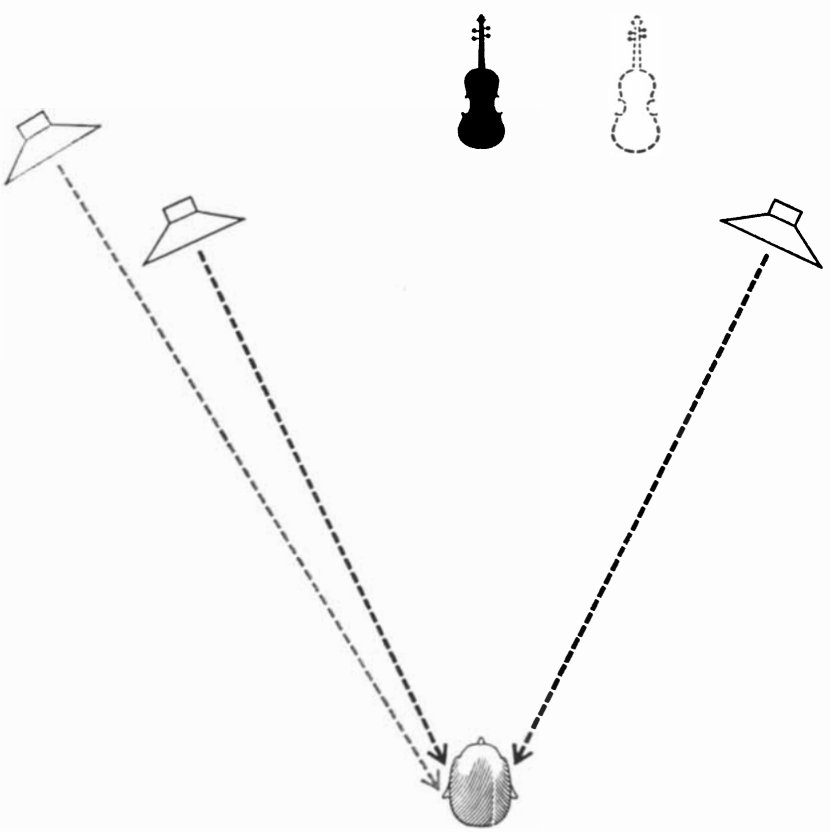
Poulsen actually built a wire recorder called the telegraphone. In the 1920's, when amplifiers had come into use, the device was revived in Germany. Wire was expensive and difficult to handle, however, and magnetic recording did not come into its own until F. Pfleumer, a German engineer, developed plastic tape coated with powdered magnetic material. Before World War II a tape recorder much like those of today had been built in Germany.

Magnetic tape is now the best medium for storing sound. Its intensity range reaches as high as 65 decibels. This is still short of the full symphonic demand but it may be extended with further research. The limits are set by the range of maximum possible variation in magnetic strength of the tape—from the noise level to the overload point. Improvements in the magnetic materials and techniques of fabrication should make it possible to operate over a wider range.

Although wear is less of a problem



CONDENSATIONS of low-frequency sound waves from rear of a loudspeaker (*"back sound" at top*) tend to cancel rarefactions simultaneously produced at the front (*"front sound"*). A baffle (*shaded area at bottom*) delays back sound, thereby reducing interference.



SOUND OF VIOLIN from two symmetrically placed loudspeakers is perceived by a listener as coming from a violin (*black*) midway between them. If one loudspeaker (*gray*) is moved away, the listener locates the source (*dashed violin*) nearer the other loudspeaker.

than it is with disks, tape recordings are not permanent. They may deteriorate in storage when temperature and humidity are not carefully controlled. Moreover, each layer on the reel tends to "print through" to the next, resulting in an annoying "pre-echo." No solution for the latter problem is in sight.

The Transducers

Other critical points of the sound-reproduction chain lie at the junctions between sound and electricity. At the microphone end, high-quality instruments have been available for many years. For example, the principle of the condenser microphone dates from before 1880. The microphone is an electrical condenser consisting of a thin diaphragm mounted in front of a rigid plate [*see illustration at top left on page 78*]. A constant electric charge is maintained on the plate. As the diaphragm vibrates under the influence of impinging sound waves, the spacing between it and the plate changes, changing the capacitance of the instrument and therefore the voltage between the plates. The small voltage variation is fed into an amplifier. In the early days the condenser microphone had to be abandoned because, without amplification, it produced too little power. Now it is one of the strongest links in the chain of sound reproduction.

At the other end of the chain is a weak link—the loudspeaker. The principle of operation of the modern device was discovered in 1874 by Werner von Siemens, founder of the German electrical equipment firm Siemens & Halske. Siemens placed a coil of wire in a magnetic field directed radially outward from the coil axis and passed an alternating current through the wire. As the field of the coil interacted with the permanent field, the coil moved back and forth along its axis.

Modern electrodynamic speakers embody Siemens' principle in the "voice coil," which receives the fluctuating electrical output of an audio amplifier. As the coil oscillates it communicates the motion to a flaring cone of paper or fabric and thence to the air. In the early days great difficulties were encountered in achieving a uniform frequency response over a wide range. In the 1920's C. W. Rice and E. W. Kellogg of the General Electric Company analyzed the mechanism and found that the coil and magnet respond less efficiently to the electrical signal as its frequency increases. By proper design, however, this effect can be offset by an increase in the efficiency with which the cone sets up air vibra-

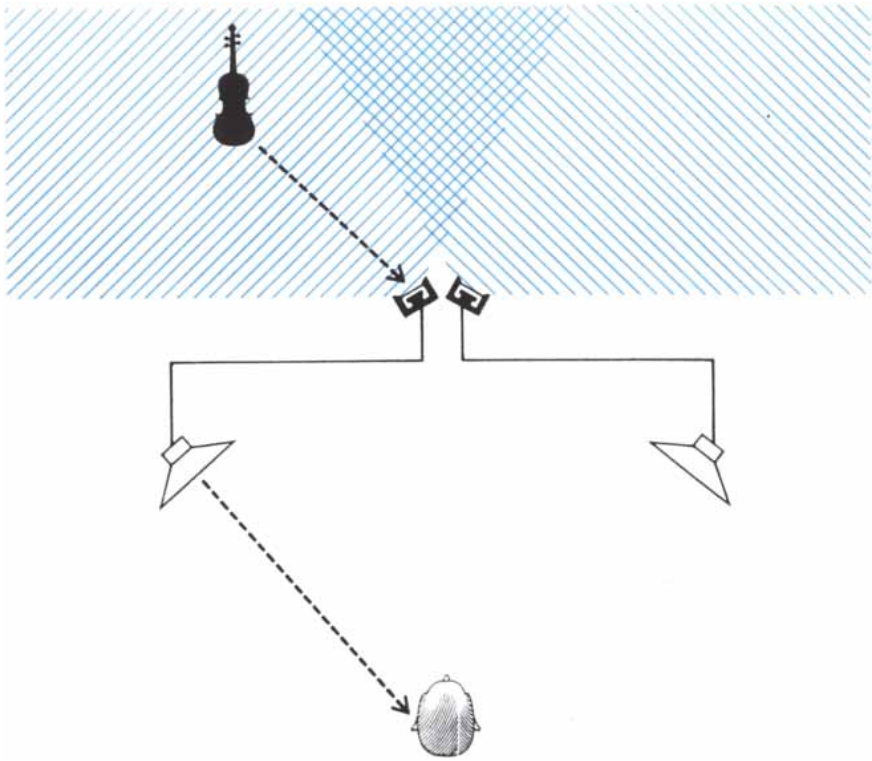
tions. This is still the basic design principle of cone loudspeakers.

In analyzing the action of the speaker cone, Rice and Kellogg found that the surface should be large for good low-frequency reproduction and small for high frequencies, a conflict that still plagues designers. One compromise makes use of a cone that is stiffer near the center than it is near the outer edge. At low frequencies the cone vibrates as a unit; at high frequencies the stiff inner portion moves almost independently of the flabby rim. A second way out is separate speakers—small ones for the highs and large ones for the lows. Although multiple speakers are now the preferred solution, they still present difficulties in achieving a smooth response at the frequencies of crossover from one speaker to another.

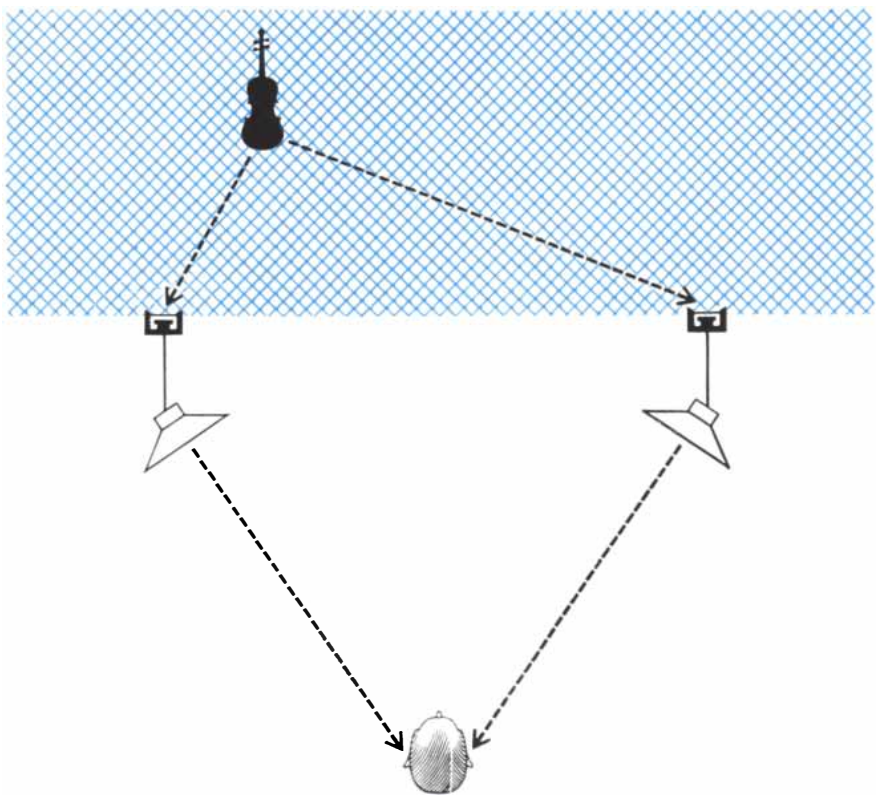
Designers of loudspeakers face other troubles. One arises from "back sound": each time the front surface of the cone creates a compression, the back surface creates a rarefaction and vice versa. Some of the energy from the back wave reaches the front of the speaker, after traveling a longer distance than the direct wave [*see top illustration on opposite page*]. At low frequencies, where the wavelength is measured in feet, the extra distance is not enough to shift the relative phase of the two waves substantially, and the back sound tends to cancel the front sound. Below a certain frequency, therefore, the speaker muzzles itself.

One answer to the problem is to surround the speaker with a baffle, which increases the length of the path of the back sound and reduces the frequency at which it begins to interfere. This notion was carried to its logical conclusion in the "infinite baffle," which took the form of a large box lined with absorbent material that completely soaked up the back radiation. This radiation can, however, be turned to useful account in the "bass reflex" enclosure. Here the speaker is mounted in a box that has an open port in the front. A box of proper dimensions resonates at low frequencies and emits radiation from the opening that reinforces the direct sound. Still other schemes lead the back sound through a labyrinth so that it reaches the front in an advantageous phase.

The horn loudspeaker provides an even better solution. Here the cone or a small piston is placed in the throat of a long horn. This allows the moving surface to drive the air efficiently and uniformly over a wide range of frequencies and reduces the back radiation. Horns are large and unwieldy, however, even



STEREOPHONIC SYSTEM of A. D. Blumlein is based on directional microphones and separated loudspeakers, which reproduce sound from source at center (*crosshatched area*) with equal intensity. Loudspeaker at left reproduces violin sound with greater intensity.



SEPARATED MICROPHONES connected to separated loudspeakers is basis of stereophonic system developed by Harvey Fletcher. Sound coming from source nearer one microphone is reproduced earlier and sometimes louder in the corresponding loudspeaker.

when folded up and placed in a corner of a room.

These shortcomings imply that loudspeakers offer a great opportunity for further improvement. By the same token, the purchaser of a sound system will do well not to stint on his speaker, since it is likely to set the limit on the quality of the set.

Perspective and Ambience

Even an ideal loudspeaker at the end of a chain of ideal components could not reproduce for a listener the sensation he experiences in a concert hall. Sound has spatial as well as tonal quality. At the concert the listener has auditory "perspective"; he can hear that the violins are on the left, the cellos on the right and the soloist in the middle. He also hears sound from many directions other than from the stage—diffuse reverberations from walls and ceiling, curtains and carpets. The impression produced by this diffuse sound is called ambience. Both perspective and ambience disappear almost entirely when sound is projected from a single speaker. It is like listening to a concert from the lobby of a concert hall through a chink in the door to the auditorium.

The ability to locate a source of sound, which is responsible for the sense of perspective, depends on hearing with two ears. Sound from any direction other than straight ahead or behind arrives at one ear a little earlier than at the other and, because of the shadowing effect of the head, a little louder. Somewhere in the brain the signals from each ear fuse into a single, composite image. The minute time and intensity differences between them serve to fix the location of the source.

Ambience arises when many successive echoes of a sound arrive at the listener's ears from different directions. Again the brain combines the complex train of events into a unified impression of the size, shape and texture of a room or hall.

Any attempt to reproduce perspective and ambience must provide something different for each of the listener's ears. As long ago as 1881 a Frenchman, Clement Ader, demonstrated a system in which sound from two spaced microphones was piped separately, via telephone lines, to a corresponding pair of earphones. In the 1920's it was found that the perspective effects from such a binaural arrangement were enhanced by putting the microphones on each side of a dummy head. Binaural systems pro-

vided a startlingly realistic impression, except in one respect: when the listener turns his head, the sound rotates with him—he is always facing the orchestra. Besides, the headphones are a nuisance. For both reasons the binaural scheme has now given way to stereophonic systems, in which the two earphones are replaced by loudspeakers fed by independent microphones.

Each speaker sends a sound wave to both ears of a listener, but he perceives a single image. If the two sources are equidistant from the listener and are equally loud, he hears the sound as coming from halfway between them. If one speaker is moved a little closer, so that its sound arrives a little earlier, the image shifts toward it. This phenomenon is known as the precedence effect: the first sound to arrive from an acoustical event pre-empts the location mechanism. An interval of about five-thousandths of a second between the two sounds is enough to shift the apparent source all the way to the earlier speaker. The same result is obtained by making the sound from one speaker louder than that from the other. A ratio of 10 decibels moves the image to the louder speaker. For larger differences in delay or intensity the image stays at the earlier or louder speaker.

Although these effects are the source of the stereophonic illusion, such systems had been developed long before the principles were understood. In the 1920's an ingenious British inventor, A. D. Blumlein, Harvey Fletcher of the Bell Telephone Laboratories and K. de Boer and A. van Urk of the Dutch firm N. V. Philips' Gloeilampenfabrieken laid the groundwork for stereophonic reproduction. They hit on the same basic plan: two separate sound channels from microphone to speaker. The schemes differed in the way in which they picked up the sound.

Blumlein used the equivalent of a pair of directional microphones, placed close together with their axes of maximum sensitivity at right angles to each other [*see top illustration on opposite page*]. In this arrangement a sound originating off the center line gives a louder response in one microphone and in the corresponding speaker. The system operates on the intensity effect described above. Fletcher's setup, on the other hand, consisted of a pair of nondirectional microphones spaced several feet apart [*bottom illustration on opposite page*]. Here the precedence effect is applied: sound from an off-center source reaches one microphone sooner than it reaches the other

and therefore emerges first from the associated speaker.

Both approaches are in current use; Europeans generally prefer the Blumlein system and U.S. engineers the Fletcher system. While they rely on different physical principles, their psychological effects are very similar. The closely spaced microphones do give more consistent reverberant patterns, however. When the microphones are widely separated, the echoes arriving at each one may be quite dissimilar. Moreover, the echoes can vary drastically with the progress of the music since echoes from various surfaces may reinforce each other at some wavelengths and interfere at others. In extreme cases an instrument such as a piano will seem to "ping-pong" from side to side as different notes are sounded. Such undesirable effects can be largely controlled by proper studio design and careful placement of the microphones.

In both systems the auditory perspective changes if the listener moves off the center line between the two speakers. Most people do not mind the distortion; the exact location of each instrument is not important. As a matter of fact, many listeners feel that the principal advantage of stereo lies not in the localization of particular sources of sound but in the ambience that the system affords. The somewhat different echo patterns picked up by the two microphones and projected by the speakers combine at the listener's ears to call up an impression of a diffuse field of sound coming from the general region of the speakers.

Recently some investigators have used twin speakers to produce ambience from a single microphone or recording track without regard to the spatial separation of sound sources. M. R. Schroeder of the Bell Telephone Laboratories has devised a system that generates multiple echoes, simulating reverberation. The sound is continually recorded on a rotating magnetic drum, picked up at a later point in the rotation and fed back into the system. Two delay units supply different echo patterns to two speakers, which give the impression of a diffuse source of sound. Many listeners find this "quasi stereo" system hardly distinguishable from the real thing and some even prefer it. The system is no simpler or cheaper than stereo, but it does project single-channel recordings much more satisfactorily than one speaker can. It is particularly helpful in improving the sound of old recordings with limited frequency range and considerable distortion.

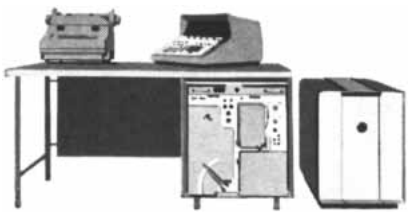
A Dutch engineer, Roelof Vermeulen, has carried quasi stereo a step further in a technique he calls ambiophony. He places speakers around the listener (or listeners): at the sides and in the rear of the audience as well as in front. The speakers at each location are fed through delays that allow the direct sound to reach that point before the corresponding sound emerges from the speaker. The result is an all-around system of artificial echoes that resemble those in a concert hall. Increasing the delays to the speakers increases the apparent size of the enclosure. Ambiophony can turn a living room into the acoustical equivalent of an auditorium. Artificial reverberation is the only way to augment the direct sound in outdoor concerts, and it can enhance the acoustical properties of real concert halls and auditoriums.

A similar scheme can also remedy the effects of too much reverberation. Prolonged reverberation severely reduces the intelligibility of speech because each sound "rings" for several seconds, masking what comes after. Railroad stations and churches are traditional offenders. Halls designed primarily for music, therefore, are often not suitable for speech. Excessive reverberation can be offset by increasing the direct sound through directional loudspeakers, which beam their output to the audience. The additional direct sound adds little reverberation of its own since most of it is absorbed, principally by the clothing of the audience. If the reinforcing sound arrives somewhat later than that from the person speaking, the precedence effect hides the electroacoustic system.

Through these techniques the acoustics of an auditorium can be tailored to each occasion. Both St. Paul's Cathedral in London and the Palais de Chaillot in Paris employ directional speakers to increase the intelligibility of sermons and plays. The musical acoustics in the famous Teatro della Scala in Milan have been markedly improved by an ambiophonic arrangement. The Grand Auditorium at the 1958 Brussels Exhibition contained a system permitting flexible control of both direct and reverberant sound. Plays, speeches, orchestral and choral concerts, chamber music, solo recitals and film presentations were each accommodated with appropriate acoustical support. In this country there is still prejudice against electroacoustic sound reinforcement but it is dying out. In the future electroacoustic systems will doubtless become an integral part of the design of theaters and auditoriums instead of an afterthought. Indeed, the fusion of electroacoustics with architectural acoustics is the new frontier in sound engineering.

ANOTHER IN THE CAUTIONARY SERIES ABOUT RECOMP II [in which we reveal nearly all the computer's subtle enticements]

Here, for the very first time, is an unexpurgated listing of the allurements of Recomp II. They are potent. They are persuasive. They are enticing. Indeed, in reading them it would be wise to exercise a decent restraint... for you may find yourself falling in love with a computer:



1] The *first* solid-state digital computer on the market was Recomp II. The *finest* computer on the market is still Recomp II. Recomp II's dedicated engineers are determined that the situation shall remain this way; they have an obsessive regard for this precise machine they have so carefully developed.

2] Recomp II is the *only* compact computer with built-in floating point arithmetic. It defies being hemmed in on a problem. With its large capacity it obviates computer-claustrophobia.

3] Always the darling of the medium-scale computer user, Recomp II has been so well accepted that it can now be offered at a *significantly lower price.* It still provides the identical quality, solid-state performance, and features that can't be found on computers costing three times what Recomp II *used* to cost.

4] Recomp's memory, employing the new optional Recomp Magnetic Tape Transport units, would stagger an elephant. Each unit has a memory of over 600,000 words. Up to eight of these transport units can be connected to Recomp II, giving you a computer with a total memory capacity of over 5,000,000 words. Remarkable!

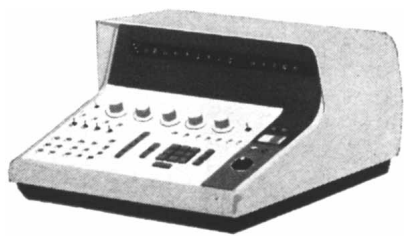
5] The speed of the new magnetic tape control described above is quite remarkable, too. Read and write speed is 1850 characters a second; bidirectional search speed is 55 inches per second.

6] Always the darling of the medium-scale computer user, Recomp II has been so well accepted that it can now be offered at a *significantly lower price.* It still provides the identical quality, solid state performance, etc.

7] Recomp II seems to have more built-in features than a dream-home kitchen. It has built-in square root command. Built-in automatic conversion from decimal to binary.

8] Would you say that a RUG is important to a computer? Well, it is. The RUG we mean is Recomp Users Group. This is a highly active group, sharing up-to-date information, and keeping in close contact by monthly bulletins. A consideration not to be overlooked when buying a computer.

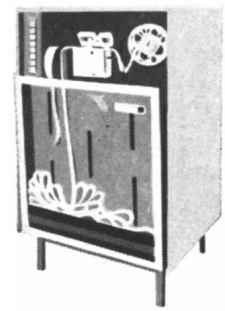
9] Always the darling of the medium-scale computer user, Recomp II has been so well accepted that it can now be offered at a *significantly lower price.* It still provides, etc., etc.



10] Recomp's keyboard, which you can see above, looks easy to operate. It is. And because it requires no specialized talents, anyone with computer problems can be taught to use Recomp II. Quite a handy machine to have around.

11] Recomp II can easily be installed anywhere, requiring no more electricity than an ordinary electric toaster.

12] Another new optional feature for your Recomp II is the Facitape tape punch and reader console, shown below. It punches 150 characters a second, reads 600 characters a second, and stops on a character. It adjusts to read and punch from 5 through 8 channels. Quite uncanny.



13] A visual readout on the control panel allows you to check any information about to be entered into Recomp II before you press the "enter" button. The information can be corrected easily if necessary. This is further evidence of Recomp II's staunch adherence to efficiency.

14] Recomp II's programming is highly efficient. It has 49 basic instructions, expandable to 72. Word length is 40 binary bits; very large, indeed.

15] Always the darling of the medium-scale computer user, etc., etc., etc.

16] Recomp II has a large sub-routine and program library, and a large program exchange.

17] Each word programmed into Recomp II contains two instructions.

Recomp II has many other features, but as you can see, space is running short. We would have liked to have lingered upon the details of Recomp II's own full scale compiler called SALT, and even maybe discuss the high-speed loops a little... but. Perhaps, if you are beginning to feel the stirrings of your acquisitive instinct toward Recomp II, you should see it in action. We can arrange a demonstration for you through our local offices in New York, Chicago, Boston, San Francisco, and Long Beach. Or, at the very least write for more information. We have some nice brochures you will enjoy reading.

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HACILAR: A NEOLITHIC VILLAGE SITE

A small mound on Turkey's Anatolian plateau has yielded the remains of early communities that provide a long-sought link between the prehistoric cultures of the Near East and Europe

by James Mellaart

The Anatolian plateau of western Turkey has long represented a challenge to archaeologists. A glance at the map on pages 88 and 89 will show why. To the southeast lies the edge of the Fertile Crescent, on which, some 9,000 years ago, the earliest Neolithic men began to practice agriculture and live in villages. To the northwest is the Balkan Peninsula, the gateway to western Europe. It is logical to suppose that Neolithic culture moved out of its birthplace (from what is now Israel, Lebanon, Jordan, Syria, northern Iraq and western Iran), westward across Anatolia and thence into Greece and the rest of the Balkans. Yet until a few years ago there was no direct evidence for the journey.

The gap was obvious and embarrassing. On the one hand, the earliest Greek and Balkan Neolithic remains showed distinct suggestions of Near Eastern origin, particularly in certain types of rather advanced painted pottery. On the other, Neolithic sites had been uncovered in Turkey only at Mersin and Tarsus, in the lowlands near the Syrian border. Many years of digging in western Turkey had failed to turn up any trace of Neolithic occupation.

Faced with this problem, archaeologists came to consider Mersin and Tarsus as mere backwaters on the periphery of the Syro-Mesopotamian culture area. Presumably this area had been cut off from a bleak and uninhabited Anatolian plateau by the Taurus Mountains. A few scholars went so far as to propose that primitive farmers had traveled by water from Syria or the neighboring Turkish coast all the way to Greece, sailing the entire length of Asia Minor!

Now it has become apparent that such tortured theories are unnecessary. Anatolia had a number of settlements of sufficient antiquity to fit the picture of a gradual overland migration of ideas. One of these, near the village of Hacilar, has been thoroughly excavated by the author, assisted by a group of colleagues from the British Institute of Archaeology at Ankara. Not the oldest site, it nevertheless dates back to the early, prepottery stages of Neolithic culture and extends (although not without a break) into the Chalcolithic era, when copper implements began to appear along with stone. Some of the materials show an unmistakable relationship both to Syro-Mesopotamian culture and to the Neolithic cultures of northern Greece.

In addition to offering their own testimony, the extensive findings at Hacilar throw new light on fragmentary discoveries elsewhere. As long ago as

CLAY STATUETTES OF 7,500 YEARS AGO were the most remarkable finds in Hacilar VI, the Neolithic level of the prehistoric Turkish site. The naturalistic and handsomely modeled figurines apparently represent the Anatolian "mother goddess" at various ages and in dif-

1910 some stone figurines were picked up at Çukurkent, near Lake Beysehir in Anatolia. Prehistorians noted their resemblance to Neolithic Greek sculpture but overlooked their real significance. In 1952 a survey of the region around Çukurkent showed widespread evidence of a Neolithic culture with affinities to that of Mersin. Still, the fact that the district was isolated among the peaks of the Taurus Mountains seemed to fit the backwater theory; moreover, the date of the settlement was uncertain. In the same year painted fragments of pottery of a new type were found somewhat farther west, in the region of Burdur. But they resembled nothing at Mersin and they could not be dated.

Then, in 1956, came the discovery at Hacilar, some 15 miles west of Burdur: a whole mound littered with the same painted pottery fragments and some complete pots, unobscured by later remains. Excavations beginning in 1957 and extending to 1960 have revealed the remains of three distinct, superimposed cultures covering some 2,000 years.

The site of Hacilar is small by later standards, measuring no more than 165 yards in diameter; the mound rises only about two yards above the level of the cultivated fields around it and is nearly invisible from the road that passes nearby. The site was apparently chosen for its proximity to a spring that still issues from a great limestone rock towering over the modern village. Hacilar is about 3,000 feet above sea level and has an annual rainfall of about 20 inches. The countryside is now open grassland and farm, but the number of bones of deer and wild pig taken from the mound suggests that the region used to be wooded.

The Hacilar mound was built up in a peculiar manner. After the destruction of each settlement the next occupants apparently laid a courtyard over the rubble of the buildings and built their houses above the earlier court. This archaeological "split level" plan compressed no less than 16 distinct building levels into a total depth of only 15 feet [*see illustration on page 94*].

At the bottom are seven layers belonging to a prepottery culture. No radiocarbon dates have as yet been obtained for these earliest remains, but they probably go back to the seventh millennium B.C. The levels, according to our designation, are Hacilar Aceramic I through VII. Above them lie two feet of earth, representing a gap of many hundreds of years. The next people to occupy the site brought with them a most sophisticated late Neolithic culture. According to radiocarbon evidence, they flourished there for only three centuries, from about 5700 to 5400 B.C., leaving four distinct occupation levels. Following the destruction of the last Neolithic village, the mound was resettled by Chalcolithic peoples, whose six centuries of residence, divided into five levels, ended roughly in 4800 B.C.

The findings at Hacilar will be described here in their chronological order, that is, from the bottom up. Their designations, however, were given in the order of their uncovering—from the top down. The five Chalcolithic levels at the top are Hacilar I (the latest) through V (the earliest). The four Neolithic layers are Hacilar VI through IX.

As with all prepottery cultures, relics in the Hacilar Aceramic mound are

ferent guises. The two basic physical types are shown at far left: one with pendent breasts and flat back and the other with pronounced buttocks. Next is the broken head of a statuette. At right the goddess is shown in a number of poses: as "mistress of animals" seated on a leopard, holding a child (*top*), sleeping and as a young girl. The figurines were all less than 12 inches high.

scanty. The architectural remains, however, testify to a settled village life. We do not know the size of this early village. The houses excavated are small but each has a few rectangular rooms. Their walls, set on stone foundations, were made of mud brick covered with mud or, in the best rooms, with a fine lime plaster. The plaster floors were stained red and burnished; occasionally the red pigment was applied in patterns on cream-colored plaster.

Having no ceramic vessels, the people probably used clay-lined baskets for cooking, and gourds, skins and stone bowls for containers. Except for the stone vessels, such utensils usually leave no trace, and Hacilar is no exception. Evidence of domestic pursuits could be seen, however, in the great communal courtyard north of the houses. It held the remains of grain bins, bread ovens and hearths. Putting the fireplaces in an open court reduced the risk of fire, and in fact not one of the seven building levels shows any signs of destruction by burning. Straw still lay on the court-

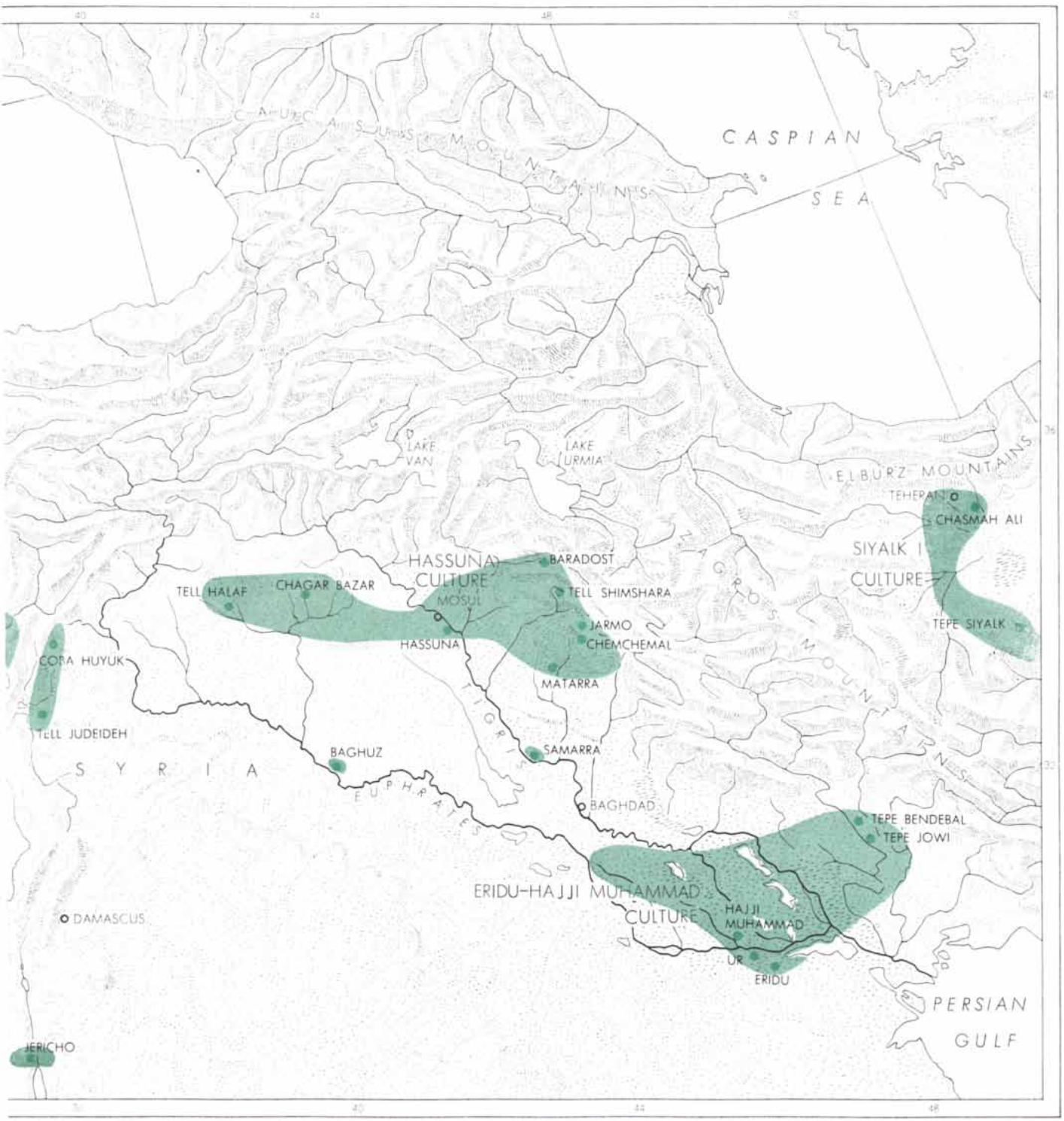
SPREAD OF EARLY CULTURES from the Near East into eastern Europe is suggested by this map, on which approximately contemporaneous late Neolithic to early Chalcolithic cultures are designated by the colored tone, and excavated sites within them by

yard floors. Together with the bread ovens it points to the practice of agriculture. There were bones of dogs, sheep, goats and cattle, all domesticable but not necessarily domesticated.

If these animals were wild and the early villagers hunted them, we do not know what weapons the hunters used. There were no lance- or arrowheads or slingstones. We found a few tools: awls of bone; axes of polished stone with handles of deer antler; numerous small blades (made of chert, the local flinty rock, or of obsidian), which may have been mounted in sickles.

No graves were uncovered. But human skulls, propped up with stones on the floors of many houses and at the corners of the hearths, indicate that the inhabitants practiced an ancestor cult, preserving heads to protect the home.

Settled occupation, primitive agriculture—perhaps with domestic animals—and rectangular houses of mud brick are typical of prepottery Neolithic culture in the Near East. The red plaster



colored dots. Archaeological findings imply links between the Syro-Mesopotamian cultures and Hacilar on the one hand and between Hacilar and such Balkan and Greek cultures as the Cris, Starčevo and Sesklo on the other. The open circles indicate modern cities.

TWO KITCHENS OF HACILAR VI in this photograph can be found on each side of the passageway in the center foreground of the diagram on the facing page. An oven is set against the screen wall of the nearest kitchen, with a hearth in front of it and a grinding platform with tools to the left. The measuring stick is graduated in one-foot intervals.

floors and the skull cult, however, are quite special. They provide an unmistakable link to the so-called Prepottery B Phase of Jericho in Jordan, which can be dated roughly between 6500 and 5500 B.C. At Jericho this culture was more advanced, and its equivalent at Hacilar, 300 miles to the north and 300 to the west, may be from an earlier time. Many students have suggested that the Jericho culture came from the north, and the finds at Hacilar agree with this view. With so much of the intervening country in Syria and southern Anatolia unexplored, however, one can do no more than draw attention to the remarkable similarities. The presence of obsidian at Jericho as well as at Hacilar is also noteworthy. The material at Hacilar undoubtedly came from volcanoes that were then still active in central Anatolia. It is possible that the stone at Jericho originated in the same place.

Why the early people abandoned their settlement at Hacilar we cannot tell. The site lay deserted for a long time. During the interval men learned to make pottery, and the newcomers who arrived about 5700 B.C. were experts in the art. Their pottery and also their stone bowls, clay statues and architecture vouch for an extended previous development elsewhere; what we found at Hacilar is the end product of a fully developed Neolithic culture.

Late Neolithic Hacilar lasted only about 300 years. Most of our information on it comes from the excavation of the last settlement, Hacilar VI, which was destroyed by fire. Such a holocaust means a rich find for the archaeologist: things are left at the site instead of being carried away by a migrating population.

The houses of this period were very large, consisting for the most part of an enclosed room some 18 feet wide and from 26 to 35 feet long, with access through a wide doorway in the middle of the long side [*see illustration on opposite page*]. Stout posts supported an upper story, which in one case was reached by a well-built exterior staircase with a balustrade. We do not know what the upper stories looked like, but they may well have resembled those in the modern houses of the region. The present architecture shows many resemblances to the late Neolithic, and the conservatism of the people makes this long ancestry not unlikely.

The house walls in Hacilar VI were about three feet thick, built of two rows of large, plano-convex mud bricks laid on stone foundations and carefully plas-

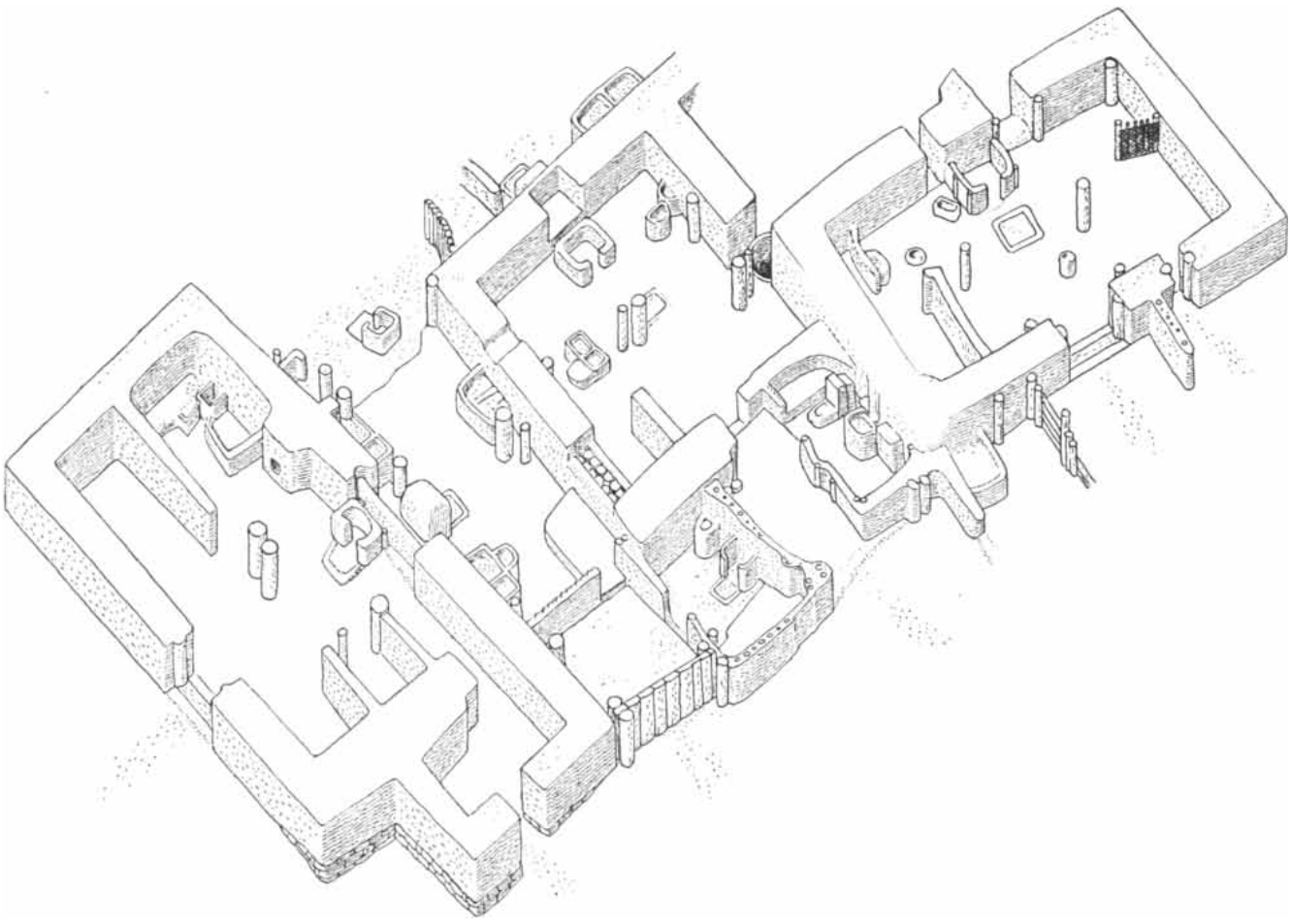
tered. Each building had a raised hearth and a flat-topped bread oven; a second fireplace was placed near a partition that screened off part of the room for greater privacy. Some of the houses had large wall cupboards; in one case three niches were built into a brick pillar to make a sort of chest of drawers. Near it was what seems to have been a peephole looking into the adjacent house; it was blocked up at some stage, perhaps by an irate neighbor.

In addition to the main room and upper story, each dwelling had at least one lean-to kitchen—lightly built of posts screened with plaster—next to the front entrance. These chambers contained platforms, grain bins, tables and a profusion of grinding and pounding implements. On many of the saddle-shaped querns, or grinding surfaces, crushed wheat, peas or lentils bore silent witness to the sudden disaster that had overwhelmed the settlement. (Some people were trapped in the fire, as the powdered remains of their bones show, but most of the population apparently escaped.)

Large deposits of carbonized wheat, barley, lentils, bitter vetch and peas found in all the houses indicate that the inhabitants were successful farmers. The sickles with which they reaped grain were made of deer antlers, polished and grooved to receive a row of small chert blades. With the sickles we found bone spatulas, or spoons, some with handles on which animal heads had been carved with great naturalism and delicacy. One bone spoon, unfortunately damaged, is decorated with a human figure wearing a horned headdress. Maces and slings seem to have been the primary weapons: we found large piles of pebbles and spheroidal clay pellets used as slingstones.

Among the stone implements white marble bowls are common. Some had three or four stumpy feet, and the largest ones were fitted with tubular lugs for handles. Stone was also used for beads, small mortars and pestles for grinding cosmetics, axes, chisels and polishing tools. Spindle whorls (stone disks with which a spindle was weighted) indicate that the people knew how to spin, and a textile impression on a pot shows that they could weave. Children played with marbles of variegated stone, and their elders indulged in a knucklebone game that is still played in Anatolia. Signs of prospecting and trading include obsidian from central Anatolia, red and yellow ocher from Lake Egridir to the northeast, sulfur from nearby Lake Burdur, shells from the Mediterranean, copper ore and various nonlocal stones.

The pottery of this period was a fine red, brown or buff burnished ware. Most of it is of a single color, but some pieces display rather simple linear designs in red on cream or white on red. In nearly every dwelling we found stone slabs reminiscent of Western monoliths in which a simple outline of a face—eyes,



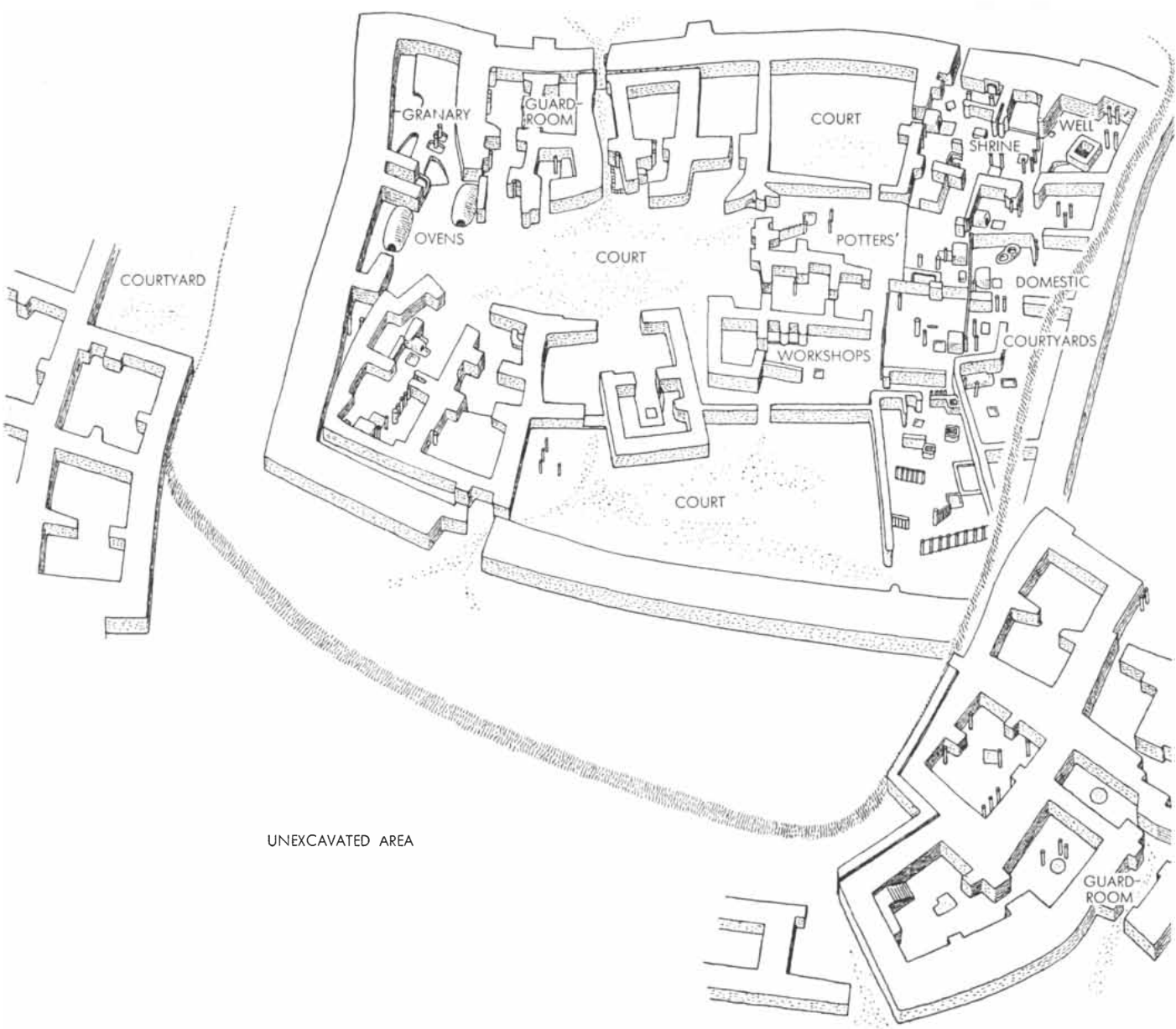
PLAN OF HACILAR VI was reconstructed by the author on the basis of excavated walls, postholes and other features. This diagram shows one section of the late Neolithic settlement. Each mud-brick house consisted of one large room on the main level; an upper story supported on posts was built of wood and therefore not preserved. Most of the clay figurines were found in these houses.

chin and hairline—had been cut. Two houses contained instead somewhat less primitive-looking doll-like clay idols. Both the slabs and the clay dolls, which apparently represented the protective spirit or genius of the house, provide evidence of a domestic cult perhaps related to the skull worship of the earlier period. Their crudeness is out of keeping with the other artifacts of Hacilar VI. They may well have been archaic heirlooms or carefully copied replicas, their form preserved by religious tradition.

A completely different artistic style is represented by the most striking relics of Hacilar VI: a collection of naturalistic statuettes of the Anatolian "mother goddess" [*see illustrations on pages 86 and 87*]. They give us, for the first time in Near Eastern prehistory, a reliable picture of what late Neolithic woman looked like, how she dressed and did her hair. The figurines are all less than 12 inches in height; they were made locally of clay, and many were unbaked. Originally they were buff, cream or red with burnished surfaces. Articles of dress are painted on the pieces; eyes, hair and other details are incised into the surface and sometimes emphasized with black paint.

Almost all the pieces show the goddess alone. When males appear, they are subsidiary—either children or lovers. Two physical types of woman are represented. One has a round head, pendent breasts and flat buttocks; the other and more common type, a long head, smaller breasts and very pronounced buttocks. Girls wear pigtails; matrons have their hair in a bun. Some figurines are adorned with tiaras, and the first type sometimes has a fringe of curls on the brow. None of the statuettes has a mouth. Evidently the late Neolithic concept of the ideal woman was one with her mouth shut. If there is any analogy with modern Hacilar, one can sympathize.

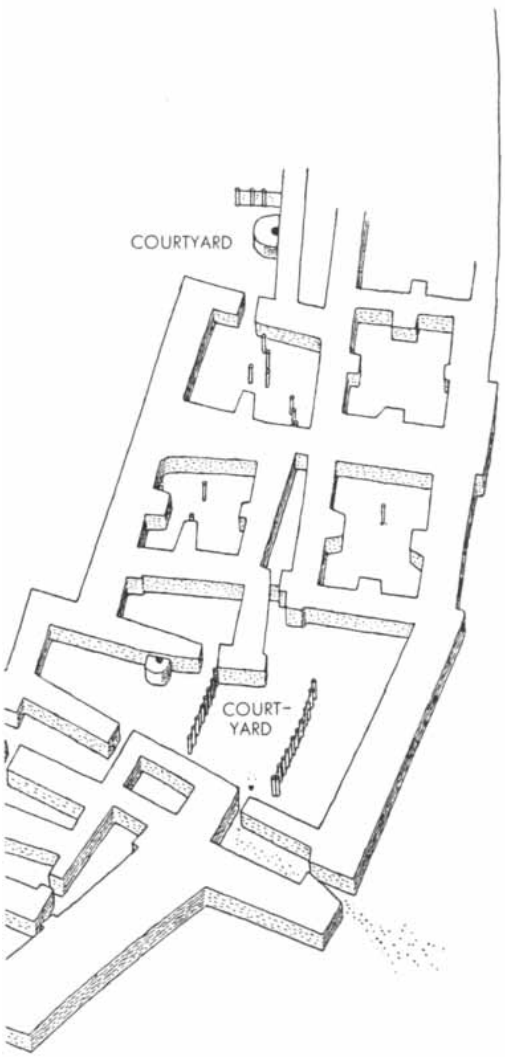
The girls wore very brief garments or loincloths. Some mature women appear in aprons, ankle-length dresses or grass



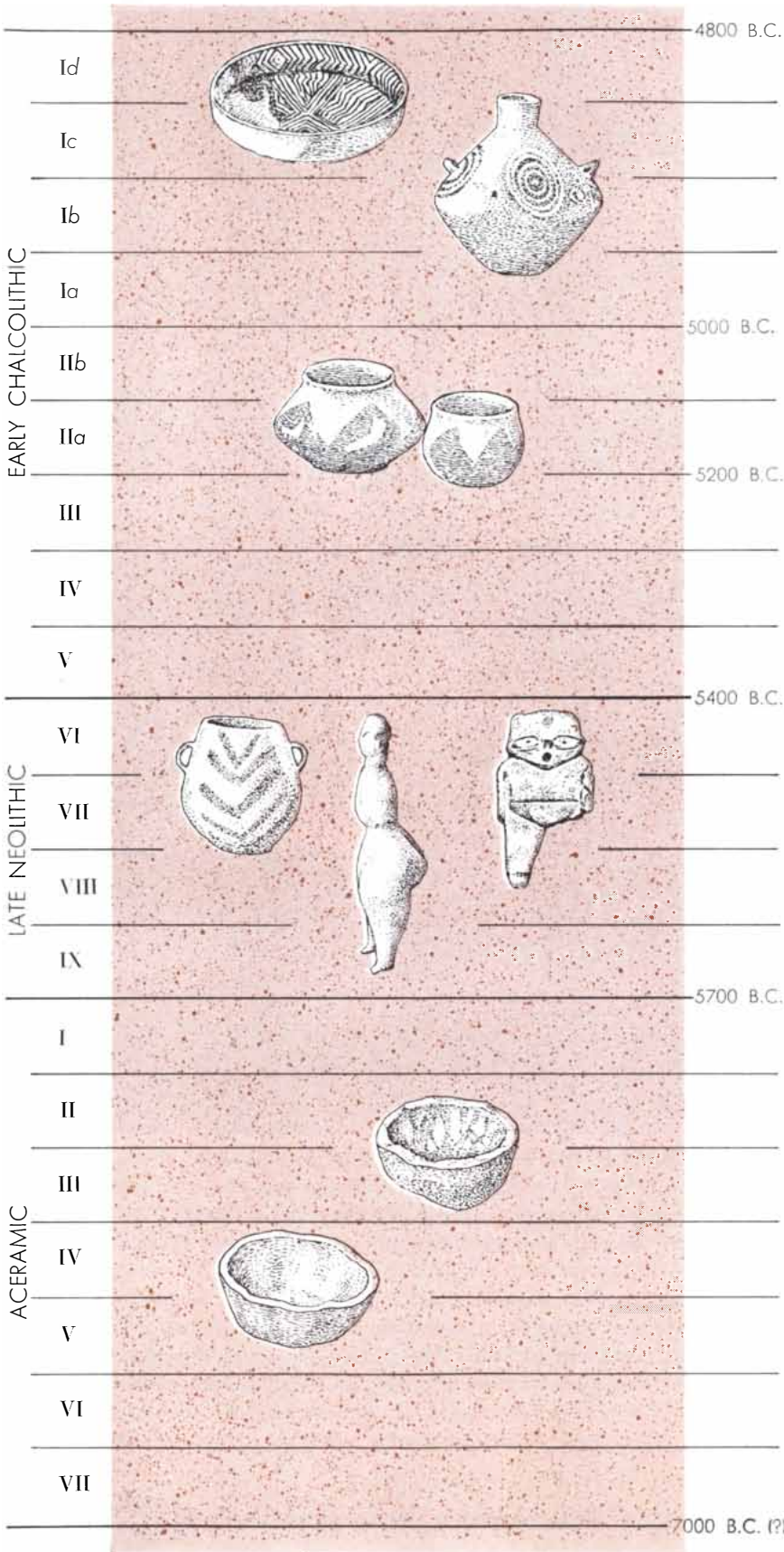
HACILAR II AND I are shown in relation to each other in this reconstruction. Level II, a fortified village, is the rectangular settlement in the center. The main characteristic of the community was specialization of function in distinct sectors of the village, most notably in the shrine. When Hacilar II was destroyed, the survivors leveled the ruins to make a central court around which

skirts, but most of the figures are naked. It would appear that the women of the time generally wore very little, at least in summer.

Some 25 of the small figures were found more or less complete. The various types together give the strong impression of outlining the life cycle of the goddess. Whether their makers practiced a monotheistic or polytheistic religion we shall probably never know; however that may be, all the figures represent a force of overriding importance in early farming communities: fertility. The goddess is seen lying down as well as standing. In some compositions she is embraced by an adolescent boy-god, the



they built a heavily fortified community. As the diagram shows, only a small part of the Hacilar I fortress has been excavated.



ARCHAEOLOGICAL SEQUENCE AT HACILAR goes back to Neolithic times. Here the various levels of the mound are shown schematically, with artifacts typical of each era. In the Aceramic period stone and gourd bowls were used instead of pottery. Hacilar I and II are subdivided, in the author's designations, to account for various phases of the same community. A gap of undetermined length intervened between Aceramic levels and Hacilar IX.

subject being handled with admirable taste and a mastery of modeling heretofore unknown until late classical times. Equally striking are groups showing mother with child. Finally, as a reminder that the goddess is mistress of animals, we find her holding a pet or standing or sitting on one or two leopards—the prototype of Cybele, the earth-mother of Phrygian Anatolia 4,800 years later.

This naturalistic late Neolithic art of Anatolia is some 7,500 years old; only the painted skulls of Jericho or the famous cave art of southwestern Europe can claim an earlier date. Nothing comparable in quality or in age has turned up in surrounding areas, yet the perfection of this work is such that it must have had forerunners during the early Neolithic period. But its ancestry and that of the remarkable culture to which it belongs remain to be discovered. This summer our group has started digging 150 miles east at Çatal Hüyük, which we hope will help to fill the gap between prepottery and late Neolithic.

With the great fire in about 5400 B.C. the Neolithic culture at Hacilar came to a sudden end. The next building level shows a slow transition to early Chalcolithic. The first copper implements appear, and with them painted pottery in force. At Hacilar, as elsewhere in southern Anatolia, these developments appear to have been gradual and local and to have owed nothing to foreign influences.

The survivors of Hacilar VI leveled the burned houses and probably built at first outside the area we have excavated. A succession of villages followed on the site, and the community's prosperity increased steadily. There is little more to say about levels V to III, but Hacilar II was also destroyed by fire and so it has provided a wealth of archaeological material.

A small fortified village of about 5200 B.C., Hacilar II measured only some 82 by 38 yards and was as usual built of mud brick [*see illustration on preceding two pages*]. A wall with bastions and buttresses surrounded it. Openings in the wall gave access to interior courtyards around which the houses were arranged. These were approximately rectangular, narrower and smaller than those of the late Neolithic period and less skillfully built. Each house had a small anteroom as well as a main room; again there was apparently a second story of light construction.

At this level we found evidence of a

new specialization in various sections and buildings. In the northwest corner of the community there was a granary filled with bins and with two large ovens for drying grain. A room near one of the entrances, with no doorway at ground level, probably served as a guardroom; the guard looked out through a narrow slit in the wall and in times of danger could slide large timbers through it across the entranceway.

Three buildings in the eastern part were potters' workshops. Their contents included unused pots, stones for grinding red and white ocher, cakes of ocher, paint jars, palettes and tools for modeling, burnishing and polishing. In the northeast corner lay a building that, unlike any of the others, preserved the late Neolithic floor plan and the flat-topped oven, posts and screen walls, cupboards and fireplaces. In one niche stood a large slab of stone with two libation holes and assorted pottery in front of it. Unfortunately the top of the stone was broken, so that we could not tell whether it had incised features like the idols of Hacilar VI. Under the floor we found one single grave and two double ones, each with a mother and child. No graves were uncovered in any other building.

All these features suggest that the structure was a place of worship. In Hacilar VI every house contained appurtenances of the domestic cult. In the Level II village sacred objects were confined to one building. Apparently the household-centered cult was shifting to a village cult; instead of worshiping in their homes, the early Chalcolithic men of Hacilar congregated in a communal shrine.

The truly superb pottery of this period developed out of the late Neolithic, some still in monochrome but most of it gaily painted in red on cream. Geometric patterns, many derived from textiles or woven mats, prevailed in the early phases of the period; later the patterns took on bold curves, the so-called fantastic style.

The clay statuettes of the mother goddess were still made in Hacilar II, but with less artistry, less naturalism and less variety. The goddess was shown only in the standing position, and the figures had become conventionalized fertility sym-

ASSORTMENT OF POTTERY from three levels of Hacilar shows how the style changed. In the top row are a cup from Hacilar VI shaped like a woman's head, and two pots from Hacilar II decorated in red on cream in the "fantastic" style. In the bottom row are three pieces from Hacilar I: two ovoid jars and a large open bowl. The bowl shows the linear designs that were introduced in that period.

ANCESTOR WORSHIP in the earliest (Aceramic) community at Hacilar is suggested by these human skulls, which were found propped on the virgin-soil floor at the bottom of the mound. Skulls were also found on hearths at this level. The yardstick shows the scale.

DOMESTIC CULT in Hacilar VI, perhaps related to early skull worship, is indicated by stone idols found in most houses. This three-inch-high slab has facial features cut in it.

bols rather than the inventive art form they had once been.

Hacilar II was destroyed by enemy action. This time the new occupants were apparently a nonlocal people, although probably from within the Hacilar cultural zone. They leveled the ruins of the burned village, cut down and terraced the slopes of the old mound. Around it they built a roughly circular fortress with a diameter of about 160 yards; the surface of the mound became a great central courtyard some 100 yards across. Whereas Hacilar II probably had a minimum population of 100 to 150, the fortress may have accommodated 500 to 1,000 persons, and Hacilar I should perhaps be regarded as a royal castle rather than just a fortified village.

The fortress was again constructed of mud brick, and the walls were enormously thick—in many cases out of all proportion to the rooms they enclosed [*see illustration on pages 92 and 93*]. We found no doors in the excavated walls. It is the basement of the fortress that is preserved, and it was inaccessible from ground level. All the rooms were entered from an upper story or stories built largely of wood, where the inhabitants probably lived—just as the local peasants do nowadays in summer.

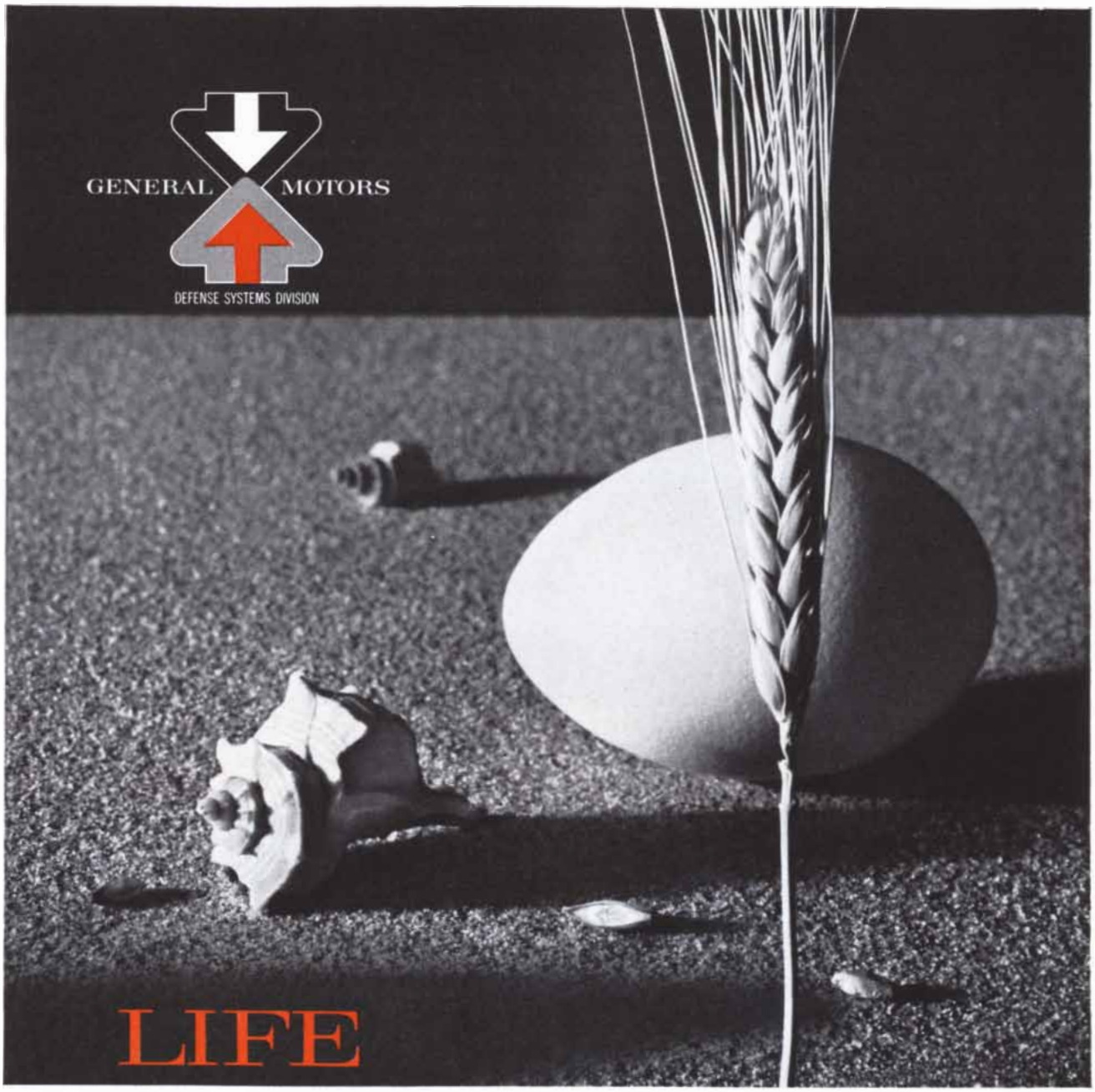
The economy of Hacilar I represented little advance over that of the previous level. The people had few metal tools as yet and still used implements of polished stone set in antler hafts.

The clay figurines and the pottery were still in the basic Hacilar tradition. The figurines, however, had become still more stylized, whereas the pottery displayed an increase in the number and variety of shapes. Most of it was decorated in a linear style quite unlike that of Hacilar II.

The Hacilar I fortress was invaded and destroyed in turn. It must have been hard to breach, but once it gave way its occupants had no chance. As the upper stories collapsed and burned the people were trapped in the basements, where we found masses of calcined human bones, broken pottery and thick ashes. After this disaster the survivors seem to have made two attempts to resettle the site, but they built only poor hovels of which not much remains. The arrival of barbarians had put an end to one of the most artistic cultures the Near East has ever seen. Hacilar vanished without exercising any direct influence on its successors on the Anatolian plateau, but by the time of its violent end it had served to pass on Neolithic culture to the continent of Europe.

A HOUSE OF HACILAR VI lies open to the sunlight after seven millenniums. The thick mud-brick walls are still well preserved, as are the flat hearth and the oven (*left foreground*) and an exterior staircase (*right foreground*) that once led to a wooden upper story.

OBLIQUE VIEW OF SAME HOUSE shows a large posthole in the floor and a cupboard in the side wall at the right. The main entrance is in the foreground, and two small fireplaces can be seen in the corner (*center*). The walls are about three feet thick.



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Enzymes in Medical Diagnosis

Certain diseases are accompanied by changes in the enzyme content of the body fluids. Already used in some diagnoses, these changes may make it possible to detect a cancer before it is a malignancy

by Felix Wróblewski

Enzymes are manifestations of nature's impatience. They are catalysts; as such, they serve to speed up the chemical reactions that constitute the processes of life, making reactions proceed spontaneously that might otherwise require a millennium for completion. The kinds and amounts of enzymes secreted by the cells of a particular organ of the body are highly specific to the function of that organ. One complement of enzymes in lung tissue promotes the dissipation of carbon dioxide and the accumulation of oxygen; an entirely different enzyme system in the kidney triggers the reactions that conserve sugar and discard urea. Thus enzymes account in good measure for the growth, respiration, excretion, secretion and other vital processes that go on in the human body.

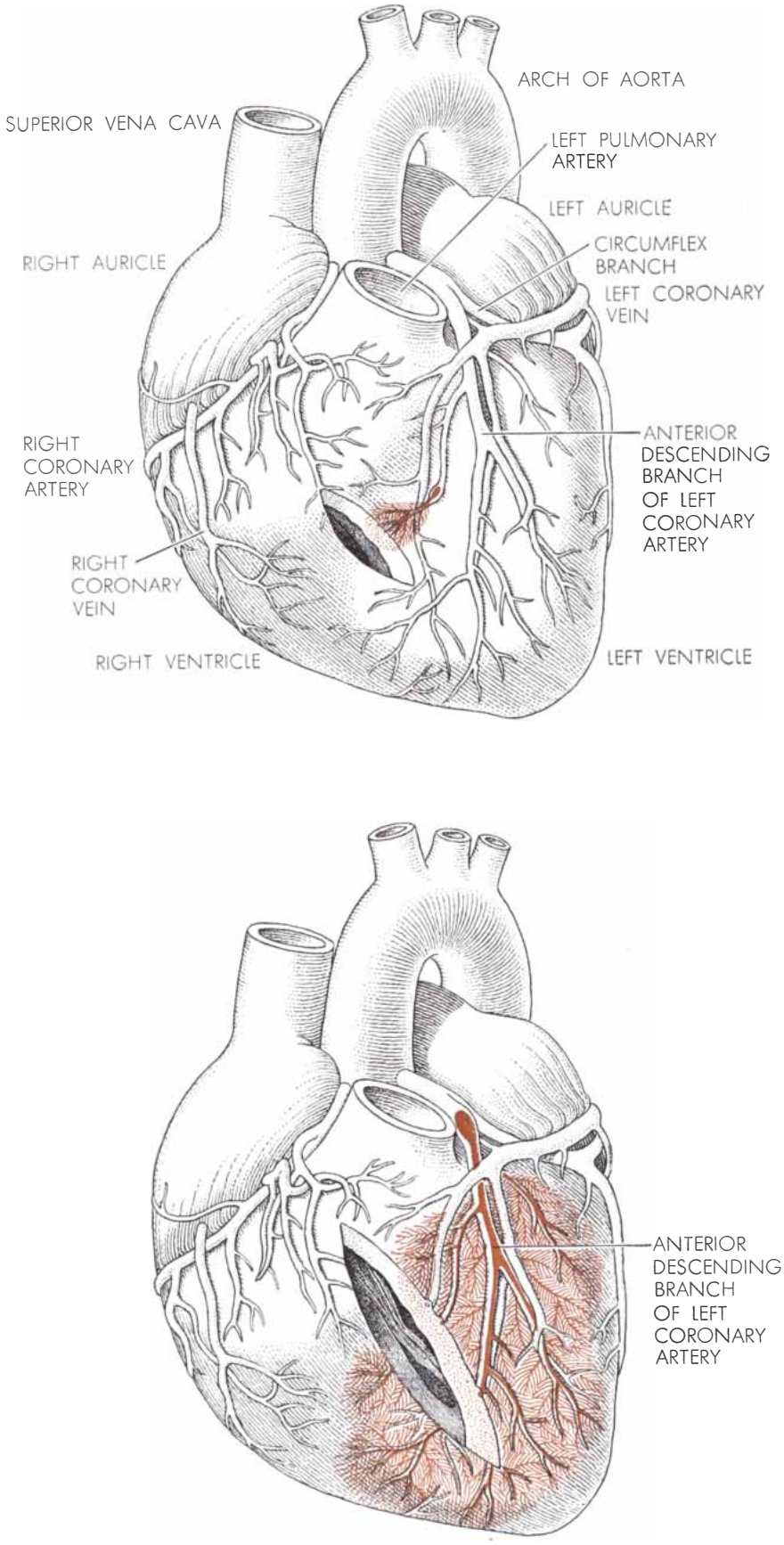
For the most part enzymes carry on their work inside the cells; it is there that the biochemical reactions they mediate are translated into the physiological activities of tissues and organs. The extracellular body fluids such as urine, bile, blood plasma and cerebrospinal fluid usually contain only infinitesimal quantities of enzymes. Recently, however, it has been learned that the enzyme content of one or another body fluid will increase precipitately in the course of various diseases. Because the enzymes that show up in the fluid are characteristic of the organ affected, the identification of the enzyme and the measurement of the quantity present in the fluid can tell a great deal about the disease. Physicians accordingly are learning to use routine laboratory tests to maintain surveillance over the enzymes in the blood plasma after heart attacks, in hepatitis and other liver diseases, in various bone and pancreatic maladies and in cancer of the prostate gland. Such tests now facilitate the diagnosis and management of these conditions. There is hope that one day they will detect the presence of at least some forms of cancer before the appearance of the symptoms that so often give their warning too late.

The idea of assaying the body fluids for their enzyme content occurred to me in 1950 when I was studying under Oscar Bodansky at the Sloan-Kettering Institute in New York. We were working in the knowledge that disease processes invariably involve abnormalities in the amount, kind and behavior of enzymes within the cells. Because each enzyme usually mediates only one step in the long chain of reactions involved in the synthesis or breakdown of a compound, enzymes characteristically operate in teams. Diseases disrupt these interlocking enzyme systems much as though a crowbar were jammed in a train of gears. The disease may cause a shortage of a particular enzyme, interrupting a chain of reactions. Some diseases damage the cell wall, allowing enzymes to leak out at a rate faster than the rate at which the cell can replace them. Other diseases provoke cells into the pathological overproduction of an enzyme.

The object of our studies was to develop methods for measuring the enzyme changes peculiar to various diseases. In practice it is difficult to take samples of tissue from the body; biopsy necessarily involves some inconvenience and risk. I decided to investigate instead the possibility that the enzyme content of body fluids might reflect some of the enzyme changes associated with disease.

The ready availability of the fluids, particularly blood plasma and that fraction of it known as serum, suggested that "biochemical biopsy" would prove to be a much more feasible procedure. Because enzymes are so specific in their action, it was also apparent that the assay of the fluids could be conducted with ease and certainty. The standard method of identifying and measuring the quantity of an enzyme is to mix the sample containing it with a quantity of the compound with which it reacts (its "substrate"). The rate at which the substrate is transformed by the reaction, determined by the measurement of the product of the reaction or the amount of substrate remaining after a given time, provides an accurate estimate of the quantity of the enzyme in the sample. The determination can be made in a number of ways, all of them within the competence of a clinical laboratory. One can extract the substrate or the reaction product from the solution by chromatography and measure the quantity present. The measurement can also be made without extracting either compound from solution. The technique of colorimetry employs a dye that has an affinity for one of the compounds; with the dye mixed in the solution, the extent of the reaction and hence the quantity of enzyme is measured by the depth of color. Spectroscopy can make the measurement while the reaction is going on, by monitoring the variation in the intensity of a specific wavelength of visible or ultraviolet light transmitted by the solution. In some reactions spectrofluoroscopy yields a similar result; under ultraviolet light the solution fluoresces with changing intensity as the reaction proceeds.

A simple experiment with a dog demonstrates the effectiveness of biochemical biopsy. A string tied suddenly and tightly around one of the dog's coronary arteries causes a heart attack similar to that which occurs in a human being when a thrombus, or blood clot, occludes a coronary artery and cuts off



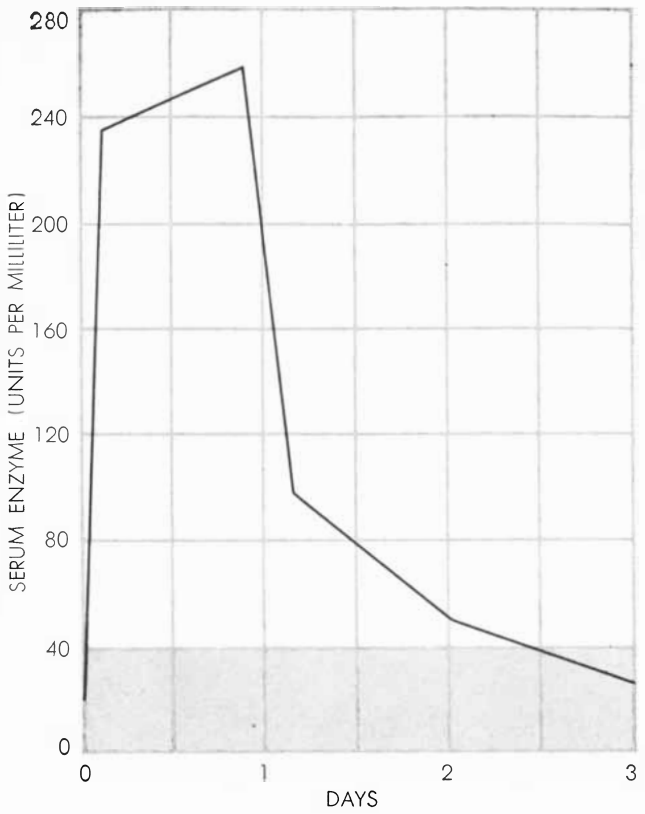
CORONARY-ARTERY OCCLUSION causes cells of the heart muscle to die. The arteries shown in color no longer carry nutrients and oxygen to the muscle. A small heart attack is shown at top, a fatal one at bottom. Such heart attacks are always followed by an increase in the enzyme glutamic oxaloacetic transaminase in the bloodstream of the patient.

the supply of blood to part of the heart muscle. The cells that normally receive oxygen and nutrients through the artery begin to die, and the tissue in that region of the heart breaks down. Heart muscle, unlike other tissue, is particularly rich in the enzyme glutamic oxaloacetic transaminase. Within six hours after the induced heart attack, the serum fraction of the blood plasma of the dog shows large quantities of this enzyme. Examination of the dog's heart at autopsy reveals that the damaged tissue contains far less enzyme than the rest of the heart muscle. It is obvious that the enzyme in the plasma came from the cells destroyed by the coronary occlusion.

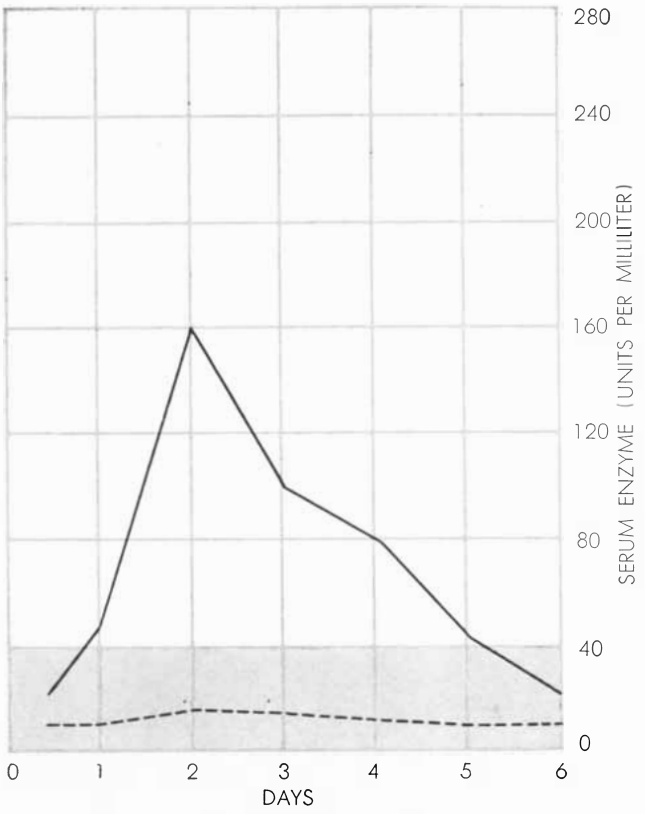
A human being who suffers a coronary occlusion followed by damage to the heart muscle also displays a marked increase in the concentration of glutamic oxaloacetic transaminase in his blood serum. At present the physician usually relies on the electrocardiograph, which measures the electrical impulses generated in the heart muscle, to make his diagnosis and to estimate the extent of damage. But in patients who have had a previous heart attack the electrocardiogram is often so distorted that the physician cannot tell if the patient's pain and other symptoms are caused by a new coronary occlusion and cannot determine the extent of the new damage. An assay of the blood serum for glutamic oxaloacetic transaminase quickly dispels such uncertainty.

Normally the amount of the enzyme in the serum does not go above 40 units per milliliter of serum. In a typical coronary patient it may rise to 110 units 24 hours or so after the attack. By the second day it may reach 240 units. Then it tends to fall on successive days to 180 units, 70 units, 50 units and, on the sixth day, back to normal, somewhere below 40 units. The serum assay not only confirms the diagnosis but tells the extent of the damage to the heart. A maximum level of 80 to 150 units indicates limited damage, whereas a measurement of 250 units or more shows that the damage is extensive. Such knowledge enables the physician to make a prognosis of the eventual degree of recovery or disability the patient can anticipate.

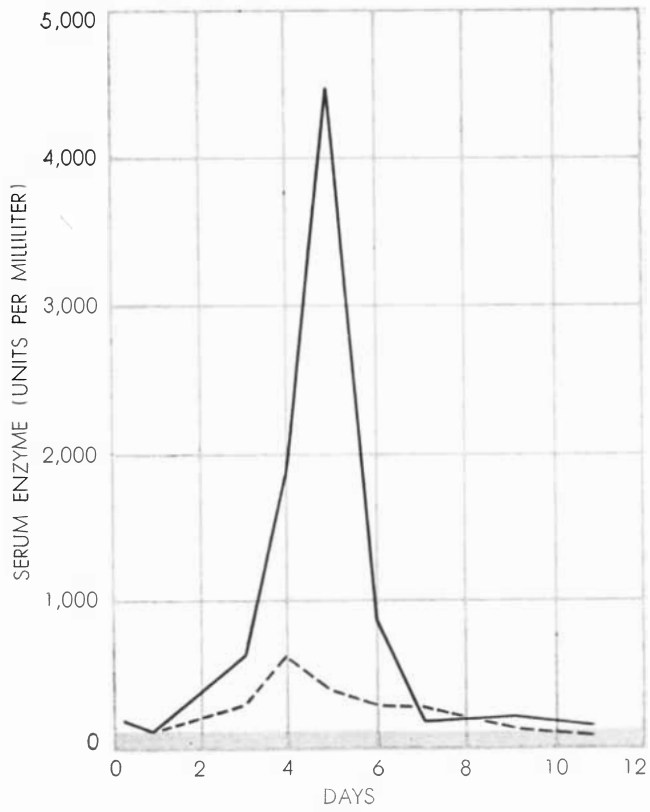
Not all diseases cause the breakdown or death of tissue, yet they may be attended by impressive increases in the enzyme content of the body fluids. In the mouse, for example, the liver normally contains a moderate amount of the enzyme glutamic pyruvic transaminase. A mouse inoculated with the virus of



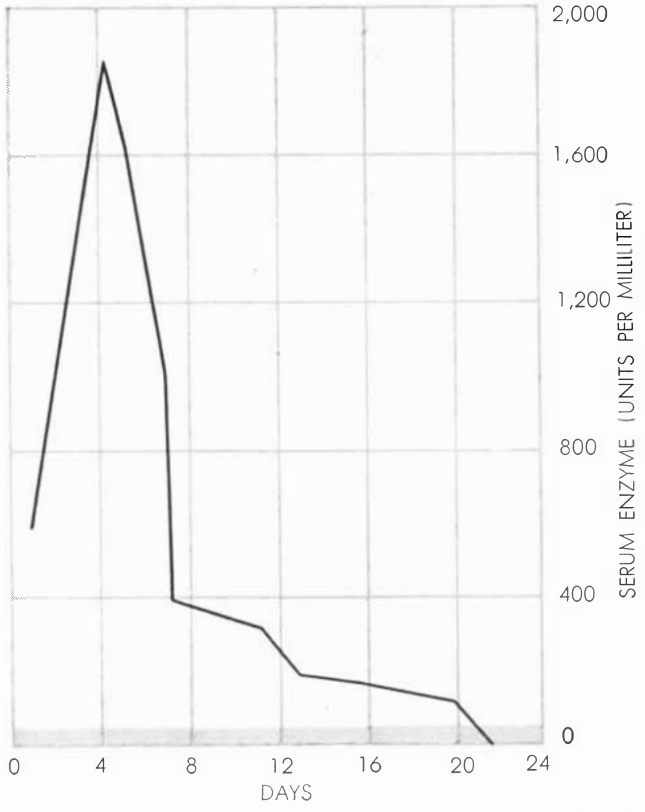
ACTIVITY OF ENZYME glutamic oxaloacetic transaminase in blood serum of a dog increases after experimentally induced heart attack. Time scale is days after attack. Shaded area in this and the following five diagrams indicates normal range of enzyme in serum.



ACTIVITY OF SAME ENZYME in blood serum of human patient also increases after a heart attack. The broken line represents serum level of another enzyme, glutamic pyruvic transaminase, which does not show an increase following heart attack.



EXPERIMENTAL HEPATITIS in two mice causes rise in glutamic pyruvic transaminase. Solid curve shows worse infection in one because it received 100 times as much hepatitis virus as the other.



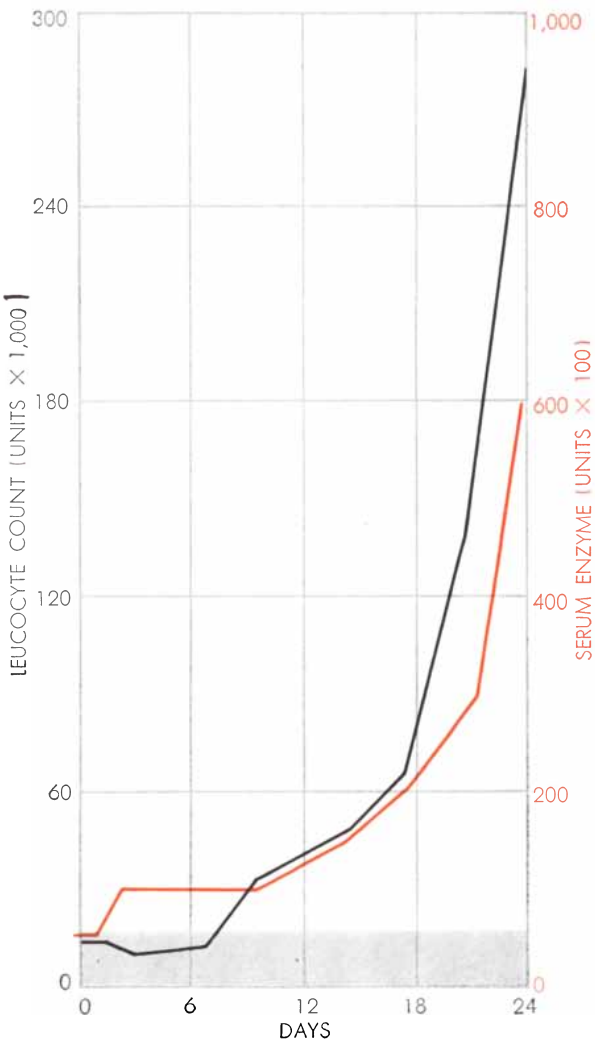
HUMAN HEPATITIS PATIENT had glutamic pyruvic transaminase assayed after exposure to disease. Increase was apparent several days before other symptoms. Jaundice appeared on fourth day.

mouse hepatitis, a disease similar to infectious hepatitis in man, develops inflammation of the liver and jaundice. Although the quantity of the enzyme in the liver drops only slightly, the diseased organ apparently elaborates it in large amounts, because it appears in large quantity in the bloodstream. Moreover, the concentration of the enzyme in the serum reflects the severity of the infection from day to day.

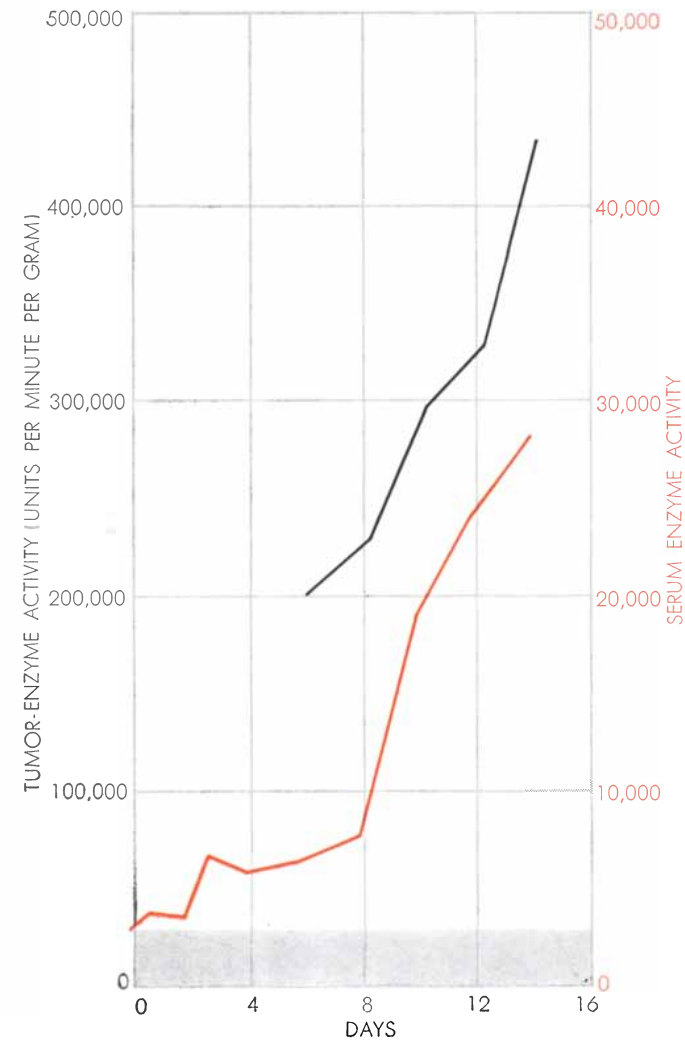
The same enzyme has proved to be a sensitive index of human infectious hepatitis. Before the familiar symptoms of the disease appear, the serum concentration of the enzyme rises to 10 times the normal level, reaches a peak when the patient is sickest and falls gradually as he recovers. Biochemical biopsy in this disease provides an exceedingly useful and objective method of following the course of the disease and planning the treatment. It also makes unnecessary the somewhat hazardous procedure, often invoked in the past, of taking a sample of liver tissue for microscopic examination.

The fact that the procedure offers a means of detecting hepatitis before symptoms appear makes it particularly useful in epidemics and in family situations where people have been exposed to the disease. Those who show a rising concentration of the liver enzyme in their serum can be given gamma globulin, the fraction of blood serum that carries passive immunity, in order to arrest or at least attenuate the infection. What is more, for every hepatitis patient who develops jaundice or distressing symptoms, there are between five and 15 infected individuals who have no jaundice and do not become very ill. They are nonetheless carriers of the disease and can unknowingly transmit it by contact and through excreta. The serum assay can identify such individuals and show when they have recovered.

The detection of hepatitis before the appearance of symptoms lends support to the hope that enzyme changes in the blood may facilitate the early detection of internal cancers. Here the enzyme involved, lactic dehydrogenase, has been observed in tissue cultures of malignant cells from both animal and human cancers; the fast-growing cells liberate the enzyme in quantity into the culture medium. That the enzyme is associated somehow with the malignant transformation of the cells is indicated by the fact that the equally fast-growing amniotic cells from an embryo and the rapidly dividing fibroblasts, or scar-tissue cells, do not secrete the enzyme into tissue-culture media. The same contrast between



VIRUS LEUKEMIA in the mouse causes an increase in the enzyme lactic dehydrogenase (*colored curve*), shortly after inoculation with the virus and before the characteristic appearance of increased leucocyte count (*black*). As disease advances, they rise together.



MALIGNANT TUMOR transplanted into a mouse causes rise in lactic dehydrogenase (*color*) in the blood serum. The enzyme also increases in the tumor. (Assays of the tumor were started six days after the transplant.) Rise in enzyme continues until animal dies.

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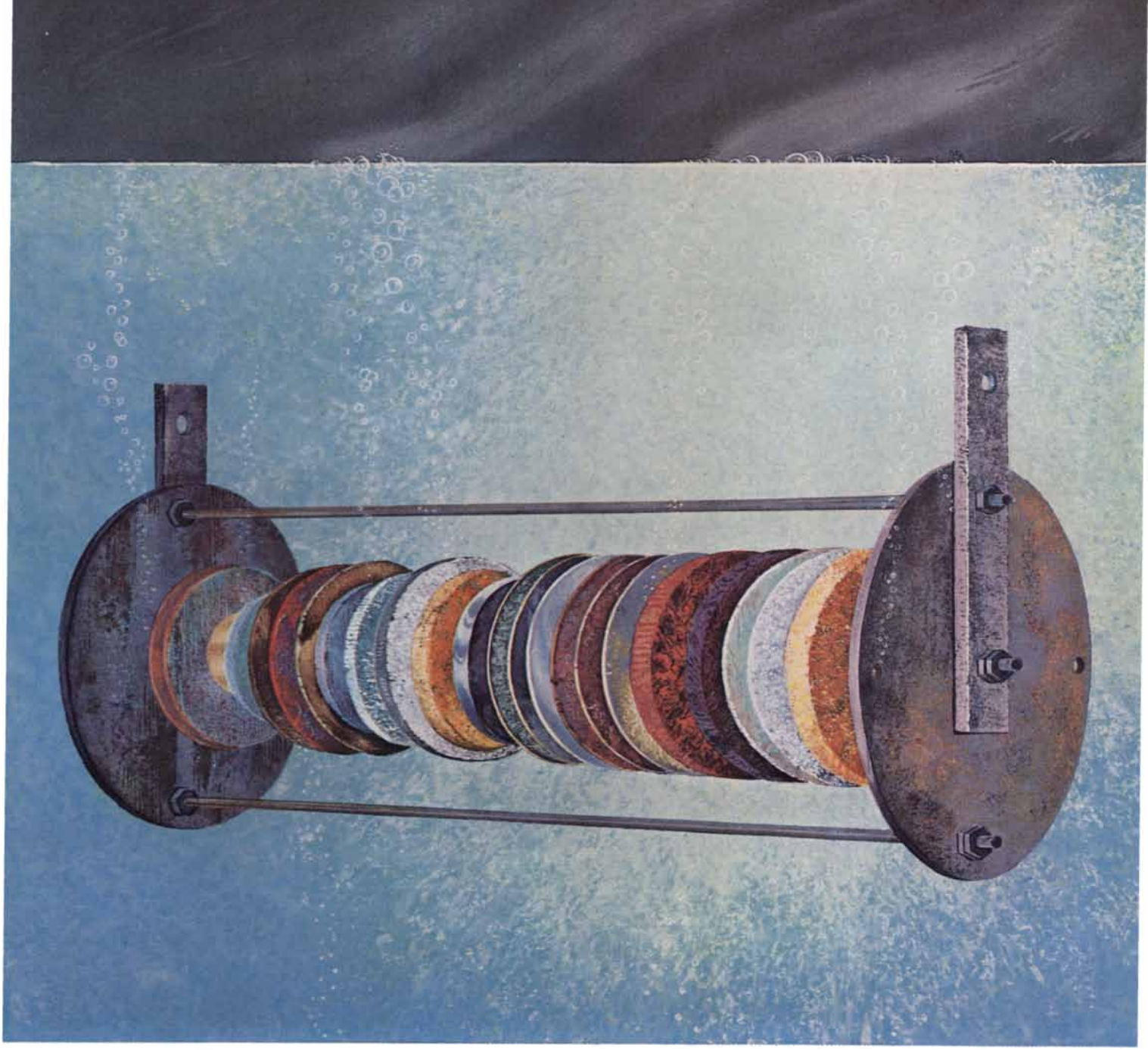

THE COUNTERATTACK ON CORROSION

The basic cause of corrosion is the instability of metals in their refined forms. Because of this, the metals tend to revert to their natural states.

The practical question is how long can a metal resist a corrosive environment?

There are as many answers to this question as there are combinations of metals and environments. In the most aggressive corrosive media, such as encountered in chemical processing equipment, the several controlling factors, composition, temperature, agitation, dissolved gases, etc. are so variable and complex that it is usually impossible to duplicate them in any laboratory experimental setup.

Inco's Research answer has been to make the processing equipment its own testing ground. By means of Corrosion Test Spools, specimens of a variety of materials can be exposed under the actual conditions of use.

Such test assemblies as introduced by Inco are being used throughout the world as a standard procedure and meet the requirements of the American Society for Testing Materials Recommended Practice for Conducting Plant Corrosion Tests—A 224-46.

Results of such tests afford a reliable guide to the selection of materials for corrosive services and for the estimation of their useful life.

Inco Research has recorded results of over 60,000 tests of this sort. Such data in hand may serve to answer your plant corrosion problems. Otherwise, Inco Research will cooperate in plant test programs to find a specific answer to your particular problem.

THE INTERNATIONAL NICKEL COMPANY, INC.
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INCO RESEARCH

malignant and normal cells can be demonstrated in the intact animal. If half the liver of a normal mouse is surgically removed, the liver proceeds to grow as fast as a malignant tumor, recovering its normal size within 10 to 12 days. Yet the amount of enzyme in the plasma remains normal.

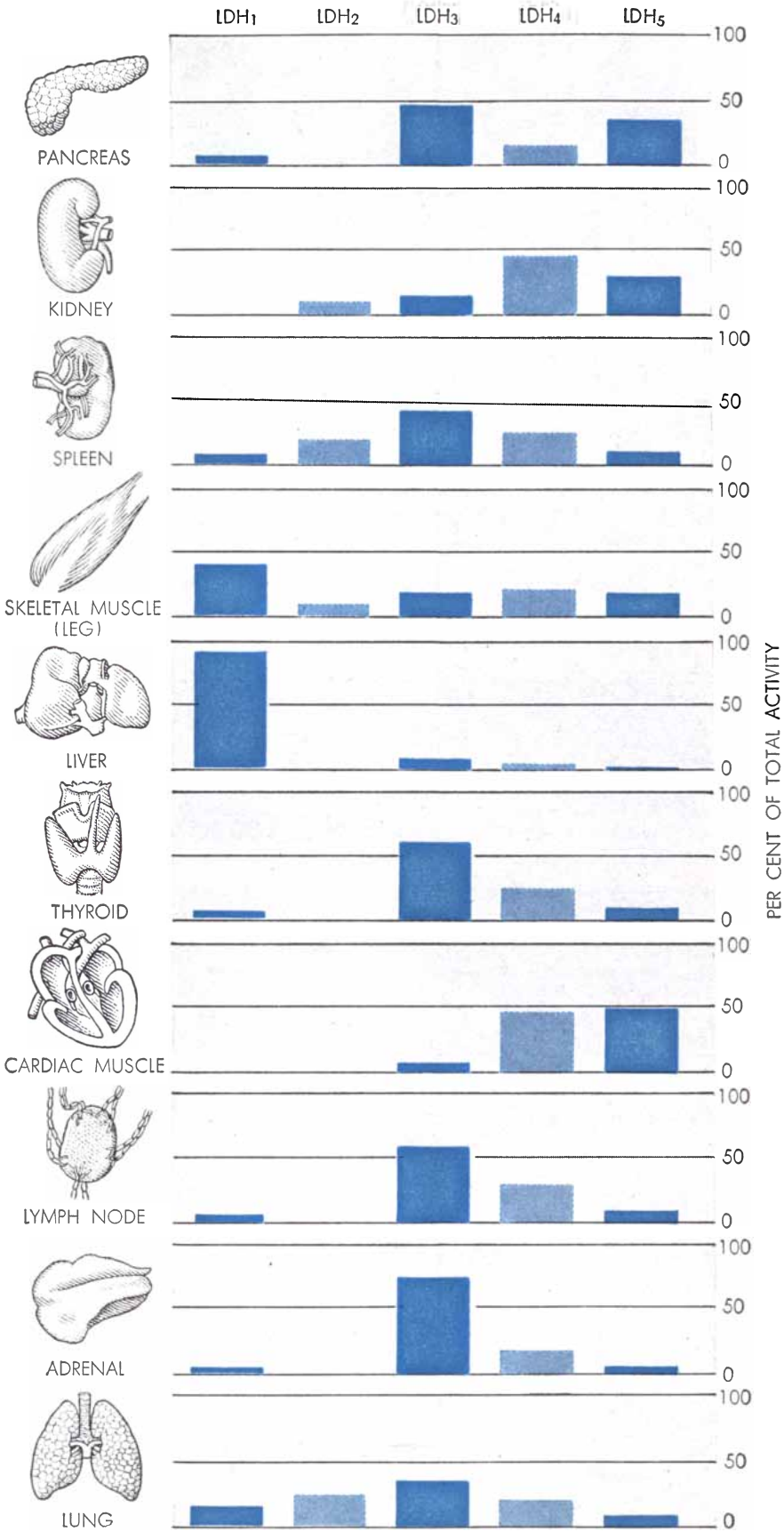
The measurement of lactic dehydrogenase in the blood serum of mice that have been given experimental cancers has given encouraging results. All types of mice have been subjected to all types of experimentally induced malignant processes, including carcinoma, sarcoma and leukemia. In each case the concentration of enzyme in the plasma has risen before any other evidence of malignancy appears. The concentration continues to rise, accurately reflecting the growth of the tumor or the increase in the number of leukemic cells. When treatment makes the tumor or leukemia regress, the enzyme disappears from the blood in direct proportion to the improvement.

These results are paralleled by observations of the concentration of the same enzyme in the plasma of human beings suffering from myelogenous leukemia, a disease characterized by an extremely high count of polymorphonuclear leucocytes, the most numerous of the white cells in the bloodstream. The concentration rises markedly as the disease progresses; it falls when treatment brings a remission. An increase in the concentration always accompanies a relapse and has been observed at times to precede it.

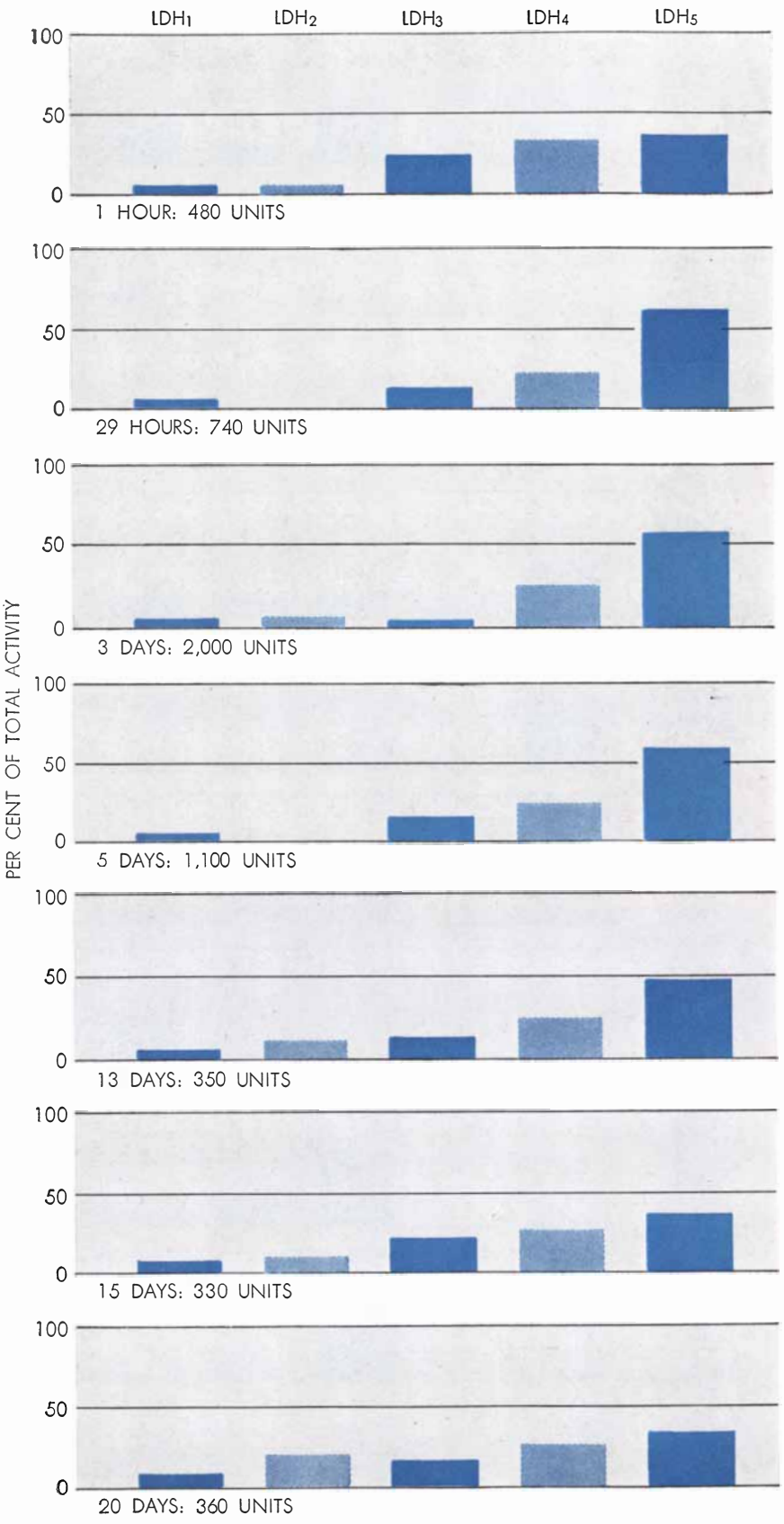
In contrast, no such change in the concentration of lactic dehydrogenase appears in the plasma of patients with the nonmalignant disease polycythemia vera, which involves a pathological multiplication of all types of red and white blood cells and even of the blood platelets. Occasionally polycythemia vera changes into myelogenous leukemia. In these cases the plasma concentration of the enzyme rises rapidly before there is any other evidence of the transformation from the nonmalignant disease to the malignant one.

Elevations in the concentration of lactic dehydrogenase accompany other types of human carcinoma and sarcoma, and variations in the concentration have also been observed to reflect the course of the disease as remissions and relapses occur. Biochemical biopsy has not yet, however, served to detect human cancer in advance of other symptoms.

James M. MacMillan, medical director of the Reynolds Metals Company, and I are now conducting an experiment with



ISOENZYME COMPOSITION of the enzyme lactic dehydrogenase (LDH) varies widely in human tissues. The one enzyme consists of five subtly different "isoenzymes." Different tissues can possibly be identified by the various amounts of LDH isoenzymes they contain.



DISEASE IS REFLECTED in the LDH isoenzyme changes in blood following a heart attack. Hours or days under the sections indicate time after the attack. Units refer to total LDH in blood. Each of the isoenzymes is responsible for a portion of the total LDH activity.

the help of 300 male employees of his firm over the age of 40. We are measuring the plasma concentration of the enzyme in each man once every four months for five years. In a group of this size five to 10 can be expected to develop cancer during that period. If they do, we will be able to see whether the concentration rises in humans, as it does in mice, before the appearance of malignancy.

Within the past three years a new dimension has been added to the diagnosis of disease through enzyme assays. Each enzyme had been thought to be a single entity, homogeneous and distinct, but in 1958 electrophoretic studies showed that some, if not all, enzymes take several forms. The members of a given enzyme species have a strong family resemblance, but chemical, physical and immunological tests show them to be subtly different. For example, one form will react with the substrate faster than another. These so-called isoenzymes may be separated from one another by a technique that combines the principles of chromatography and electrophoresis. A purified sample of the enzyme is placed on a thin sheet of starch gel, through which an electric current is passed. In the electric field the different forms of the enzyme migrate from the starting point at different speeds, gradually separating out on the gel. By this procedure lactic dehydrogenase from human plasma has been shown to consist of five isoenzymes. The lactic dehydrogenase of the mouse has three isoenzymes, and they are all appreciably different from the human forms. The enzyme alkaline phosphatase consists of at least four isoenzymes; two other enzymes, esterase and leucine aminopeptidase, each have three or more forms.

This knowledge gains significance from the finding that the isoenzymes of a given enzyme occur in characteristically different ratios to one another in different tissues. Heart muscle is rather rich in the isoenzymes of lactic dehydrogenase designated LDH_4 and LDH_5, but it has little LDH_3. About 90 per cent of the lactic dehydrogenase in the liver is LDH_1. In skeletal muscle the enzyme assays 50 per cent LDH_1 and small amounts of the other isoenzymes. It now appears that human tissues and organs can be identified almost as precisely by their enzyme and isoenzyme content as they can by their macroscopic and microscopic appearance.

Plasma and serum from normal human individuals have a low concentration of lactic dehydrogenase, but, like tissue extracts, the blood fluids show all five

isoenzymes. By analogy, the total concentration of the enzyme in the serum may be compared to the total leucocyte (white blood cell) count, and the isoenzyme composition of the total may be likened to the differentiation of the total leucocyte count into percentages of eosinophiles, basophiles, lymphocytes, monocytes and polymorphonuclear leucocytes. The serum isoenzyme pattern for any one individual remains fairly constant and can be considered a biochemical fingerprint of that individual. In disease, however, the ratios of the isoenzyme constituents present in the serum tend to change. Such changes in the isoenzyme ratio of, say, lactic dehydrogenase may appear with no change in the total concentration of the enzyme in the serum. Apparently the diseased organ contributes the isoenzymes in which it is particularly rich, and the homeostatic forces that maintain the chemical equilibrium of the body remove other isoenzymes from the plasma so that the total concentration of the enzyme remains nearly the same.

The assay for isoenzymes in these cases promises to make the technique of biochemical biopsy more specific and more sensitive. A coronary occlusion that damages the heart and liberates quantities of glutamic oxaloacetic transaminase also alters the total activity of lactic dehydrogenase in the plasma, and isoenzyme assay reveals an increase in LDH_5. Hepatitis patients have plasma rich not only in glutamic pyruvic transaminase but also in LDH_1, though the plasma shows only a moderate rise in the total activity of lactic dehydrogenase. The serum of patients with thyroid diseases shows a preponderance of LDH_2 or LDH_3, both of which the thyroid contains in abundance. These correlations give reason to hope that isoenzyme assays may be a way to identify the type of tissue and the organ affected by otherwise undiagnosed disease.

The analysis of enzyme and isoenzyme changes is now being extended from the blood plasma and serum to other fluids. Recent studies indicate that urine, bile, gastric and duodenal juices and cerebrospinal fluid will provide useful information, though the blood will undoubtedly remain the most important fluid in diagnosis by biochemical biopsy. Only a few of the vast number of enzymes known to biochemists have been explored and put to use for diagnostic purposes. Many more await study. They are sure to receive attention, because enzyme and isoenzyme assays are developing into powerful diagnostic tools.

The Life Span of Animals

What makes man and other animals age? One approach to the problem is to reflect on age records and to study the effects of different factors on the longevity of experimental animals

by Alex Comfort

"Touching the length or shortness of life in beasts," wrote Francis Bacon, "the knowledge which may be had is slender, the Observation negligent, the Tradition fabulous." The problem of getting accurate information about animal life spans has changed little in the three centuries since Bacon published his *History of Life and Death,* but the importance of such studies has increased greatly in the past few years. Now, as then, there is the hope that human life may be prolonged by interfering with the process of natural aging. Besides this, in radiation research, in experimental gerontology and in several other fields of practical importance, it has recently become necessary to draw accurate comparisons between the life spans of different species of animal, and the attempt has brought home to biologists just how negligent and fabulous the observation and the tradition have been.

Aging, or senescence, means a decline in vigor with the passing of time, which shows itself as an increased probability of dying. There is still no generally accepted theory to explain aging, nor is it safe to assume that aging is an inevitable consequence of living. Among warm-blooded animals aging is almost certainly universal; it may be universal in other vertebrates, but in some, such as large fishes and tortoises, the process is so slow as to be almost undetectable. In other forms, particularly invertebrates, aging may not occur at all.

An animal that does not age is not to be regarded as immortal. Its advantage is simply that it is no more likely to die as it grows older. It still dies, but from a cause that would have killed it at any age. The life span of such an animal resembles that of a radioactive element: it must be given in terms of a "half-life," the time required for half of a population to die.

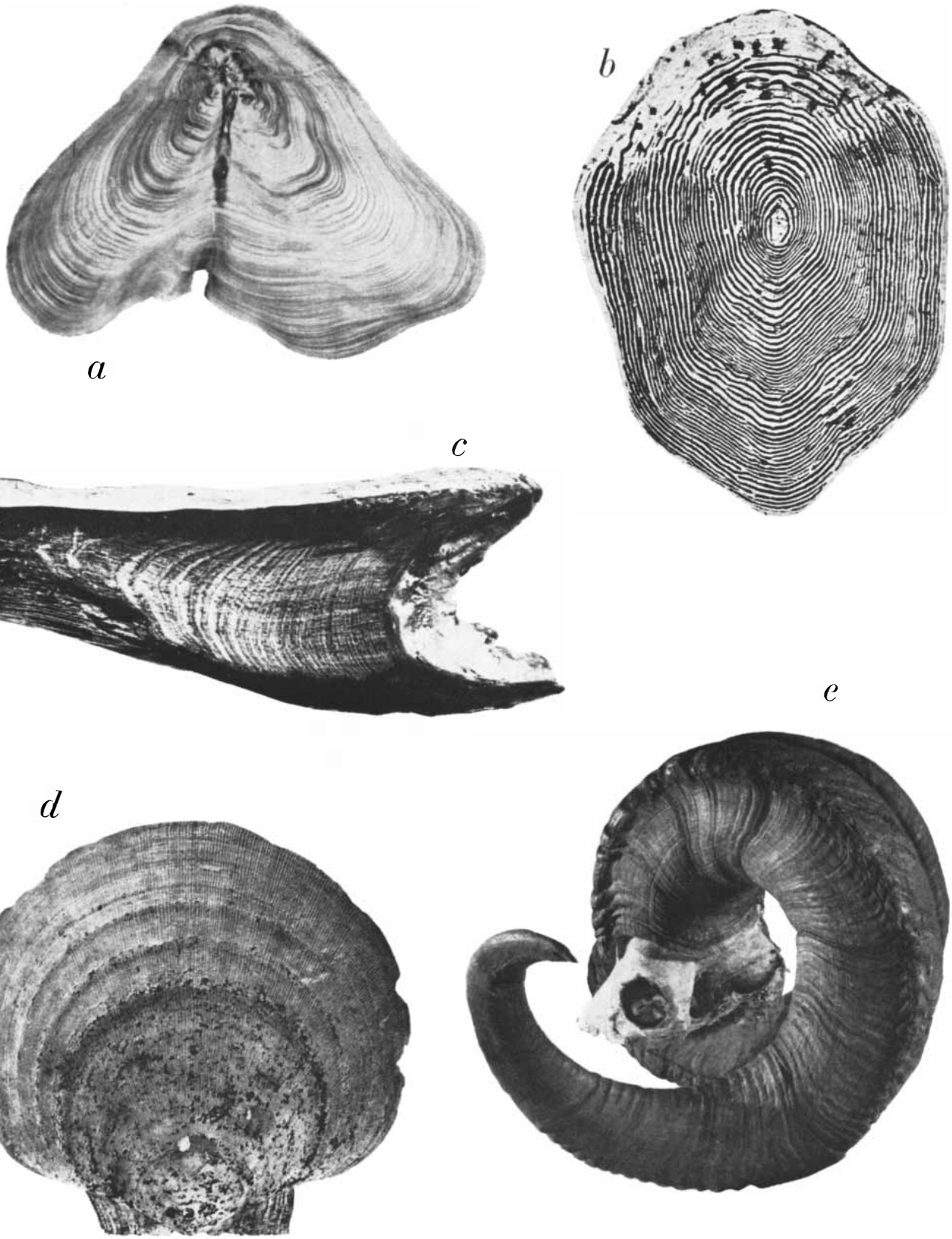
There appear to be a few organisms that are genuinely ageless for fundamental reasons—sea anemones, for instance. In jellyfishes the individual "jellies" have a fixed life span, but the scyphistoma larva from which they bud probably stays vigorous indefinitely. The larval "stub" produces a constant supply of new blanks as old ones are removed, until it eventually dies from a cause that would have been fatal at any age. This sort of agelessness depends on constant cell replacement, the organism being a stable clone.

Another sort of agelessness may be called circumstantial. Most small birds, for instance, have a constant mortality rate in the wild regardless of age; the accidental death rate is so high that few live long enough to become old. A chaffinch has been kept in a cage for 29 years and no doubt became senescent, but the mean life expectancy of wild chaffinches, young or old, is about six months.

Among animals that undergo the characteristic age-dependent loss of vigor the mortality rate increases steadily with advancing years. This increase in mortality takes place at a rate typical of the species and produces a characteristic life span, or commonest age of senile death, which is not extended by bettering conditions. In man this typical, or "specific," age is between 70 and 80 years, the figure given for it in Biblical times.

An age-mortality pattern with a fixed specific age seems to be the rule for warm-blooded animals, provided that they survive long enough for the senile increase in mortality to show itself. The "life span" of such animals usually means either the specific age or the greatest age ever recorded, which may be nearly twice the specific age. Sharply defined life spans and an exponential increase in mortality with age also occur in many invertebrates and, contrary to widespread belief, in some of the unicellular animals.

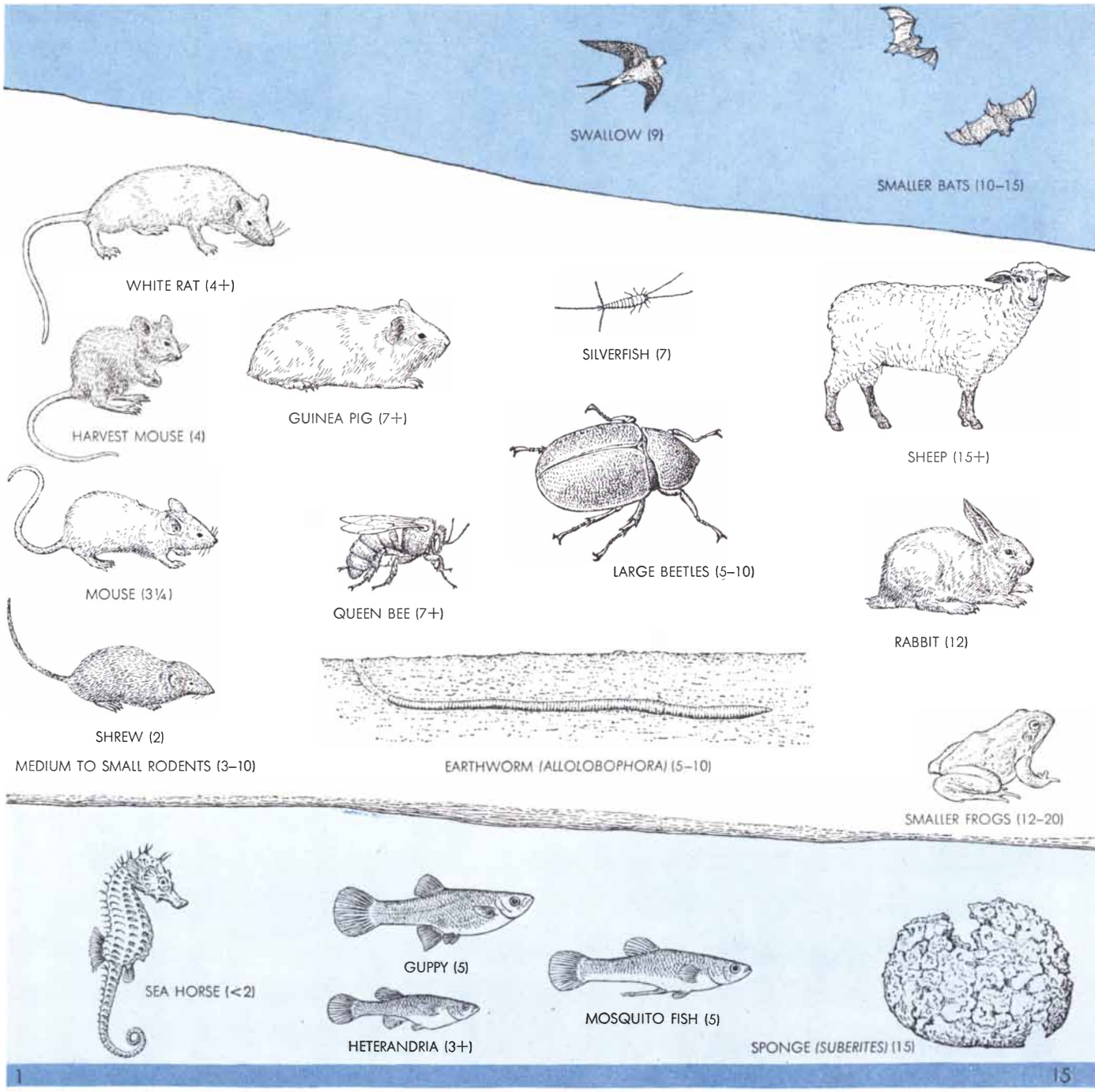
There are three ways of finding out the true life span of an animal: one can breed a large number of animals and record when they die; one can draw on existing records; or one can take a sample of animals of known, differing ages, plot their mortality at each age and construct a cross-sectional curve of survival. The first method is suitable only for animals that have a life span considerably shorter than that of the investigator. It is practicable for fruit flies or rotifers, which live for weeks or days. For mice, which live as long as three years, it is practicable but tedious; for larger mammals such as cats and dogs, which live beyond 10 years, it is barely feasible; for amphibians and reptiles, the smallest of which live for decades, this approach is hopeless. The second method, the examination of existing records (such as studbooks and the records of zoos and kennel clubs), should theoretically be able to provide both maximum and average life spans. Unhappily the chief feature of these records is their unreliability. Confusion between individuals and mistakes have repeatedly led to the exaggeration of animal ages. Studbooks, as far as they go, are usually accurate, but among the large numbers of domestic animals bred in civilized countries the date of death is far less likely to be recorded than the date of birth. Agricultural animals, moreover, are normally kept for only a fraction of their potential life before being slaughtered or culled as unproductive. The discipline of gerontology was therefore founded a few years ago with full survival curves for only three mammals: man, the white rat and the laboratory mouse. It has taken 10 years



STRUCTURES FOR ESTIMATING AGE, though not infallible, can be found in certain animals. In the sturgeon the rays of the pectoral fin show clear annual growth "rings" when sectioned. The ray shown here (*a*) is about half an inch across and has 82 rings. The scales of fishes provide another clue; this scale (*b*) is from a trout about five years old. The whale has a waxlike plug in its external ear tube that shows yearly growth. This plug (*c*), about six inches long, is from a whale about 28 years old. In the scallop, slow winter growth alternating with fast summer growth creates regular bands, normally a pair a year. This scallop shell (*d*) is about 10 years old. In rams, horns are a fair indicator of age; this specimen (*e*) is from a Dall sheep that lived about 11 years.

of hard work to supplement this information with limited records for dogs, horses and zoo animals. We still have no curve for any bird or reptile in captivity, and the first curve for small fishes has only just appeared.

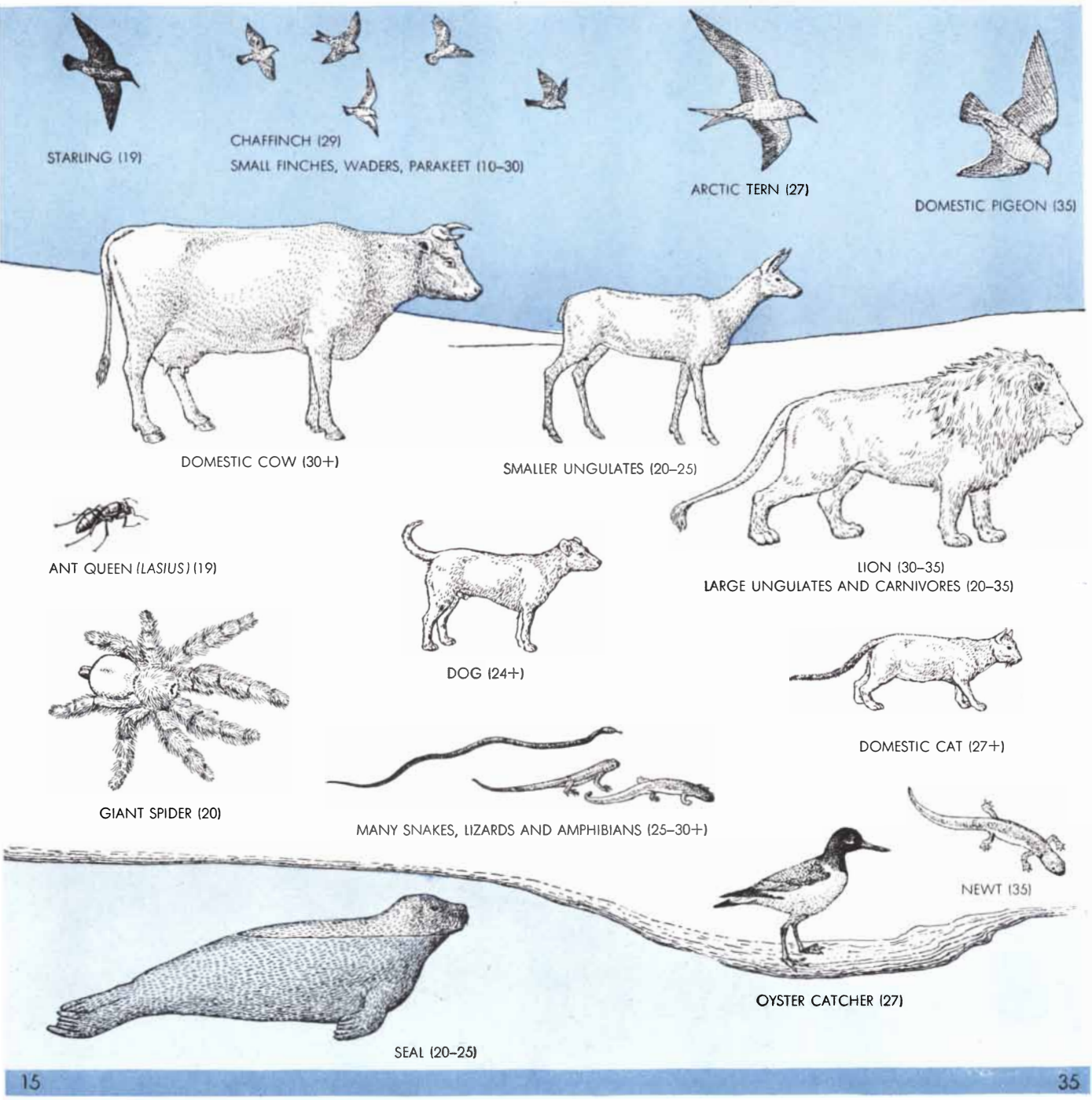
The cross-sectional method of plotting a survival curve is confined to animals that have birth certificates (pedigreed dogs, for instance) and to a limited number of animals whose ages can be determined by inspection. Such determination depends in most cases on something similar to the counting of tree rings; it requires some structure that grows seasonally and lays down a ring, or pattern of rings, each year. The horns of rams and goats are examples. Others are the wax plugs found in the ears of whales, the scales and bones of Temperate Zone fish, the bones of some reptiles, the shells of bivalve (but not univalve) mollusks, and miscellaneous structures such as the otoliths (calcareous bodies) found in the ears of some fishes [*see illustrations on preceding page*]. Given enough samples of such objects, it is possible to estimate maximum ages for a number of animals and sometimes to plot their mortality in each period of life. Cross-sectional plotting is the normal procedure by which the insurance actuary measures the human life span: he determines the mortality in each age group as it is today. The result of this procedure will be the same as that



MAXIMUM WELL-ATTESTED AGES for representative animal species and groups cover a remarkable range for which there is no simple explanation. (The illustration is continued on the following three pages.) Broadly speaking, large size is correlated with a long life span, but there are many exceptions even within families. The domestic cat, for example, lives almost as long as the lion. Among

of a lifetime study only if the rates of mortality at different ages do not change; in man, however, they have changed greatly in the last 80 years and are still changing. The man who is subject today to the mortality of an 80-year-old lived through the infant mortality of 80 years ago. Therefore two survival curves can be plotted for man: a cross-sectional curve based on present mortalities of men born at different times, and a "longitudinal" curve based only on actual survival rates in a group of men all born in the same year.

When estimating the specific age or typical life span of men and animals, survival curves are preferable to a handful of maximum records. This becomes apparent when one examines the curves for men and animals living under a variety of conditions [*see illustrations on pages 114, 115 and 116*]. As living conditions improve, more individuals survive to reach old age. The curve tends to assume the shape of half a parallelogram—the "parallelogram of survival"; it is flat for most of the life span and slopes sharply downward as the specific age is reached. But in spite of the improvement in conditions the far end of the curve tends to be pegged, so that under all but the worst conditions a few "indestructibles" are able to live as long as the oldest in better-treated samples. By inspecting a batch of curves for animals kept in the laboratory, it is easy to

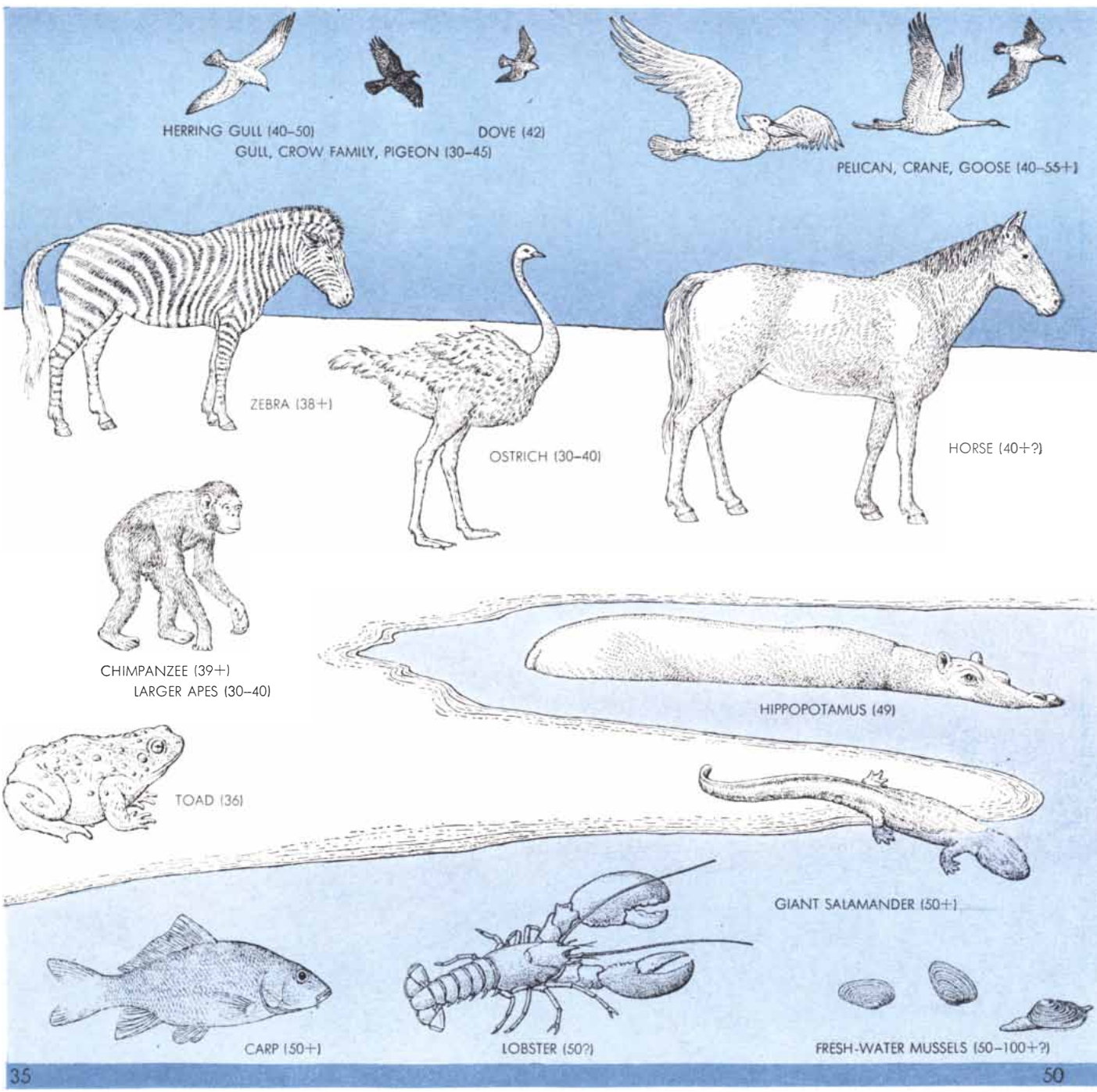


dogs the larger breeds have shorter lives than the smaller. It might appear that incentive is lacking for evolution to provide small animals (*e.g.*, rodents and small fishes) with a long potential life span because predators will not let them live to enjoy it. Yet many small birds, which may suffer a comparable attrition rate in the wild, have shown they can live for decades if protected from harm.

tell if they are living anything like their full potential life under the conditions of the experiment.

With the advent of birth certificates some check became possible on the incurable optimism and credulity with which humans approach reports of extreme age in their own species. (Their credulity with respect to the life span of other species is no doubt an overspill.) Birth certificates were introduced into Britain in 1837, so that now it should be possible to authenticate any age up to 124 years. There is no such certified record over 109 years, though in one instance absence of a certificate made an age between 111 and 115 highly probable. (In Britain when oldsters reach the age of 100 years, their birth certificates are checked to ensure the customary Royal congratulations.) In the U.S., where few states have vital statistics going back to 1837, participation in the Civil War was widely used as evidence of extreme age. The last surviving veteran of that war died in December, 1959, having claimed an age of 117.

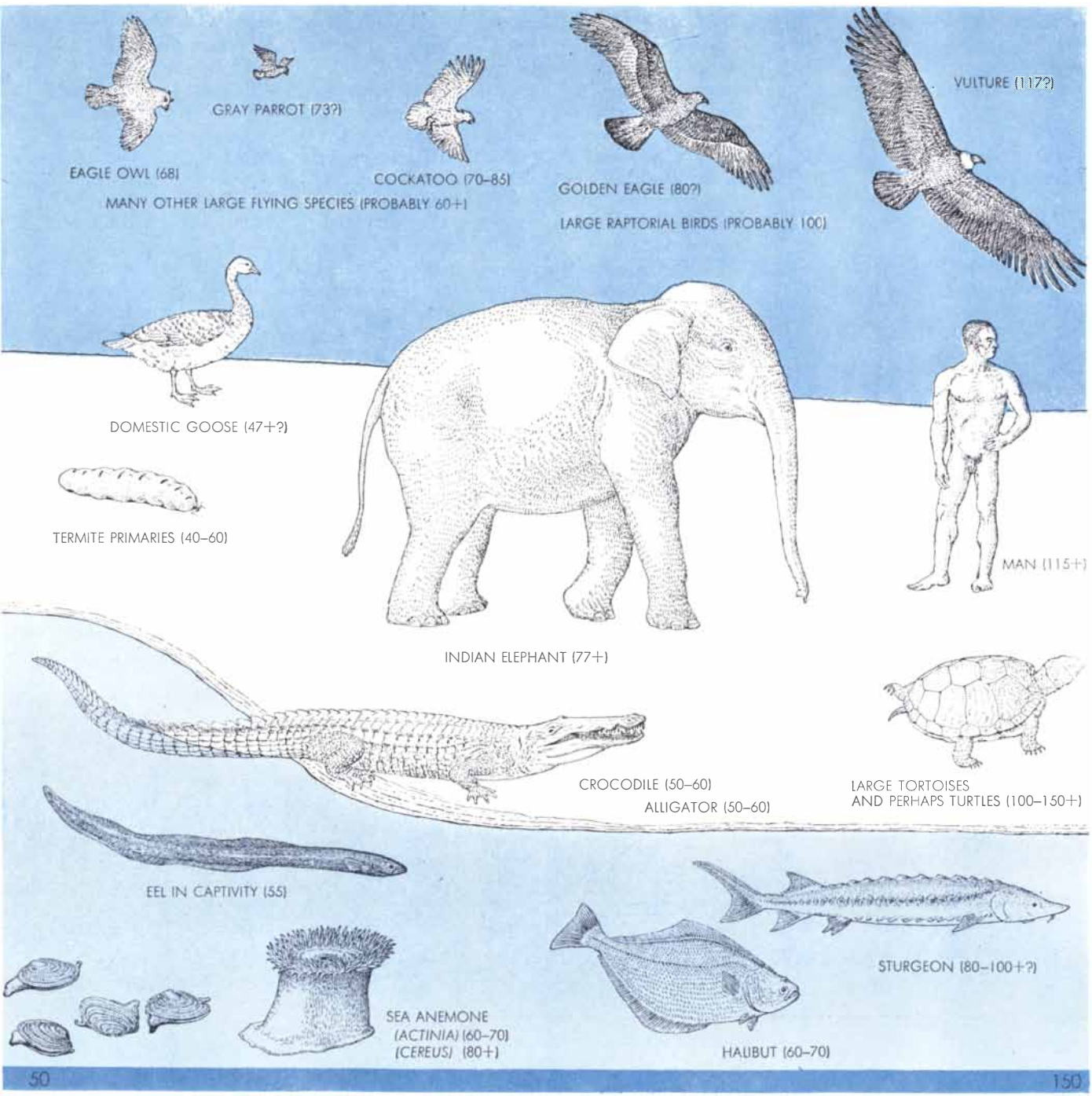
No person living in Britain is known to be even approaching this age, the oldest being about 108. Many centenarians in America and still more in the Soviet Union, where ages up to 140 have repeatedly been mentioned, have two things in common: birth under



LONGEST-LIVED ANIMALS are probably tortoises, with fishes, birds and man not very far behind. Tortoises and fishes seem to have long life spans because they can keep growing indefinitely, though rate of growth diminishes with age. For long-lived species, well-attested ages are hard to obtain unless the animal has some structure (equivalent to growth rings in trees) that can be dated;

primitive conditions, often in a remote region of the country, and inability to provide documentary evidence of age. Their claims cannot be accepted, but neither, of course, can they be ruled out. Primitive ways of life might indeed foster longevity in those who survived their disadvantages. Since such ways are perhaps incompatible with the collection of vital statistics, we may here be up against a "principle of uncertainty" in which the fact of observing disturbs the thing observed. Past claims to Methuselahism, like those of "Old Parr" (1483–1635) or Henry Jenkins (1501–1670) almost certainly represent error, fraud or both. It has been suggested that Old Parr's "longevity" was a skillful illusion perpetuated through three generations by father, son and grandson.

There are still, unfortunately, only a handful of animals for which we have survival curves; for the rest we have to rely on small numbers of maximum records in captivity, chiefly from zoos. Many of the old-age records soberly presented in reference books, from Aristotle to the present day, are pure moonshine. Francis Bacon's list is in fact better than that given in at least one current textbook. We owe the sifting of such records with rigid insistence on documents to a handful of fable-killers, of whom the late Major S. S. Flower, a British officer who was curator



examples are shown in the illustration on page 109. The age of man, unless there is a birth certificate, is especially hard to determine. Reputed human ages of 140 may be true but have not been verified.

Survival curves, which reliably show the life spans for a large sample of animals, are available only for the horse and man among the long-lived species (*see illustrations on the next two pages*).

of the zoo in Cairo, was one of the most diligent.

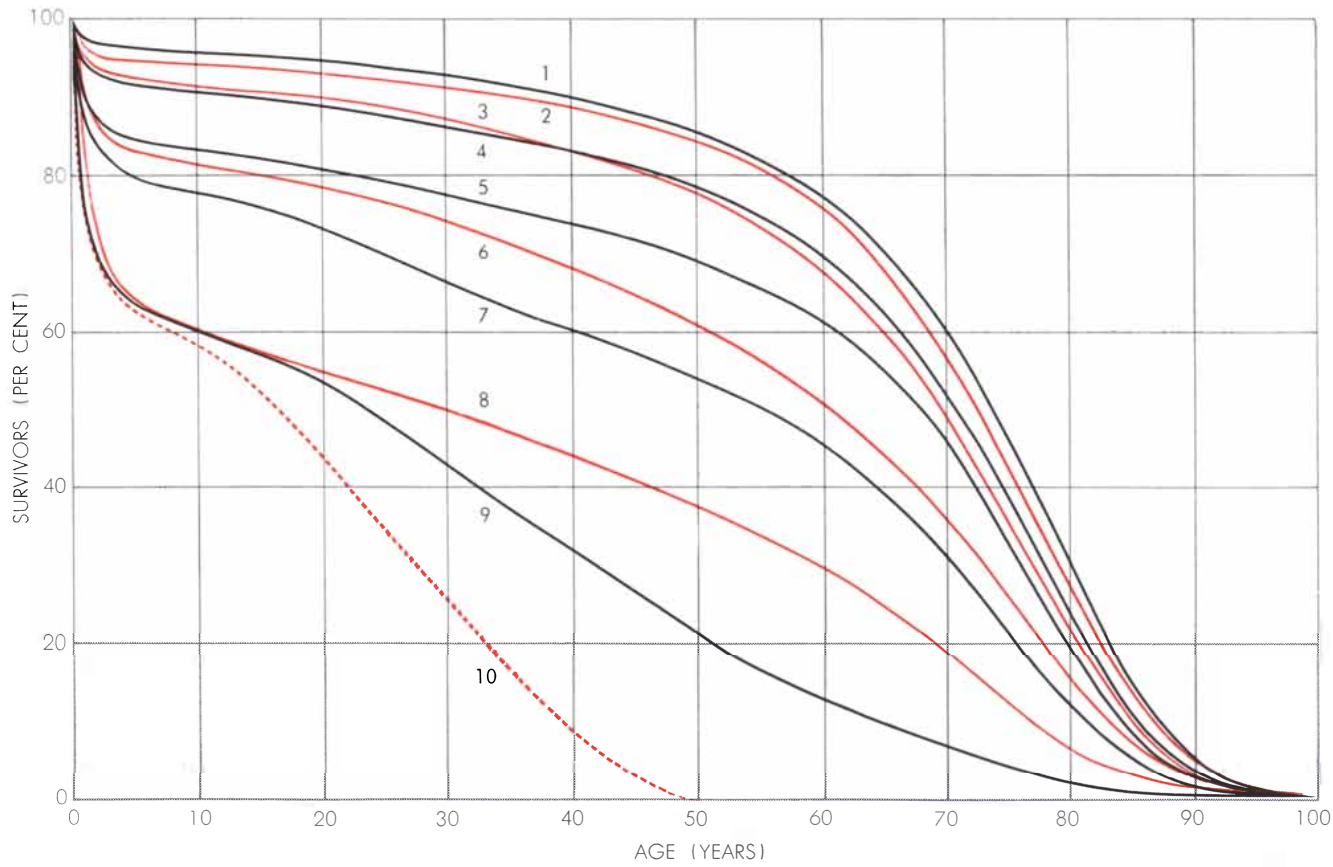
Perhaps the most widely repeated myths are those attributing great ages to whales and elephants because of their size. Actually no elephant is known to have lived beyond 77 years. For whales a life span of 40 to 60 years would be a high estimate. Apart from man, the only mammals known to live longer than 50 years are the elephant and probably the rhinoceros. Most large and medium-sized ungulates (hoofed animals) and large carnivores can reach 30 years, which may also be the upper limit for the domestic cat. It seems fairly certain that at least one house cat lived to the age of 27. Dogs, by contrast, rarely reach 20 years, and large dogs do not reach that age. Horses normally live about 25 years; the oldest thoroughbred mare in the *General Stud Book*, Blue Bell, by Heron out of Jessie, died at the age of 34. Ponies may live considerably longer, the greatest credible age being about 40 years. (A zoo zebra has lived to the age of 38.) The celebrated 62-year-old canal horse Old Jack, who has been immortalized in the literature of animal longevity, owes his reputation to evidence of a kind that has proved false time and again. Maximum records do not, of course, indicate normal life span. Reasonable estimates of the specific ages for horse, cat and dog are about 20, 16 and 12 years. Rabbits in captivity can live 10 to 15 years and guinea pigs six to eight. Because many investigators do not seem to know how long rabbits and guinea pigs can live, it frequently happens that studies comparing responses in "young" and "old" animals are really comparing responses in infants and young adults.

Many attempts have been made to find correlates of the life span in mammals. Here again Bacon was an acute observer. He wrote: "Neither do those things which may seem concomitants give any furtherance of this information (the greatness of their bodies, their time of bearing in the womb, the number of their young ones, the time of their growth, and the rest) in regard that these things are intermixt—sometimes they concur, sometimes they sever."

Longevity in mammals is roughly correlated with size but is more closely correlated with net reproductive rate. The slow-breeding and partially cold-blooded bat lives 10 to 16 years, a life span that is much greater than that of rodents of similar size. Among rodents themselves the life span is usually longer in forms that have an unstable temperature control mechanism and a consequent intermittency of energy output. Within a mammalian species—for example, the horse or dog—large breeds are almost always shorter-lived than small breeds. Possibly the closest single correlate of life span is the "index of cephalization," which measures the excess of brain size over that to be expected from the general pattern of mammalian proportion.

The potential life span of birds is usually much greater than that of mam-

1 NEW ZEALAND, 1934–1938
2 U.S. (WHITES), 1939–1941
3 U.S. (WHITES), 1929–1931
4 ENGLAND AND WALES, 1930–1932
5 ITALY, 1930–1932
6 U.S. (WHITES), 1900–1902
7 JAPAN, 1926–1930
8 MEXICO, 1930
9 BRITISH INDIA, 1921–1930
10 STONE AGE MAN

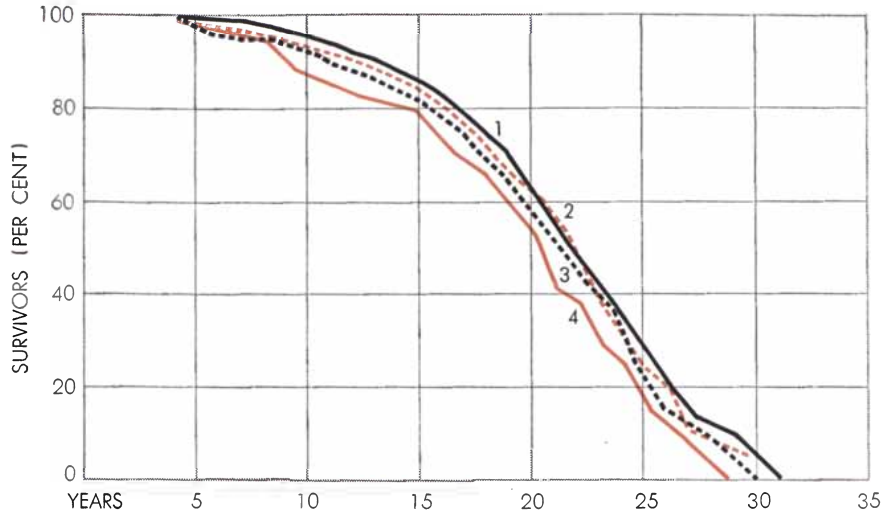


HUMAN SURVIVAL CURVES, all for females, show the effect of improvements in living conditions. Except for the Stone Age curve, which is of course an estimate, the curves are based on life insurance actuarial tables. Under optimum conditions such curves approach what is called the parallelogram of survival: a curve almost flat on top and falling sharply when commonest age of senile death is reached. In man this "specific" age is 70 to 80 years. Even under poor conditions a few hardy individuals reach it.

mals of similar size, in spite of the birds' higher metabolic rate and short growth period. Sixty-eight years is reported for an eagle owl, and records in excess of 100 years for parrots and eagles may be correct, though none is critically substantiated. Tame geese are said to have reached 50 years and pigeons 40. Many of the smaller birds reach 15 to 20 years in captivity, and notwithstanding the crushing random mortality under natural conditions a few individuals seem to reach similar ages in the wild. It would be of great interest to discover whether or not these elderly survivors have any special function in the bird community; perhaps they are bird "geniuses" with unusual powers of profiting by experience. The life span of nonflying, heavy-bodied birds seems to vary inversely with size; the ostrich lives no longer than many medium-sized flying species, probably 20 to 30 years.

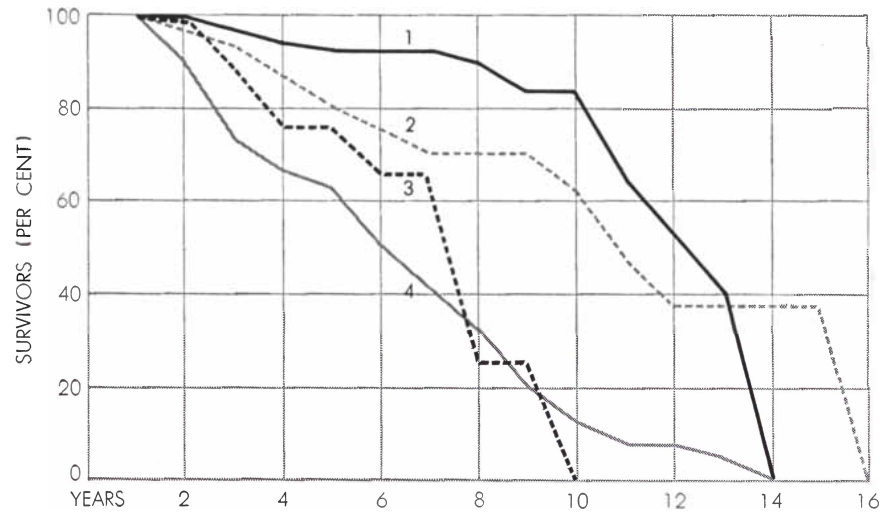
The lives of cold-blooded animals are longer still—so long, in fact, that lifetime studies even of small forms may be impracticable. As laboratory subjects the various amphibians (frogs and the like) have contributed greatly to knowledge of the embryonic stage of life, but they cannot easily be followed into old age because they may survive for 20 or 30 years. Tortoises fully live up to their reputation for longevity. Small varieties, including the box tortoise (*Terrapene*), can live at least a century. A specimen of a large tortoise (the now extinct *Testudo sumeirei*) was kept for years as a pet on the barracks grounds at Port Louis in Mauritius, a British island near Madagascar; it was killed accidentally in 1918 at a probable age of more than 150.

The slow growth of many reptiles and fishes, not all of them large, suggests that some of these cold-blooded animals may age so slowly that illness and accident probably take a greater toll than age and declining vigor alone. The possible life span of fishes such as sturgeon, carp and pike has long been the subject of argument. Dating methods based on scales and bone sections have provided a number of well-attested ages. Carp and pike are known to reach 30 to 50 years, but not the ages of 100 to 200 years attributed to them by anecdote. A halibut, 10 feet long and weighing 500 pounds, was still growing and fully fertile when caught in 1957. Its scales showed it to be more than 60 years old. Ages from 82 to 100, based on bone studies, appear probable for wild sturgeon. Beluga sturgeon have been caught that were more than 14 feet long and weighed more than a



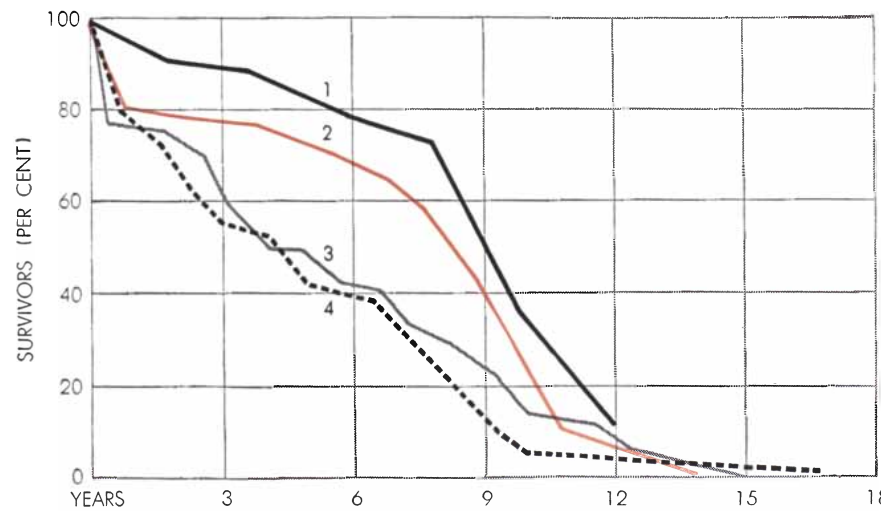
1 1860–1864
2 1875–1880
3 PROGENY OF 3 STALLIONS
4 GRAYS

HORSE SURVIVAL CURVES for British thoroughbred mares include 419 fillies sired by three long-lived stallions (*3*). Some 120 fillies sired after the stallions were 20 years old showed no difference in life span from the fillies sired earlier.



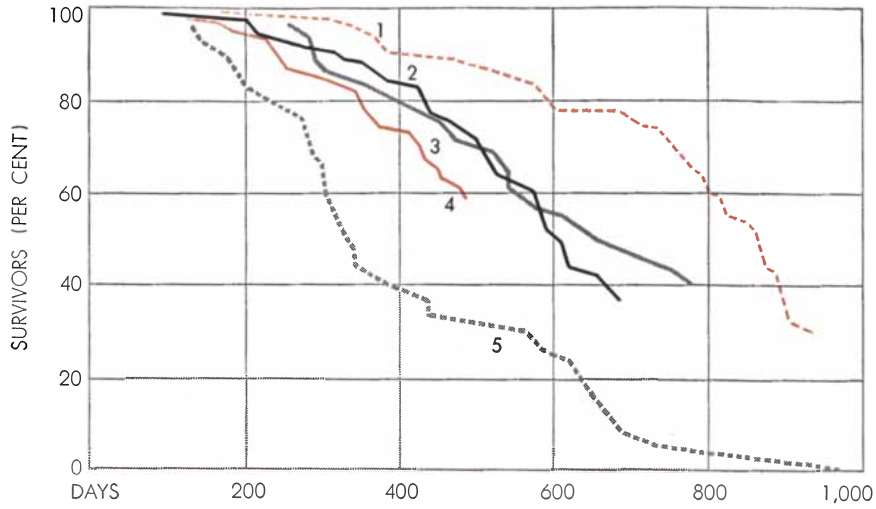
1 SPANIELS
2 PEKINGESE
3 MASTIFFS
4 WOLFHOUNDS

DOG SURVIVAL CURVES vary sharply with the size of the breed. The curves illustrate a mammalian characteristic: life span tends to increase the greater the proportion of brain weight to body weight. For mastiffs it is about 1/360; for Pekingese, about 1/95. Curves omit first-year deaths.



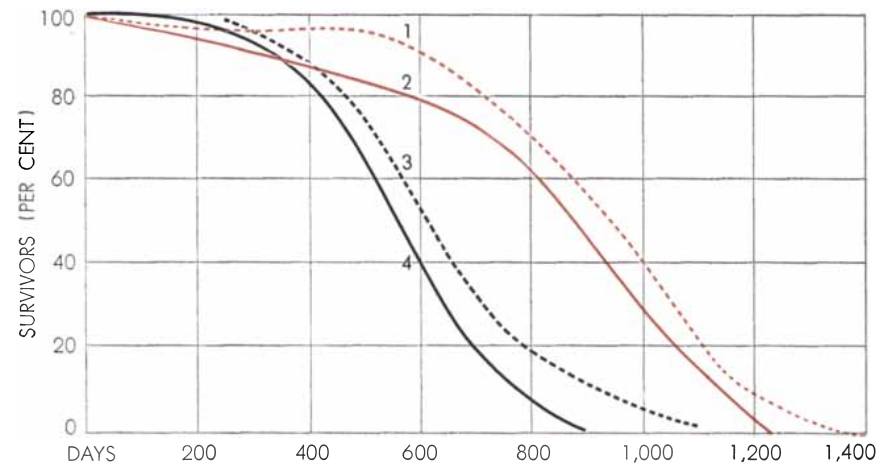
1 MERINO STUD EWES
2 WILD DALL SHEEP
3 BARBARY SHEEP
4 MOUFLON SHEEP

SHEEP SURVIVAL CURVES reflect marked variations in environment. Well-cared-for merino ewes, prized for their wool, are grazed on large ranges and slightly outlive wild sheep. The latter outlive mouflon and Barbary sheep penned up in the London Zoo.



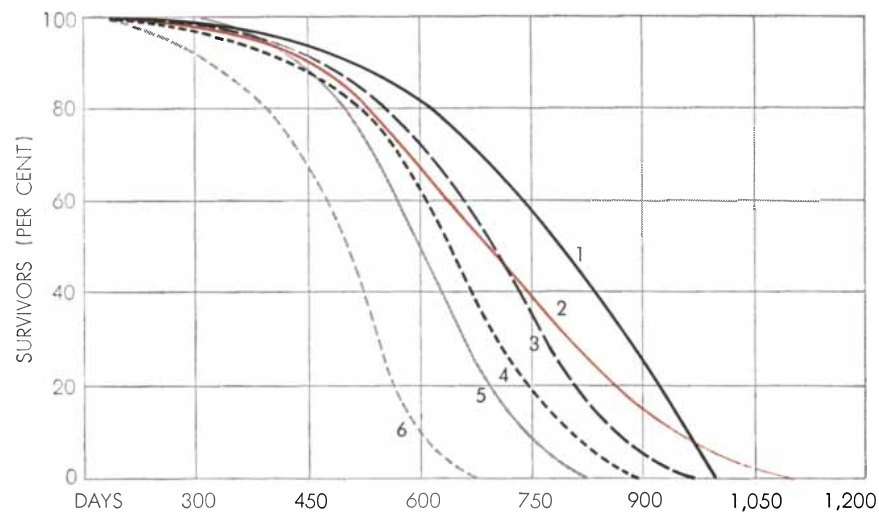
1 TANKS
2 600-MILLILITER BOTTLES
3 2,000-MILLILITER BOTTLES
4 300-MILLILITER BOTTLES
5 600-MILLILITER BOTTLES

GUPPY SURVIVAL CURVES vary with environment and care. The experiment is still going, hence the curves are incomplete. All fish have been fully fed and well cared for, except for a neglected group in 600-milliliter bottles (5), which are now all dead.



1 RETARDED FEMALES
2 RETARDED MALES
3 NORMAL FEMALES
4 NORMAL MALES

RAT SURVIVAL CURVES were obtained by Clive M. McCay of Cornell University when he restricted food intake of rats for periods ranging from 300 to 1,150 days from birth. If full feeding was then begun, rats grew rapidly and outlived normally fed littermates.



1 .11 ROENTGENS
2 CONTROLS
3 1.1 ROENTGENS
4 2.2 ROENTGENS
5 4.4 ROENTGENS
6 8.8 ROENTGENS

MOUSE SURVIVAL CURVES show effect of daily eight-hour dosages of gamma rays from radium in various amounts. The weakest dosage may have slightly lengthened average life span by killing pathogens that normally kill some young mice. The shape of the control curve shows that the life span of the nonirradiated animals was suboptimal.

ton; one specimen, the age of which was determined by bone sections, was at least 75 years old. Still larger specimens have been reported that weighed as much as two tons. If these fish were not examples of freak gigantism or plain fiction, they must have been of enormous antiquity, since growth rate declines with age and size.

The almost unlimited growth possible in certain species of fish and the larger tortoises has led to the suggestion that warm-blooded vertebrates "grow old" primarily because they have a fixed adult size. An animal capable of growing almost indefinitely might not age at all. This hypothesis, if substantiated, would be of crucial importance for understanding the aging process in man.

In our laboratory at University College London we have been trying to test the hypothesis by direct observation, using small fishes as subjects. The growth of female guppies is "indeterminate," exactly as in larger species, but the aquarium lifetime of guppies was known to be fairly short. A population study was set up to plot survival against time. Such a plot would reveal at least whether or not there is any tendency to fixity of life span and whether or not the likelihood of dying increases with age. In fact, by measuring growth and survival under various conditions we can draw curves that can be scaled up and superimposed on those of long-lived animals.

It turns out that the survival curve of guppies is not very different from that of small mammals. Moreover, if we superimpose the guppy growth curve on that of halibut or sturgeon, the advanced ages and large sizes recorded for these species are consistent with the growth-versus-longevity relationship observed in guppies. This suggests that the big, long-lived fishes may well undergo an aging process little different from—though more gradual than—the one observed in warm-blooded animals. Beyond this the question remains open. Even guppies prove able to live for five years, and the whole study has been in progress only eight.

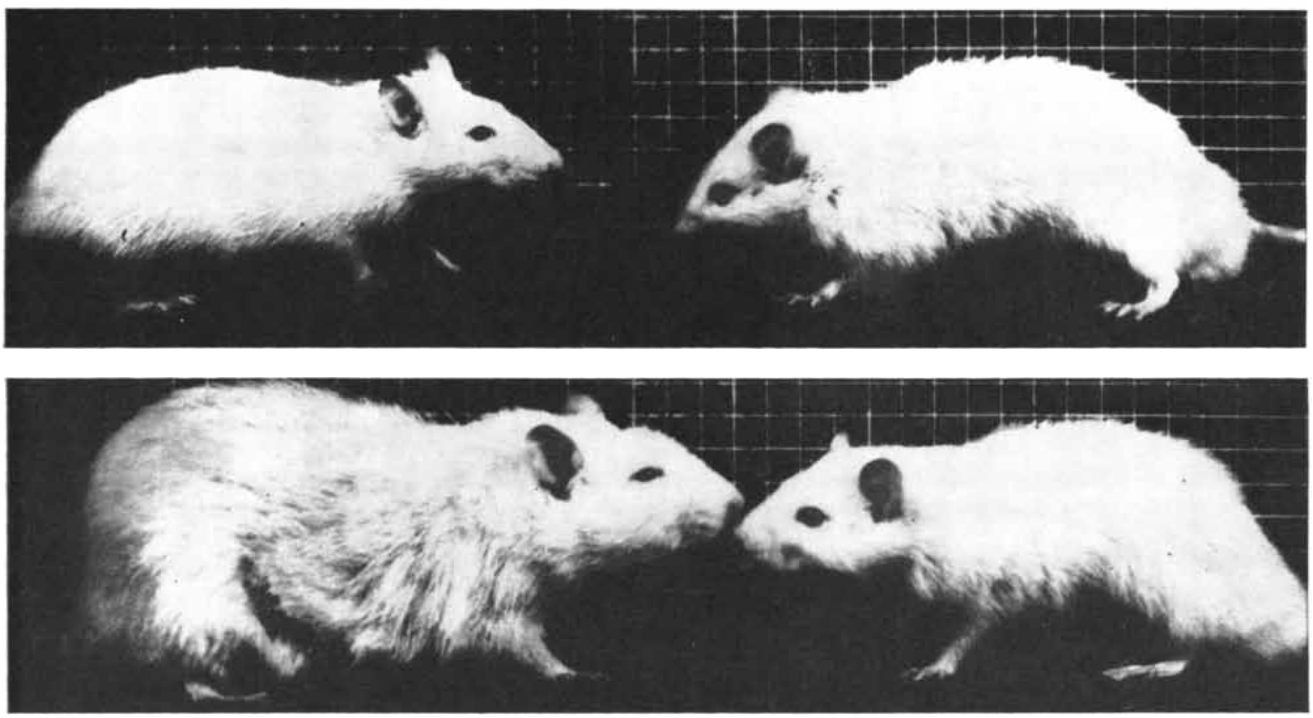
Among invertebrates we find a range of life spans even wider than that of higher animals, and those having sharply defined specific ages probably owe them to a great variety of physiological processes. There are many special cases. In some, reproduction is followed immediately by death—this also happens in some vertebrates, such as the salmon. In bees, early diet determines whether the larva shall develop into a queen, with a potential lifetime of seven or eight years,

or a worker, with a much shorter life span that itself is directly dependent on the amount of pollen the worker consumes. The longest-lived invertebrates are probably the larger bivalve mollusks. There is—again contrary to belief—no information about the longevity of giant clams, since no measurement of their growth rate seems to have been made. Washboard mussels in American rivers are known, however, to have survived up to 60 years, and some estimates (based on ring-counting) would make European fresh-water pearl mussels older than 100 years. Sea anemones have been kept alive for more than 80 years. Termite primaries, which can probably live 40 to 60 years, and some of the biggest crustaceans would appear to rank next. If we consider total life span, not just that of the adult, some beetle larvae have very long lives indeed.

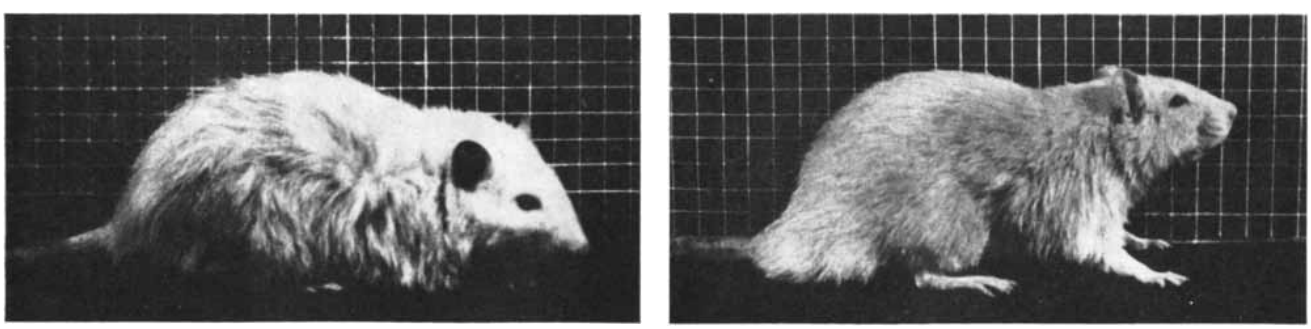
The three chief environmental factors that modify the life span of experimental animals, other than premature killing, are temperature, rate of food intake and ionizing radiation.

Cold-blooded animals generally live longer at temperatures below 20 degrees centigrade (68 degrees Fahrenheit) than at higher temperatures. The effect of temperature, however, is not simple, as J. Maynard Smith of University College has recently shown in some remarkable studies on the fruit fly *Drosophila subobscura*. If aging in these insects, which cannot replace their cells, represented a simple chemical "clock" that runs faster at higher temperatures, then a brief exposure to higher temperatures, followed by a return to a lower temperature, should move the "clock" forward and dock a few days from the life span observed at the lower temperature. In actual fact, however, groups of flies exposed to higher temperatures for several days early in life show no such loss of life span. Therefore temperature cannot accelerate aging in the same sense that it accelerates a chemical reaction such as oxidation.

The effect of food intake on the longevity of mammals was originally surprising but is now well accepted. It has been shown that in rats, as in many invertebrates, the optimum level of feeding for rapid growth produces a much shorter



THE EFFECT OF FOOD INTAKE ON RATS is shown in an experiment performed by V. N. Nikitin of the University of Kharkov. (*Also see middle illustration on opposite page.*) At top right and bottom right in these photographs are "retarded" rats that have been raised on a restricted but nutritionally adequate diet; both are 24 months old. They look about the same age as the normally fed three-month-old rat at top left. The normally fed 24-month-old rat at bottom left has reached old age, about two-thirds of his life spent.



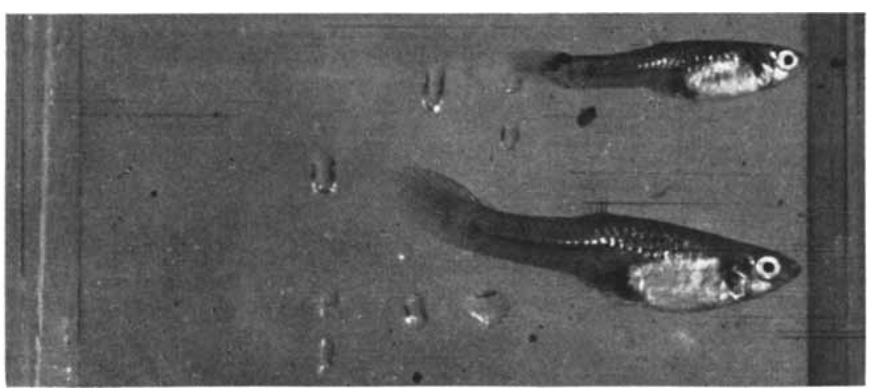
"REFEEDING" AFTER "RETARDING" makes an underfed rat grow to normal size and keeps him vigorous when his fully fed littermates have long since died. The refed rat at right is 39 months old and looks just as fit as the 24-month-old normal rat at left.

life span than a diet that checks growth without causing specific vitamin deficiencies. This observation was first made some 30 years ago by Clive M. McCay of Cornell University. He found that early calorie restriction could keep rats apparently juvenile, active and disease-free for a normal rat life span. If they were then given additional food and allowed to grow, they would mature and complete a normal life cycle. V. N. Nikitin of the University of Kharkov, who has recently repeated these experiments, has kindly permitted me to use photographs of his results [*see illustrations on preceding page*]. They show the striking difference in condition between normally fed and artificially retarded rats. The latter, in coat texture, activity and general health, are still effectively juvenile at two years of age—or two-thirds of the way through a normal life span. A study being made in our laboratory of dietary limitation in fishes seems to indicate that in fishes also slow growth is correlated with long life. The experiment is still in progress, however, and we do not yet have definite proof of prolongation beyond the maximum life so far recorded for normals. What does seem clear is that unusually rapid growth markedly shortens life.

Ionizing radiation has among its effects the power at low dosage to shorten mammalian life roughly in proportion to dosage. A single shot of X or gamma rays or of neutrons has the effect of displacing the survival curve of exposed animals to the left. In other words, radiation chops a constant amount, proportional to dosage, off each life in the sample. Lifelong exposure, as might be expected, produces a scaling-down of the whole curve of survival toward earlier death and higher age-dependent mortality. In some animal experiments the lowest lifetime exposures—proportionately well below the maximum limits set for human industrial exposure—may produce slightly longer lives than in the control series. It seems that this effect is due partly to the slight physiological stimulus arising from "stress" and partly to the fact that radiation at these low levels does more harm to parasites of various kinds than to the animals infected with them. In any case, the life extension is seen only in animal colonies where the survival curve is suboptimal. Among animals that are well cared for, radiation, if it has any visible effect, shortens life.

In man the situation is even less clear. We cannot yet say if a radiation dosage that shortens the life of a mouse by one month out of 24 would, if scaled up proportionately, shorten a human life by one part in 24, by some lesser amount or not at all. The reduction in life span among radiologists that was claimed in U.S. studies has not been found among English radiologists, who live, if anything, longer than other specialists.

The fact that radiation seems to affect aging, at least in mice, has given impetus both to life-span studies and to the speculative development of theories to account for aging in mammals. If radiation merely accelerated the natural process or processes that cause mammalian vigor to lessen with age, we would expect that the death of an irradiated animal would simply occur earlier in life from causes that normally kill that animal, without much change in the character or order of the causes. The largest and most recent study of single-shot irradiation in mice, by Patricia J. Lindop and J. Rotblat of St. Bartholomew's Hospital Medical College in London, has shown that this is not so. Instead, radiation seems to alter the order in which different causes of death appear. Presumably, therefore, the effect of radiation is not a simple acceleration in a process that would have happened in any event.



SISTER GUPPIES, 266 days old, show the effect of different levels of feeding. The larger has received a full diet; the smaller has had a restricted but adequate diet. When fully fed, the smaller will rapidly reach the size of her sister and will probably outlive her.

The theoretical arguments all turn on the nature of the main change in old mammals that makes them more vulnerable than young ones. Mammals are compound organisms, containing some cells that never divide and are normally irreplaceable, other cells that divide during life and are constantly replaced, and many inert or semi-inert structures with varying rates of turnover. So-called stochastic hypotheses of aging, based on statistical considerations, usually implicate either the loss of irreplaceable cells (analogous to "wear" or "wastage") or the faulty copying of cell components at cell division. The recent proposal of Leo Szilard, which discusses aging in terms of "hits" scored by radiation on complete chromosomes during life, is an example of the cell-loss type of hypothesis, while that of Sir Macfarlane Burnet, involving the body's processes of immunity, is an example of the faulty-copying type. Burnet has suggested, in effect, that the body eventually becomes sensitive or allergic to its own constituents. The cells that produce antibodies can normally do so only in response to foreign proteins; Burnet conjectures that because of mutations occurring over a lifetime some clones of these cells lose the built-in mechanism that prevents them from reacting against the body's own proteins and begin producing antibodies against normal body constituents, a process called autoimmunization. Such a process, Burnet suggests, might account for the bodily changes associated with aging. Still other hypotheses have been based on information theory. We are not, at the moment, short of hypotheses—only of facts and experiments to support them. A satisfactory theory of aging must account for the known range of specific ages and the relation of these ages to body size, cell number, mutation rate and so on.

Not the least puzzling question is how specific differences in life span are determined by evolution. The most satisfactory general view is the one put forward by P. B. Medawar, who last year shared the Nobel prize in physiology and medicine with Burnet. Medawar proposes that longevity in a species is the result of a balance between selection pressure that favors lengthening of life and the decrease with time in an individual's contribution to the next generation. Even in a population that did not age—whose life span, in other words, is expressed by a half-life—there would always be more young than old individuals. In any given generation, therefore, the offspring of the young would outnumber the offspring of the old, even assuming equal

fertility. Since fitness in terms of natural selection means simply the ability to contribute the greatest number of sound offspring to the next generation, it follows that the pressure of selection will be to favor the health and vitality of the young rather than that of the old. In fact, a gene that produced, say, more and earlier offspring in youth, but produced disease later on, might be positively selected. The vigor loss in animals that do age reflects this steady decline in selection pressure with age. One can imagine that the principal dimensions of the survival curve—the flat top of the parallelogram of survival—are established in this manner. The ultimate downturn, which fixes the specific age, or commonest age of senile death, represents the region where there is no evolutionary "incentive" to provide a physiological program for keeping the organism alive.

Some process of this kind must almost certainly take place, yet there are difficulties. We have already mentioned one of them: the long potential life span of small birds, much of it infertile, compared to their brief actual half-life. It is risky in such cases to invoke "indirect selection" based on social benefit from the existence of long-lived individuals, but the possibility cannot be dismissed. Indirect selection might also have operated in the case of man, for the fossil record shows that very few early humans reached their 50's in Paleolithic times, most of these being males. In modern times, however, we see that the specific age for women is approaching 80, or almost 40 years beyond the end of the childbearing period. Natural selection can only operate to prolong the life of a species after breeding ceases if it does so incidentally to some earlier effect or through some benefit that the infertile individual confers on those still fertile. In a highly sociable and educable animal such as man this is a distinct possibility.

That we know so little about animal life spans is due to the inherent difficulty of studying them. The wide interest in the subject today would have delighted Bacon, who justified his own study by the hope "that the Nobler sort of Physitians will advance their thoughts, and not employ their times wholly in the sordidness of Cures . . . but become Coadjutors and Instruments of the Divine Omnipotence and Clemency in prolonging and Renewing the life of Man." It is precisely the hope of controlling our own specific age that makes the study of factors fixing life span so absorbing for the biologist today.

Low-Altitude Jet Streams

Meteorologists have recently discovered that during the night strong winds often develop at altitudes between 800 and 2,000 feet. These winds appear to play a role in the birth of storms

by Morton L. Barad

Every so often a pilot bringing an airplane in for a night landing runs into a worrisome last-minute emergency. Starting his final approach at about 1,500 feet, he finds himself heading into a stiff wind. Because the wind provides a substantial part of the necessary airspeed, he throttles back his engines. Suddenly, a few hundred feet above the ground, the wind dies. Only a fast increase in power prevents the airplane from stalling and crashing.

As reports of such incidents accumulated over the years, it began to appear that they indicated more than isolated quirks in the weather. For a long time, however, meteorologists could only guess as to what lay behind the incidents. Finally, in 1953, a special research project confirmed the guesses. Over the plains of Nebraska during several nights there was discovered a thin, sharply defined ribbon of high-speed air at an altitude of about 1,000 feet, with no indication of such a wind near the ground. The phenomenon has since been identified elsewhere, and it has come to be known as the low-level nocturnal jet. At present a number of investigators are at work trying to learn more about its detailed characteristics and its causes. They are also examining its role in the development of certain types of severe storm.

The general features of the low-level jet are now fairly well known. On the days that it occurs it begins to build up in the late afternoon, and it reaches its maximum in the middle of the night and decays in the early morning. At the peak of the jet the winds in its core, between 800 and 2,000 feet up, can attain between 50 and 80 miles per hour, decreasing to 10 or 20 miles per hour between 3,000 and 4,000 feet and to zero at the ground. Unlike the much faster high-altitude jet that girdles the earth at about 30,000 feet, the low-level jet is essentially a local phenomenon. Nevertheless, it can sometimes be 1,000 miles long and anywhere from 40 or 50 to 500 miles wide. It probably forms occasionally in most regions of North America, but it is most common over the flat terrain of the Great Plains, and it is least likely to be found in hilly or mountainous areas.

How did so strong and distinct a pattern go so long undetected? The reason is simply that standard techniques of observation were too coarse-grained to find it. Winds aloft are normally measured only four times in 24 hours and generally only twice at night. The balloons used to trace them rise at a rate of 500 to 1,000 feet per minute, and the horizontal velocities recorded are a series of averages over successive two-minute intervals. Obviously such a system cannot clearly define—indeed, may completely miss—a jet structure where the velocity goes from zero at the ground up to 60 miles per hour, say, at peak level and back to 15 miles per hour at an altitude of 2,500 feet. It is like trying to sort peas with a grader designed for oranges.

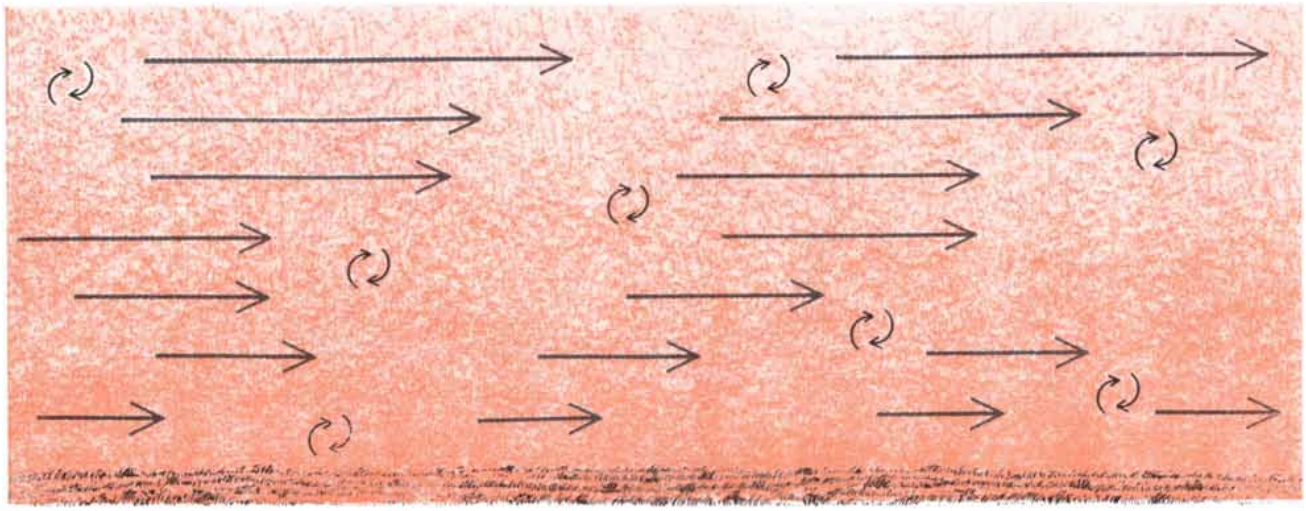
By decreasing the lift of the balloons to slow their ascent and by averaging the speeds over shorter time intervals, observers eventually obtained a better picture of wind layers at low altitudes and began to make out the structure of the jet. There remained some question, however, as to whether results from a single balloon really represented general conditions in the area.

In early 1953 Guenter Loeser of the Air Force Cambridge Research Laboratories set out to develop better methods of measuring winds in the lower atmosphere. For daylight experiments he designed a rack of 12 smoke cartridges to be dropped from a helicopter. A timer ignited the cartridges one after another, leaving a vertical line of smoke puffs spaced equally between about 5,500 feet and the ground. The altitude of the puffs changed little, and they were photographed every six seconds for two minutes by a pair of cameras a mile apart. Depending on how quickly the wind diffused the smoke, each set of photographs provided average winds for a period of 30 to 120 seconds at heights about 500 feet apart.

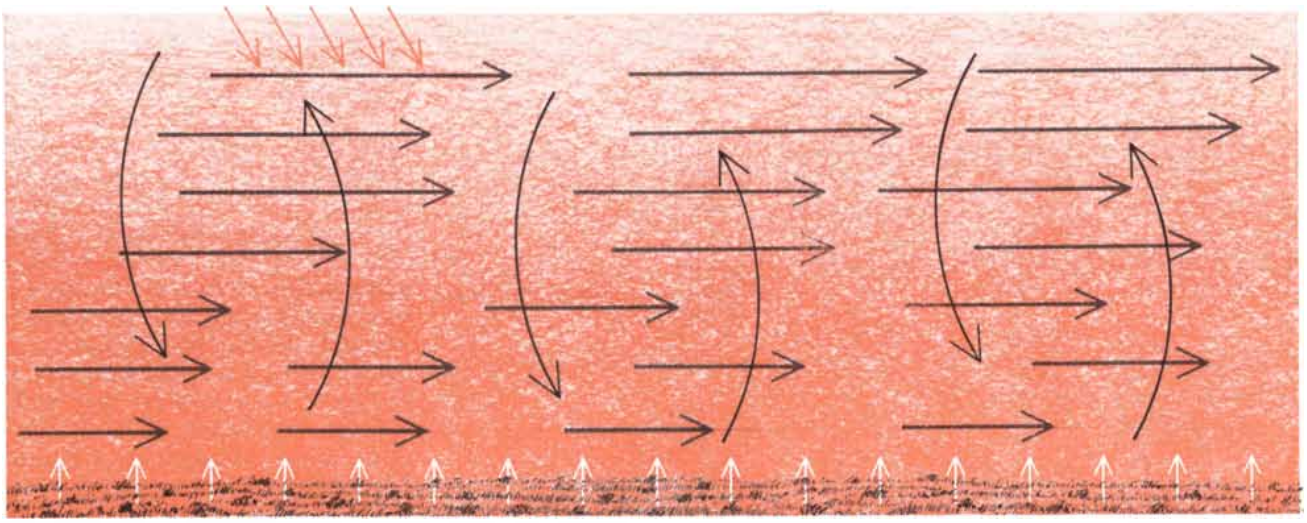
For night measurements Loeser developed a novel balloon technique. First a standard lighted balloon was released to obtain a rough idea of the wind speed and direction in the first few thousand feet. Then eight to 10 balloons, with lights attached, were spotted along a line on the ground in such a way that when they were released one at a time, they formed an almost vertical line in the sky within the field of view of two cameras, giving a set of streaks on the film that outlined the balloon trajectories. From these the wind at various heights could be accurately computed.

Just before the scheme was put into operation Loeser himself died in a helicopter accident. His colleagues carried out the tests in O'Neill, Neb., with great success. Over a six-week period in the fall of 1953 they observed several well-developed jet streams. The one that appeared during the night of September 7–8 is a good example [*see illustrations on page 122*].

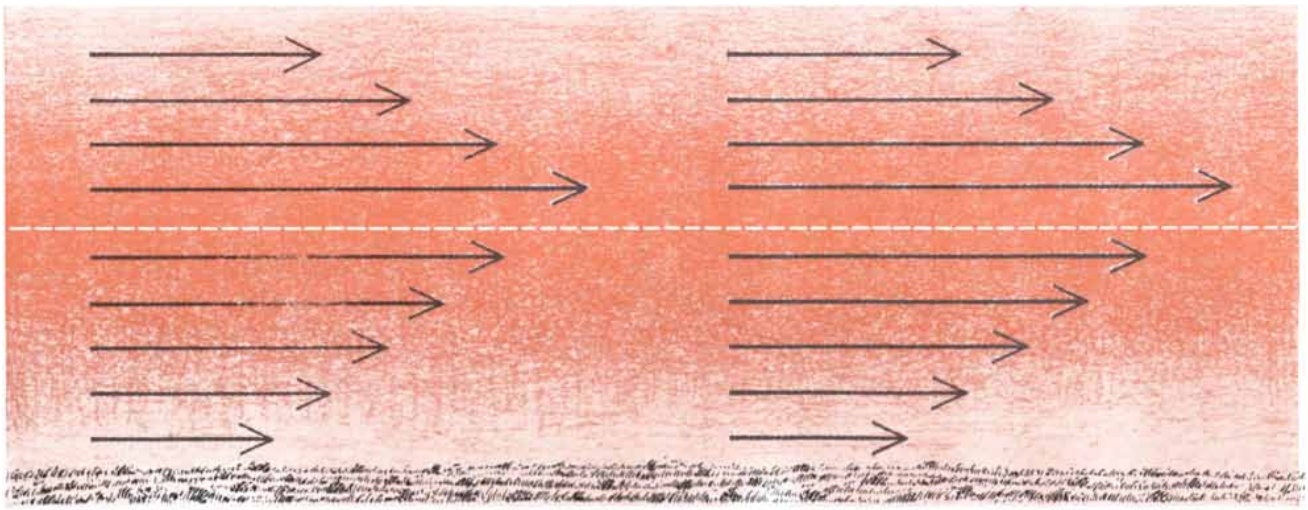
There was nothing unusual in the wind profile at 2:30 on the afternoon of September 7; wind velocities from 50 to 4,000 feet varied between 25 and 30 miles per hour. As the afternoon wore on, the wind in the layer from 1,000 to 1,500 feet began to speed up. By shortly



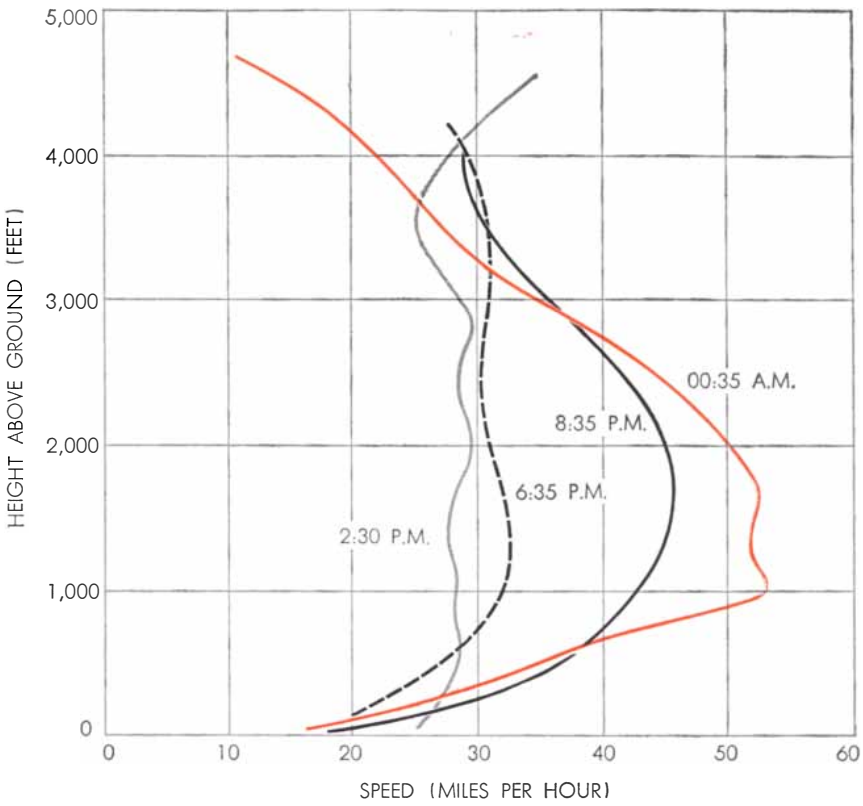
HEATING AND COOLING of the earth's surface play a major role in the formation of a jet. In these diagrams air temperature is indicated by color: the denser the color, the warmer the air. Winds at the surface are slowed by friction. On a cloudy day with light winds (*above*), turbulence (*curved arrows*) is slight. There is little mixing between layers and wind speed increases with height.



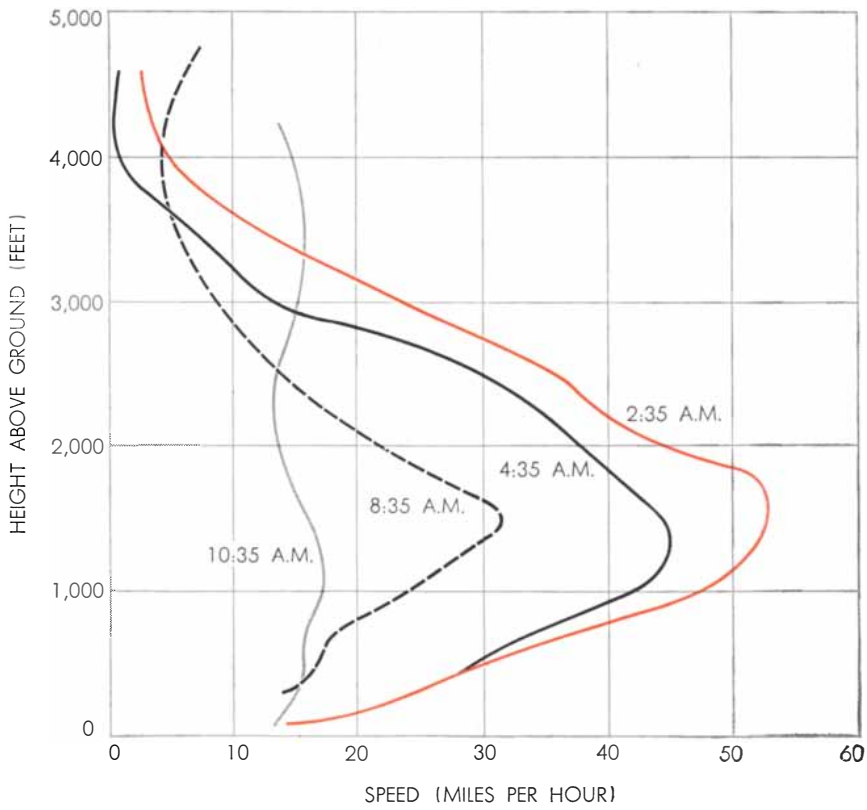
HEATING BY THE SUN (*colored arrows*) on a clear day changes the wind pattern. The earth is warmed and in turn heats the lowest layer of air (*white arrows*). Convection sets in. The warm air rises and cooler air descends (*curved arrows*). This convective turbulence mixes air of various speeds. The wind profile smooths out and wind speeds in the first few thousand feet are more uniform.



COOLING OF THE EARTH leads to jet formation. Convection ceases, and with it convective mixing. A clear evening also brings on an inversion, in which the temperature increases with height instead of decreasing. The inversion further damps vertical mixing. Freed from the daytime frictional forces, the wind above the top of the inversion (*broken line*) speeds up and the jet is born.



DEVELOPMENT OF LOW-LEVEL JET during the afternoon and evening of a September day in Nebraska is charted. Successive curves show how the wind profile changed with time.



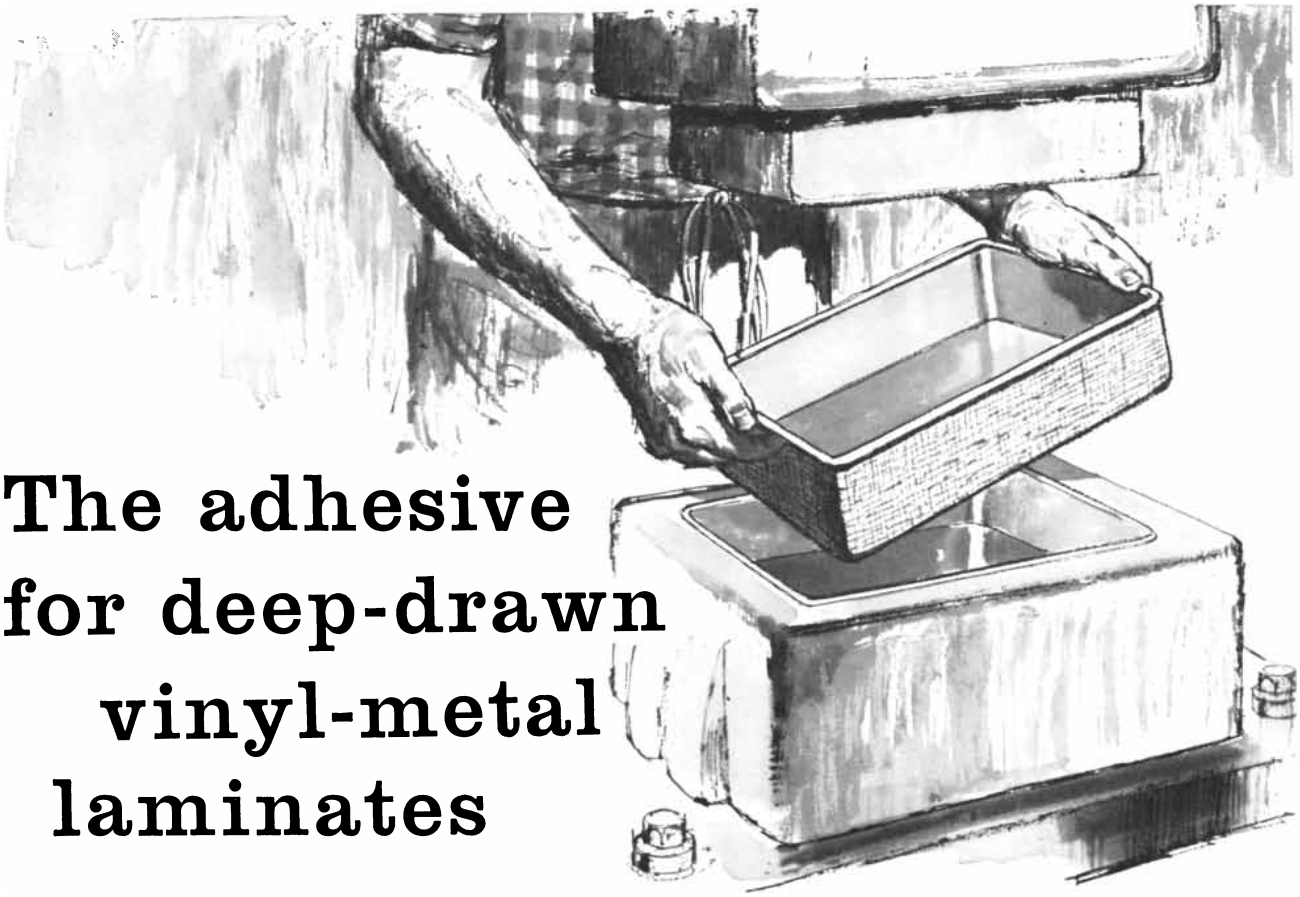
DECAY OF SAME JET through the morning hours is shown. At first the whole structure slowed down, and then the wind profile returned to normal as the jet vanished completely.

after midnight it was blowing at 54 miles per hour. At that time the wind speed 50 feet above the ground was only 16 miles per hour, and at 4,600 feet it had fallen to 14 miles per hour. After 2:35 a.m. on September 8 the jet began to weaken, and by four hours after sunrise all traces of it were gone.

Although the mechanism of the low-level jet is far from completely understood, meteorologists generally agree that the diurnal cycle of heating and cooling of the earth plays a major part in it [*see illustrations on preceding page*]. On a clear day, as the ground soaks up solar energy and grows warmer, it heats the layer of air immediately above it. If this layer gets hot enough, it begins to push its way up through the cooler air above it and a convection pattern is set up, with warm air rising over some parts of the surface and cooler air descending over others. This convective turbulence, as it is called, mixes the air at different levels. Also contributing to the mixing is mechanical turbulence, which depends on the strength of the wind and the roughness of the terrain. The interchange makes the pattern of wind speeds through the first few thousand feet more nearly uniform than it would otherwise be. Air moving closest to the surface is subject to the maximum frictional drag from the ground. As a result the wind in the lowest levels is slower than in the layers above it. Mixing partly offsets this effect: the ascending parcels of air carry up with them their lower speeds, while the descending cells bring down the higher speeds.

If the day has been calm as well as clear, with little mechanical turbulence, mixing falls off sharply as the sun goes down and the heating of the lower air decreases. The lowest air layers, still affected by surface drag but cut off now from the momentum supplied during the day from above, move slower and slower. At the same time the upper layers are no longer sapped by contributions of momentum to the surface layers or slowed by injections of slower surface air. The winds aloft therefore speed up, and the jet begins to form.

An analysis of the balance of forces governing the horizontal movement of air shows that such a process, once started, tends to build up and eventually to overshoot. When the frictional force due to mixing abruptly drops from a large value to a small one, the wind enters a cycle that can carry it to a higher speed than it would have reached if the friction had been small all the time. As



The adhesive for deep-drawn vinyl-metal laminates

A new adhesive—J-1199—has recently been developed by Armstrong research to meet the special problems encountered in assembly line bonding of unsupported vinyl films to metals that are to be deep-drawn.

J-1199 has been compounded to combine the convenience, speed, and economy of thermoplastic cements with heat resistance approaching that of thermosetting adhesives.

As a result, delamination or shrinkage of the vinyl film at elevated temperatures is virtually eliminated. And this is true even when the laminate is drawn almost to the limits of the base metal.

Special compounding also gives J-1199 resistance to the degrading effects of zinc, making vinyl-to-galvanized steel bonds practical. This is important to those who want to take advantage of the corrosion resistance and lower cost offered by zinc-coated steel.

J-1199 is, of course, also ideal for laminating vinyl film to aluminum and other sheet metals. It is easy to apply, either by spray or by direct or reverse roller coater. No jigs or unusual pressing procedures are required.

Armstrong J-1199 also meets or exceeds all adhesive requirements in the minimum standard specifications (tentative) for vinyl-metal laminates published by the Vinyl-Metal Laminators Institute.

Besides its usefulness in the fast-growing vinyl-metal laminating field, J-1199 can be used effectively in coil stock lamination.

Thin-gauge stainless steel, for example, can be bonded to baser metal substrates for subsequent stamping and drawing operations. This opens the way to more extensive use of stainless for trim and other decorative purposes.

You may have a laminating job that can be done best with Armstrong J-1199. We'll be glad to make suggestions or supply additional information if you will submit details of your application to us. Address inquiries to Armstrong Cork Company, Industrial Division, 8008 Inland Road, Lancaster, Pennsylvania.

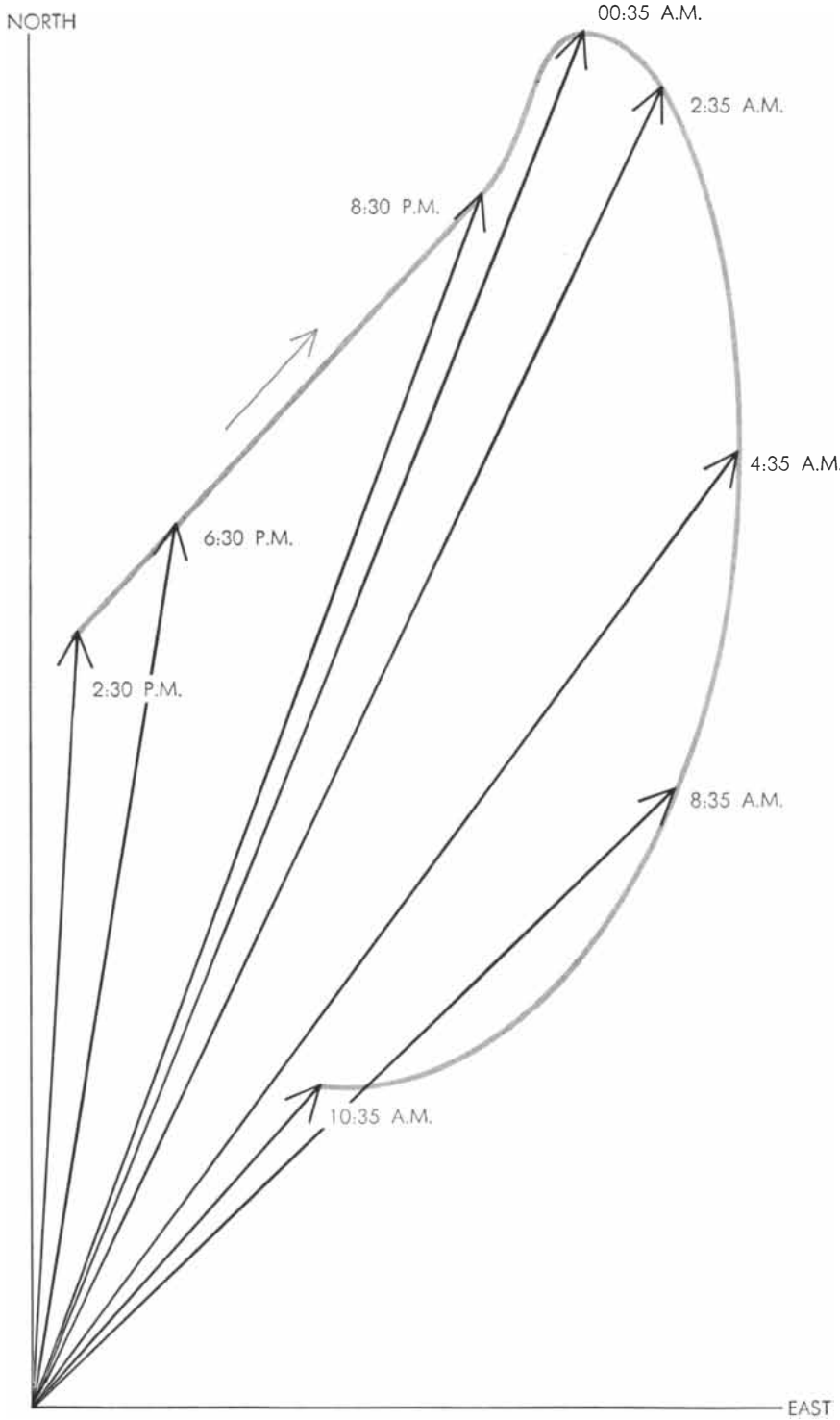
Armstrong ADHESIVES

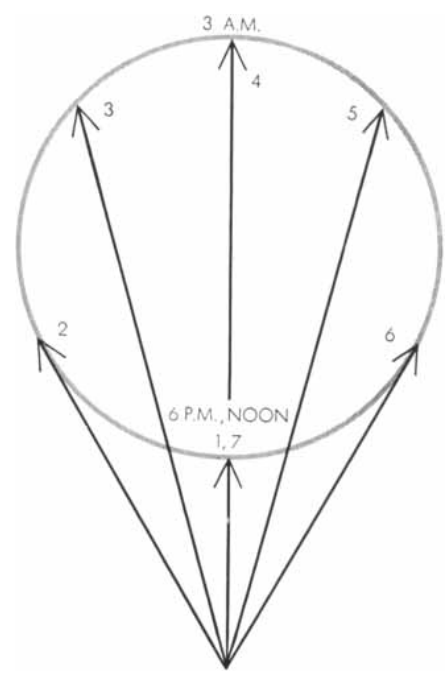
in any oscillation, the overshoot then tends to correct itself, and the wind dies down again.

The build-up of the jet is assisted by another nighttime weather phenomenon: temperature inversion. During the day the temperature of the first few thousand feet of atmosphere generally decreases with height. After the sun goes down, the ground begins to lose heat by radiation. If there is no blanket of clouds, the surface and the adjacent layers of air soon become cooler than the air above them. Here the temperature increases with height through the first thousand feet or so, and each succeeding parcel of air through the layer is warmer and lighter than the one below it. This is a stable arrangement, which further damps out vertical mixing. On nights when the jet develops, the depth of the inversion layer increases during the hours just after sunset, and the fastest winds are just above the top of the deepening inversion.

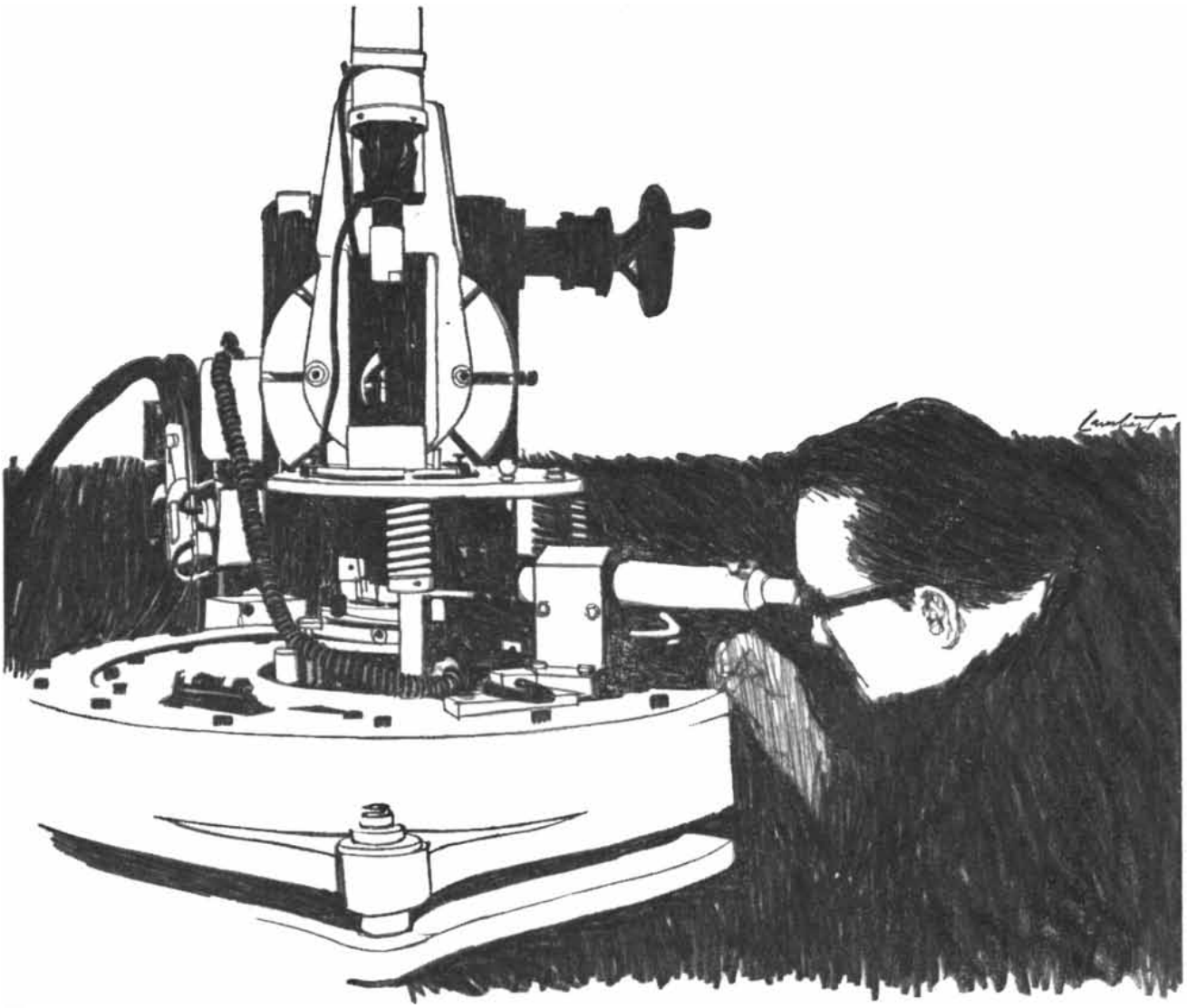
As the illustration at the left on this page shows, the direction, as well as the speed, of the O'Neill, Neb., jet changed during its life cycle. Beginning from a southerly direction, the wind swung to the right as it speeded up and was blowing from the south-southwest when it reached its maximum speed. Then it continued around to the right as the speed decreased until an hour or so before the end of the cycle, when it began to move back to the left. The picture suggests that if conditions were exactly duplicated during the next afternoon and evening, the wind would continue to move around and retrace the pattern. Similar patterns, suggesting an oscillation in both direction and speed, have been found in most of the jets that have been recorded so far.

Theoretical studies confirm the idea of such an oscillation. A mathematical





REAL JET AND THEORETICAL MODEL conform in some respects. Changes in wind speed and direction at 1,650 feet in the O'Neill, Neb., jet of September, 1953, are diagramed at left. The arrows are proportional in length to the speed of the wind and indicate its direction. The arrowheads move clockwise, and a portion of the path they trace is a rough ellipse. According to the mathematical model, the heads of jet wind arrows trace out a perfect clockwise circle as they change in speed and direction (*right*). At the latitude of O'Neill, a cycle beginning at 6:00 p.m. (*1*) should reach a peak at 3:00 a.m. (*4*) and end at noon the next day (*7*).



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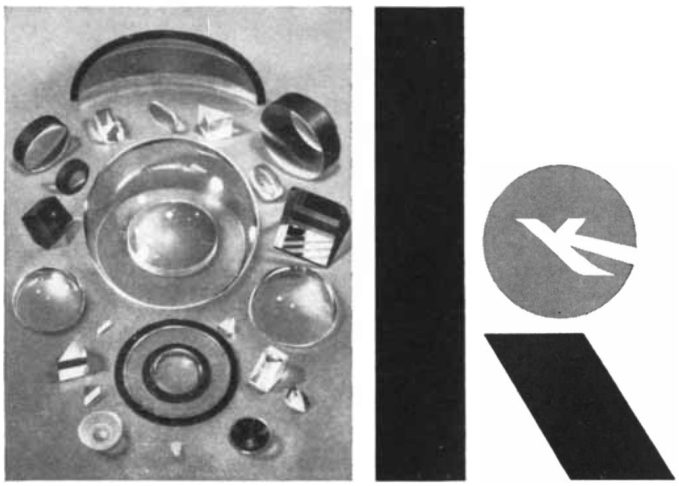

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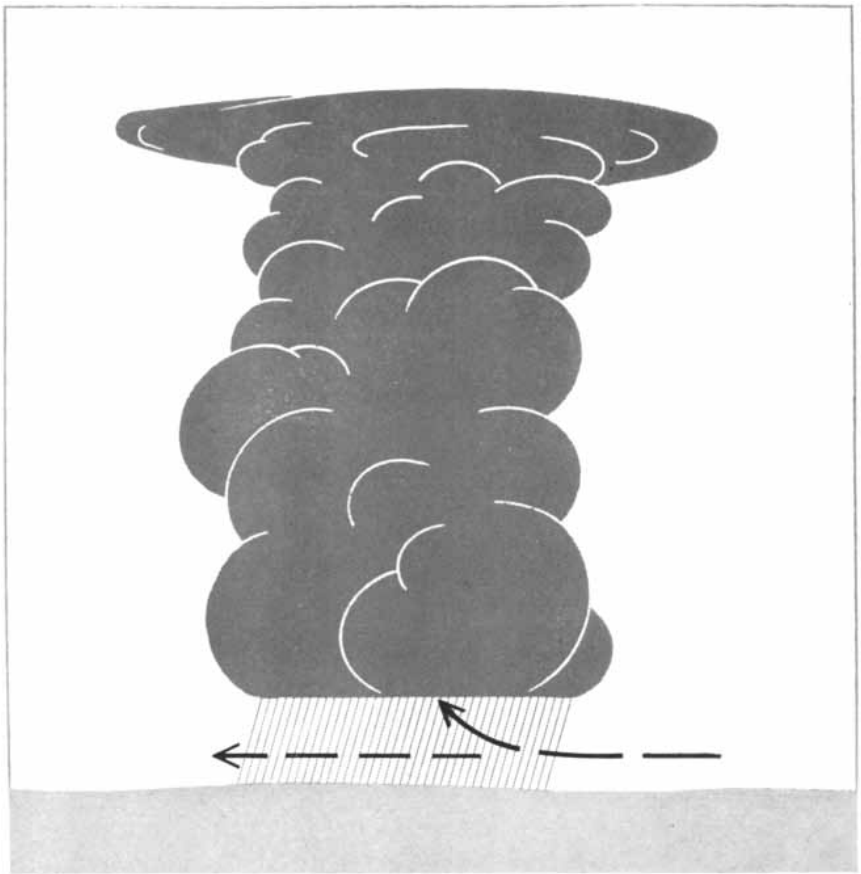
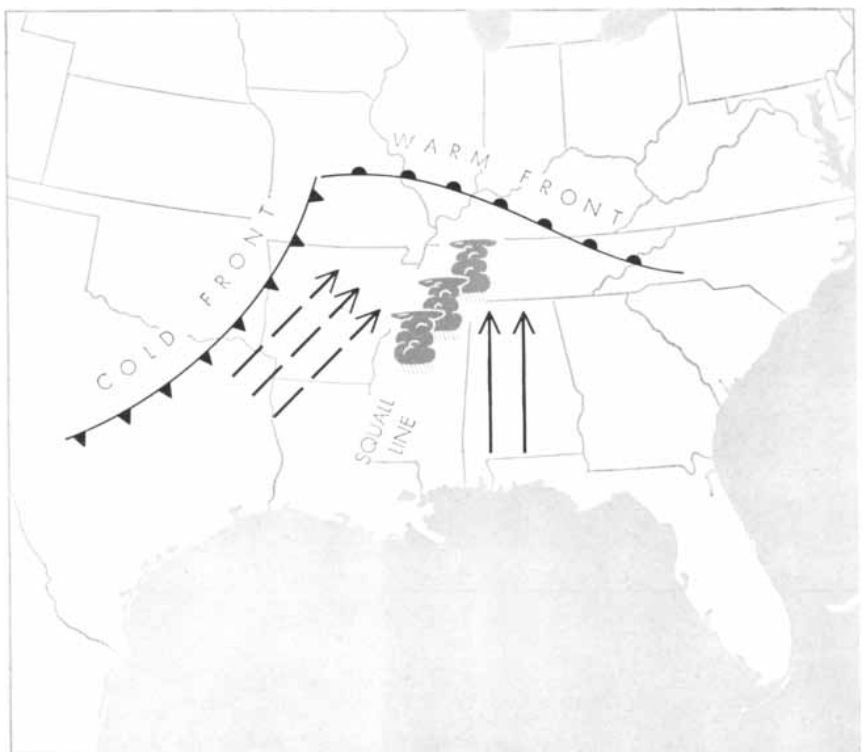


NOCTURNAL THUNDERSTORMS over the Great Plains can be caused by jets, which vary in speed with latitude. A strong jet from the south overtakes a weaker jet to the north and is lifted. The lifting of a mass of warm, moist air leads to the formation of thunderheads.



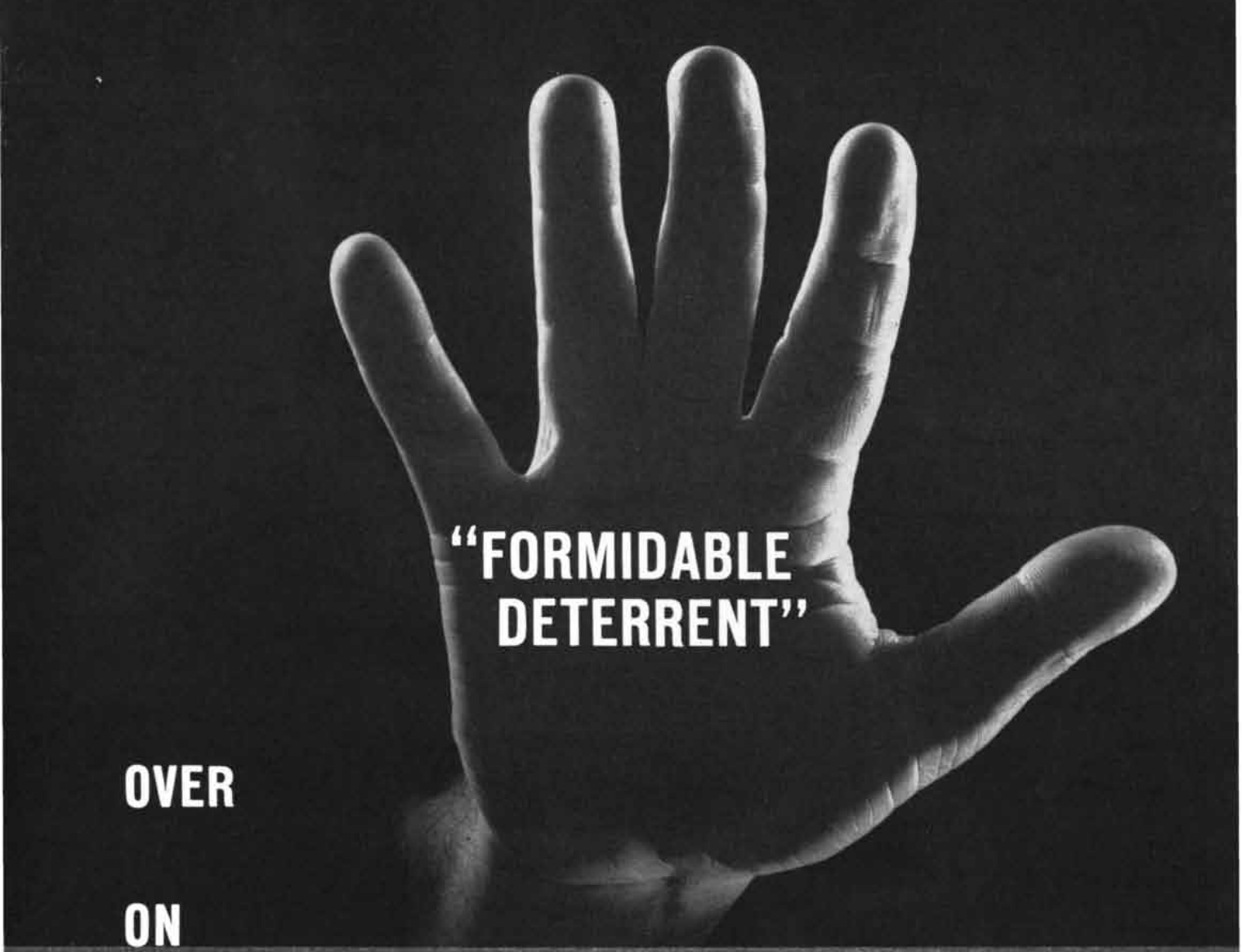
SQUALL LINES in the Gulf Coast states may arise in a similar way. The southerly jet (*solid arrows*) several hundred miles ahead of a cold front converges with the winds (*broken arrows*) nearer the front. Again the southern air is lifted and the squall line is formed.

model of the low-level jet developed by Alfred K. Blackadar of Pennsylvania State University shows that, with certain simplifying assumptions, the wind passes through a perfectly regular and symmetrical cycle. Blackadar considers the case in which the horizontal air motions during the day result from just three forces: the pressure gradient, a force directed from areas of higher atmospheric pressure to areas of lower pressure; the Coriolis force (the turning effect due to the spinning motion of the solid earth), directed to the right of the line of motion in the Northern Hemisphere; and the force of friction.

At sunset, according to Blackadar's model, friction completely and instantaneously disappears above the inversion layer. Now the wind moves under the influence of only the pressure gradient force and the Coriolis force. The sudden upsetting of the previous equilibrium sets off an oscillation. Solving the appropriate equations of motion, Blackadar found that the wind swings first to the left as it begins to strengthen, then shifts to the right as the speed continues to increase, passes through its maximum speed still moving to the right, and finally moves left at the end of the cycle. In this ideal case the head of the arrow that represents the speed and direction of the wind traces a perfect circle in a clockwise direction [*see illustration at right on page 124*]. In the real jet at O'Neill the curve was stretched out into a shape that is elliptical over a good portion of its length.

As one would expect, a feature of weather as pronounced as the low-level jet can manifest itself in a number of ways, some fairly spectacular. Its effect on the landing of airplanes has already been mentioned. The advent of jet planes increases the potential hazard, since they take longer to respond to a demand for increased power than propeller-driven aircraft do. Other types of aerial operation must also take the jet into account. Men or materials dropped by parachute from levels in or above the jet will be blown far from their intended landing point unless its presence is allowed for. Similarly, large rockets are still traveling quite slowly in the first 1,000 feet or so, and their performance can be sharply affected by the high winds of a jet.

Forest fires sometimes spread with such rapidity that they appear to "blow up." The low-level jet is probably responsible. Apparently burning branches, lifted several hundred feet into the air by the strong updrafts, move horizontal-



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ly in high-speed jet winds until they are clear of the upward motion in the intensely hot chimney. Then they fall and start new fires.

According to recent reports, some migrating birds seem to make use of the low-level jet. On their way north during the spring birds generally seek out the southerly flows ahead of cold fronts. These winds are frequently associated with conditions favorable for the jet. Some species of bird do most of their flying at altitudes between about 1,000 and 3,000 feet, and at night. It seems reasonable to suppose that they find the core of the jet, where they can enjoy strong tail winds with moderate temperatures and smooth air.

To the meteorologist, and perhaps eventually to the public, the most interesting aspect of the low-level jet is its possible place in the chain of events leading to the nocturnal thunderstorms of the Middle West and the so-called squall lines of the Gulf Coast states. Over Nebraska, Kansas, Iowa and Missouri thunderstorms frequently occur not when solar heating reaches its maximum during the day—the usual time for such storms—but at night. Some necessary factor, missing during the day, must be present at night. That factor is large-scale lifting of warm, moist air masses, which leads to condensation and triggers the development of thunderheads. The lift can be supplied by the low-level jet. Southerly jets are rather common in this region, and their speeds decrease as they move north. The faster moving and warmer southern jet air therefore tends to pile up behind the air farther north and eventually turn upward.

The squall line, a spring storm that causes major damage and loss of life from northern Texas to Alabama, is a line of thunderstorms accompanied by strong winds. It usually appears 150 to 200 miles ahead of, and roughly parallel to, an advancing cold front. Although the details of its origin are not yet clear, the low-level jet seems to play the same sort of role in a squall line as it does in a thunderstorm. Immediately ahead of the front the sky is cloudy and there is no jet. A few hundred miles farther on the weather is clear and quiet, favoring the development of the southerly jet. This swift flow converges with the winds, generally southwesterly, in the cloudy area. Again the warm and humid air of the jet is lifted, and squall lines form.

The most accurate and detailed data on the low-level jet are still those obtained at O'Neill in 1953. The observa-

The Uses of Space

Man is the searcher. He has a driving urge to know. After centuries of speculation, we now know that the world of space is infinitely more vast even than in our dreams. How shall we rise to the challenge of space knowledge? Ask any scientist and he will tell you: space is not something to be conquered but to be used--for reconnaissance, instant world-wide TV and radio communications, weather forecasting and basic research. Where will it all end? It never will.

Shown above is one feature of Republic's Space Environment and Life Sciences Laboratory, largest space chamber in the nation capable of testing men and space systems at simulated altitudes of more than 150 miles. Republic's new Research & Development Center is the only fully integrated industrial research complex engaged in every vital area of space investigation. Eight laboratories comprise the Center: Space Environment and Life Sciences; Re-Entry Simulation; Materials Development; Nuclear Radiation; Electronics; Guidance and Control Systems; Fluid Systems; Transonic, Supersonic and Hypersonic Wind Tunnels. Behind Republic's record of military aircraft success is the idea of man as the "irreplaceable element." This same concept is the basis of Republic's wide-ranging exploration of every field of space knowledge.

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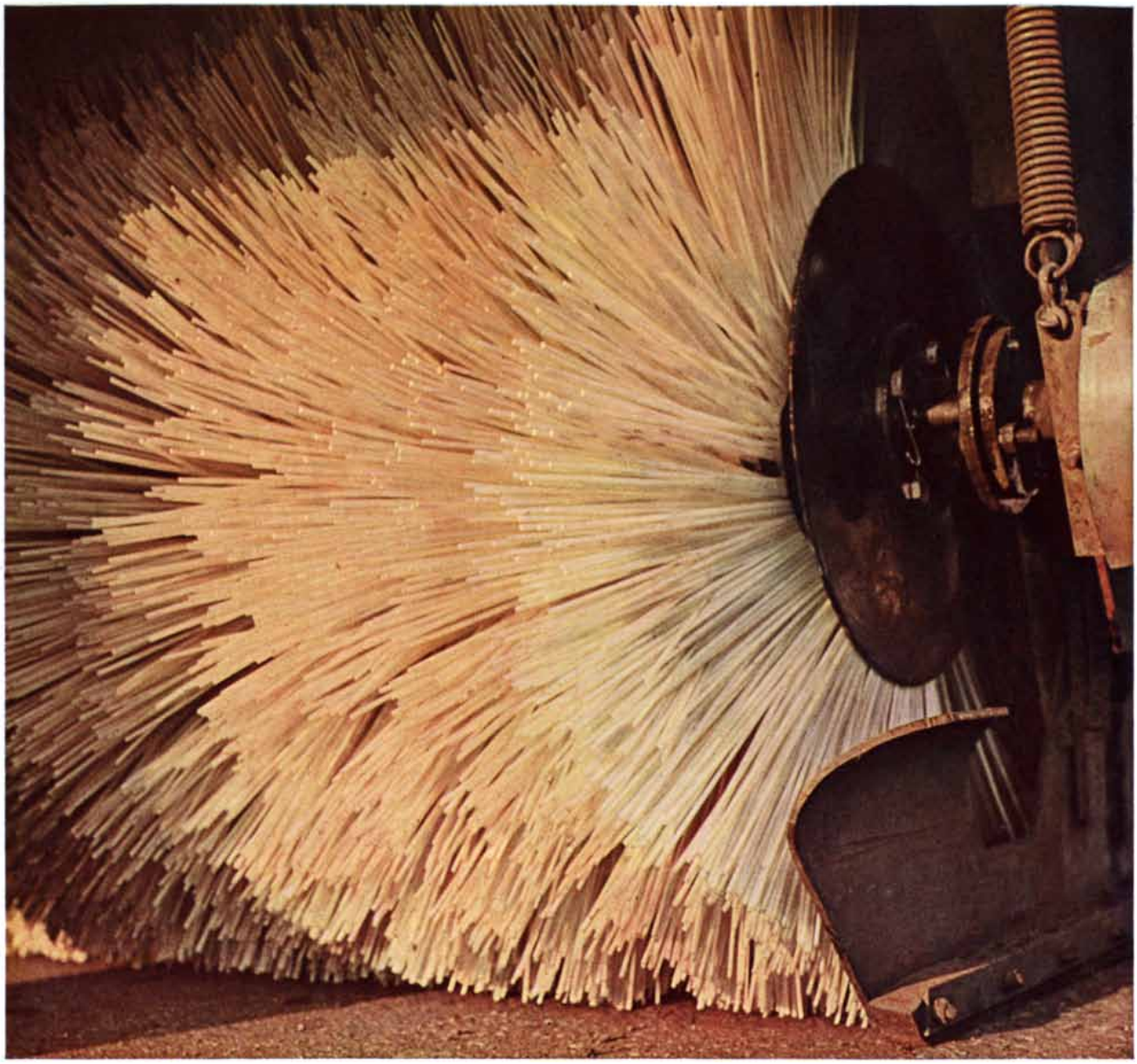

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The brush shown above was manufactured by Roadmaster Brush Company, Union, N. J., using bristles extruded by Keystone Plastics, Inc., Newark, N. J., from Escon polypropylene resin supplied by Enjay. It is only one of many interesting new uses for Escon. For technical information, write to Enjay, 15 West 51st St., New York 19, N. Y.

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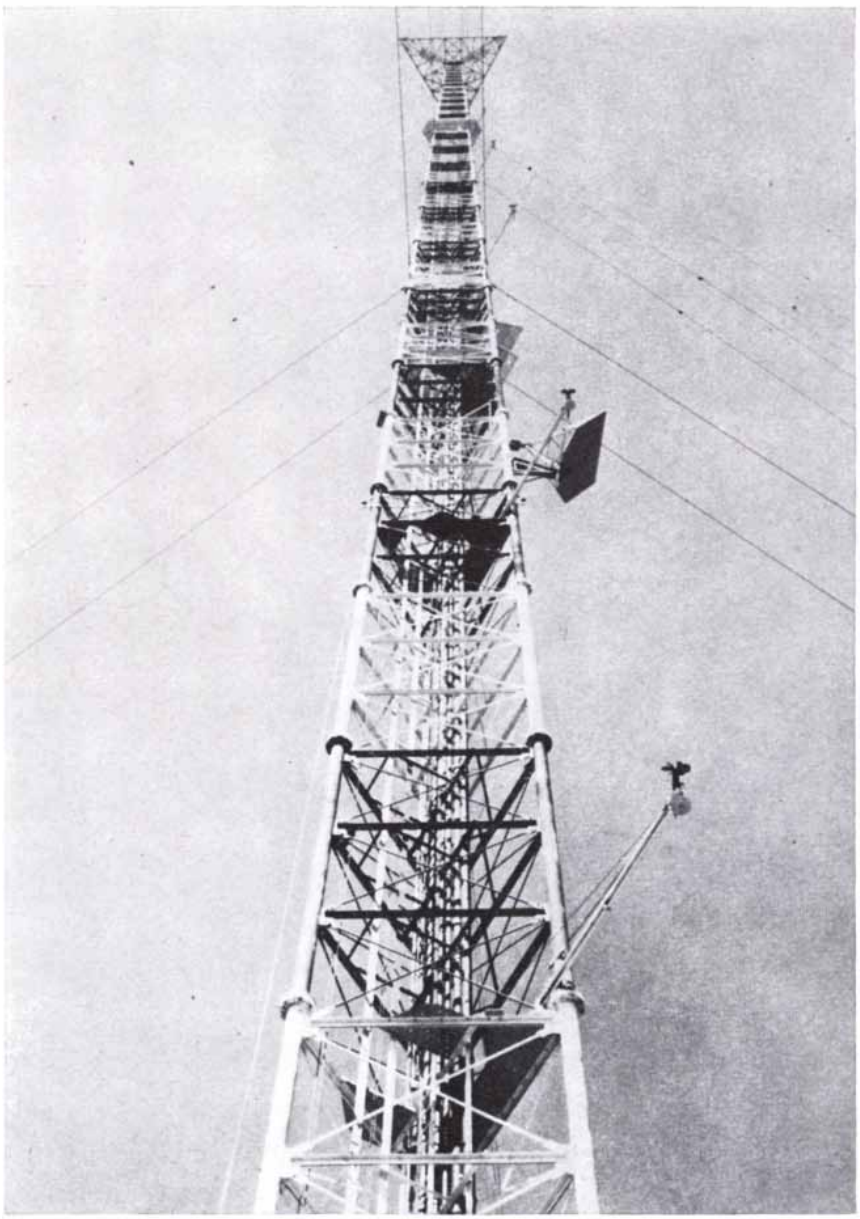
tions there covered a period of only six weeks. It would be highly desirable to have comparable measurements for the year round and for selected periods in all seasons. The Loeser techniques, however, are expensive and provide a limited range of information. Some years ago the author suggested a new approach: mounting instruments on television transmitting and relay towers, many of which are more than 1,000 feet high. One, at Cedar Hill near Dallas, Texas, reaches a height of 1,428 feet. Last year it was fitted out with instruments to make continuous recordings of wind and temperature at 12 levels from 1,420 feet down to 30 feet.

The system went into operation last December, and in the first four months of 1961 a number of jets were detected, all with their maximum winds below 1,200 feet. The strongest one developed during the night of February 22–23. At 5:00 p.m. the wind at 900 feet was about 28 miles per hour; by 3:00 a.m. it had increased to 67 miles per hour. At that time the wind speed 30 feet above the ground was only 15 miles per hour; the difference of 52 miles per hour in 870 feet is one of the largest on record.

The tower at Cedar Hill promises to be an important tool, both for learning more about the low-level jet and for investigating other meteorological phenomena in the lower atmosphere. Research in this area has just begun.



TELEVISION TOWER at Cedar Hill, Tex., rises to a height of 1,428 feet. Wind and temperature are automatically recorded by instruments at 12 levels, providing new data on jet.

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The advantages of using components specifically designed for high-temperature operation represent a significant advance in microminiaturization techniques in that electronic equipment can now be designed which becomes more efficient as packaging densities are increased. Here's what TIMMS can mean to you in terms of:

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Using TIMM circuits, the engineer will not have to "design around" the thermal barrier and stabilization problems of temperature-limited components. Bulky cooling equipment can now be eliminated and packaging space utilized more effectively and efficiently.

Practical Microminiaturization

Depending on output and frequency requirements, TIMM component densities as high as one million parts per cubic foot are possible. This density can be maintained for very extensive systems, not merely small, isolated circuits. The TIMM bistable multivibrator, illustrated, has a component density of 250,000 parts per cubic foot and an operating temperature of 580°C. as compared to 26,350 parts per cubic foot and 250°C., *for the best conventional* circuitry.

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TIMM circuits, constructed only of metals and ceramics, tolerate more than 10,000 times the nuclear radiation of circuits employing conventional devices. Shields, or protective covers, surrounding typical electronic systems are almost completely transparent to these radiations. High-temperature operation of TIMM devices eliminates the need for special nuclear radiation shielding and prevents output transients which normally result from high intensity gamma pulses. No transients were produced in the output of a test TIMM, operated in air at 580°C., during a 5×10^7 R/Sec. gamma pulse. In addition, all materials used in TIMM circuits are at the top of the steady-state nuclear radiation tolerance scale.

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MATHEMATICAL GAMES

Some entertainments that involve the calculus of finite differences

by Martin Gardner

The calculus of finite differences, a branch of mathematics that is not too well known but is at times highly useful, occupies a halfway house on the road from algebra to calculus. W. W. Sawyer, a mathematician at Wesleyan University, likes to introduce it to students by performing the following mathematical mind-reading trick.

Instead of asking someone to "think of a number" you ask him to "think of a formula." To make the trick easy, it should be a quadratic formula (a formula containing no powers of x greater than x^2). Suppose he thinks of $5x^2 + 3x - 7$. While your back is turned so that you cannot see his calculations, ask him to substitute 0, 1 and 2 for x, then tell you the three values that result for the entire expression. The values he gives you are -7, 1, 19. After a bit of scribbling (with practice you can do it in your head) you tell him the original formula!

The method is simple. Jot down in a row the values given to you. In a row beneath write the differences between adjacent pairs of numbers. In a third row put the difference between the numbers above it. The chart will look like this:

$$\begin{array}{ccccc} -7 & & 1 & & 19 \\ & 8 & & 18 & \\ & & 10 & & \end{array}$$

The coefficient of x^2, in the thought-of formula, is always half the bottom number of the chart. The coefficient of x is obtained by taking half the bottom number from the first number of the middle row. And the constant in the formula is simply the first number of the top row.

What you have done is something analogous to integration in calculus. If y is the value of the formula, then the formula expresses a function of y with respect to x. When x is given values in a simple arithmetic progression (0, 1, 2...), then y assumes a series of values (-7, 1, 19...). The calculus of finite differences is the study of such series. In this case, by applying a simple technique to three terms of a series, you were able to deduce the quadratic function that generated the three terms.

The calculus of finite differences had its origin in *Methodus Incrementorum*, a treatise published by the English mathematician Brook Taylor between 1715 and 1717. The first important work in English on the subject (after it had been developed by Leonhard Euler and others) was published in 1860 by George Boole, of symbolic-logic fame. Nineteenth-century algebra textbooks often included a smattering of the calculus, then it dropped out of favor except for its continued use by actuaries in checking annuity tables and its occasional use by scientists for finding formulas and interpolating values. Today, as a valuable tool in statistics and the social sciences, it is back in fashion once more.

For the student of recreational mathematics there are elementary procedures in the calculus of finite differences that can be enormously useful. Let us see how such a procedure can be applied to the old problem of slicing a pancake. What is the maximum number of pieces into which a pancake can be cut by n straight cuts, each of which crosses each of the others? The number is clearly a function of n. If the function is not too complex, the method of differences may help us to find it by empirical techniques.

No cut at all leaves one piece, one cut produces two pieces, two cuts yield four pieces and so on. It is not difficult to find by trial and error that the series begins: 1, 2, 4, 7, 11... [*see illustration on page 137*]. Make a chart as before, forming rows, each representing the differences of adjacent terms in the row above:

Number of cuts	0	1	2	3	4
Number of pieces	1	2	4	7	11
First differences		1	2	3	4
Second differences			1	1	1

If the original series is generated by a linear function, the numbers in the

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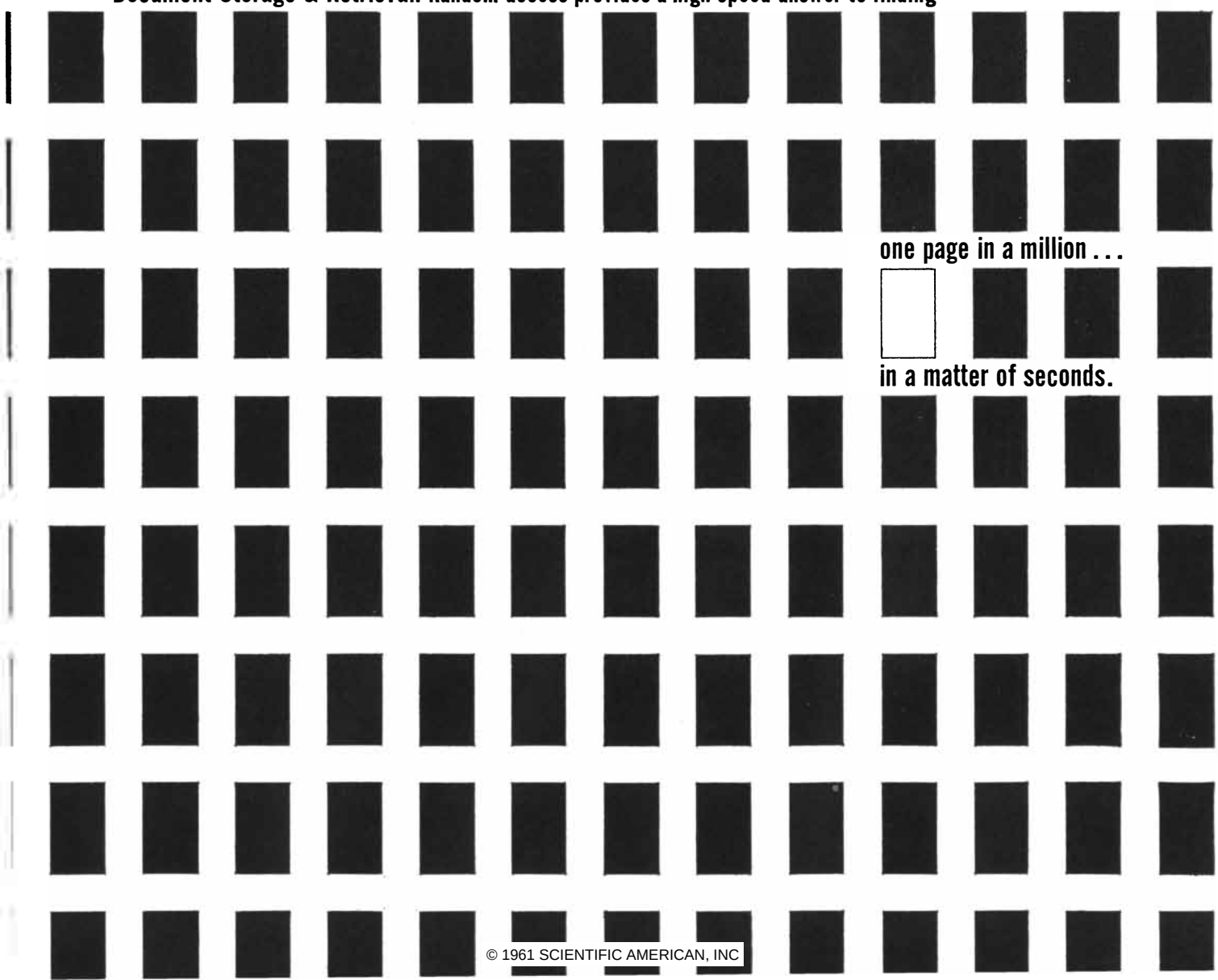

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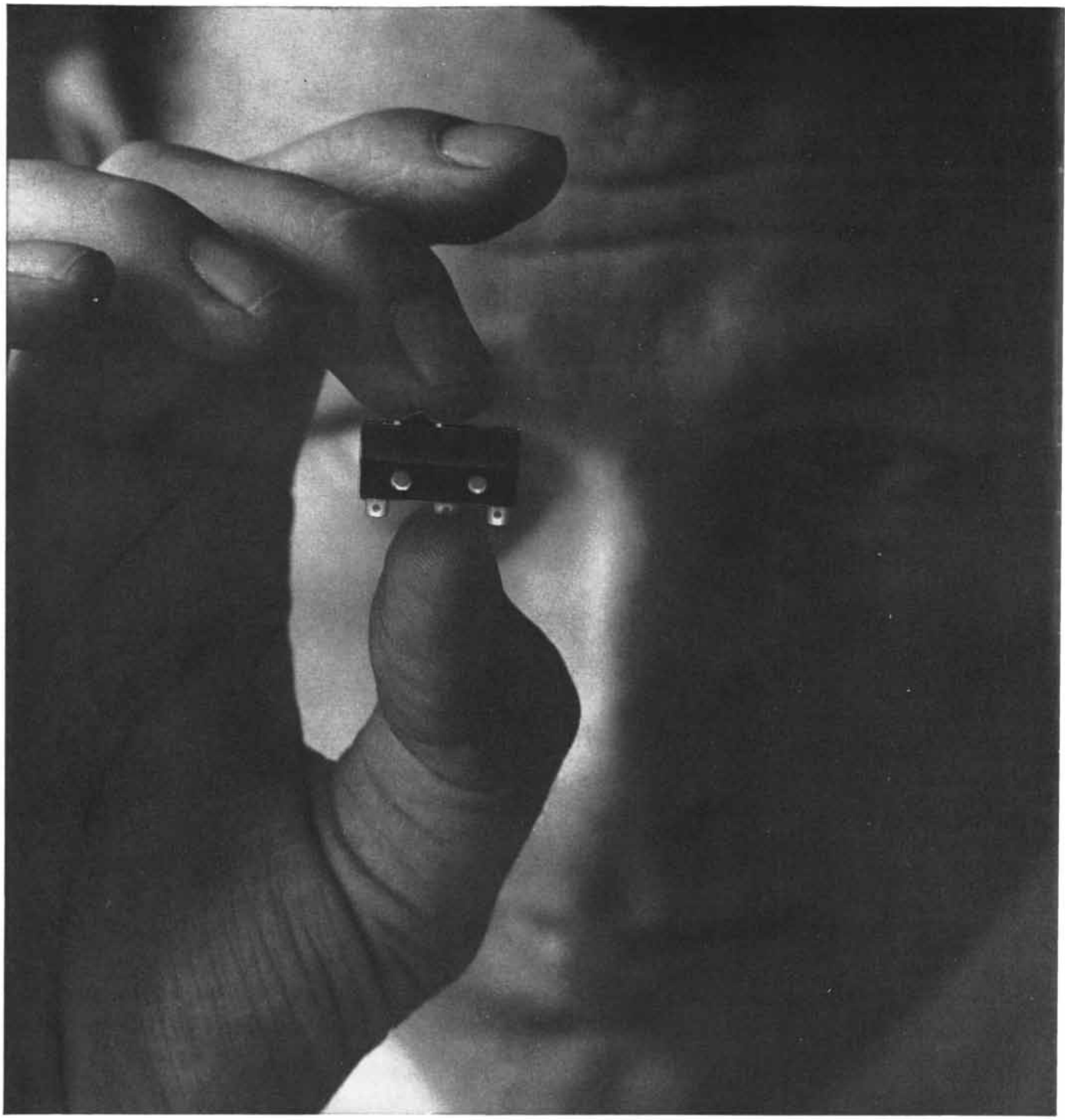

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row of first differences will be all alike. If the function is a quadratic, identical numbers appear in the row of second differences. A cubic formula (no powers higher than x^3) will have identical numbers in the row of third differences, and so on. In other words, the number of rows of differences is the order of the formula. If the chart required 10 rows of differences before the numbers in a row became the same, you would know that the generating function contained powers as high as x^{10}.

Here there are only two rows, so the function must be a quadratic. Because it is a quadratic, we can obtain it quickly by the simple method used in the mind-reading trick. What do we do if the function is of a higher order? We can make use of a remarkable formula discovered by Isaac Newton. It applies in all cases, regardless of the number of tiers in the chart.

Newton's formula assumes that the series begins with the value of the function when n is 0. We call this number a. The first number of the first row of differences is b, the first number of the next row is c and so on. The formula for the nth number of the series is:

$$a+bn+\frac{cn(n-1)}{2}+\frac{dn(n-1)(n-2)}{2\cdot 3}+$$

$$\frac{en(n-1)(n-2)(n-3)\ldots}{2\cdot 3\cdot 4}$$

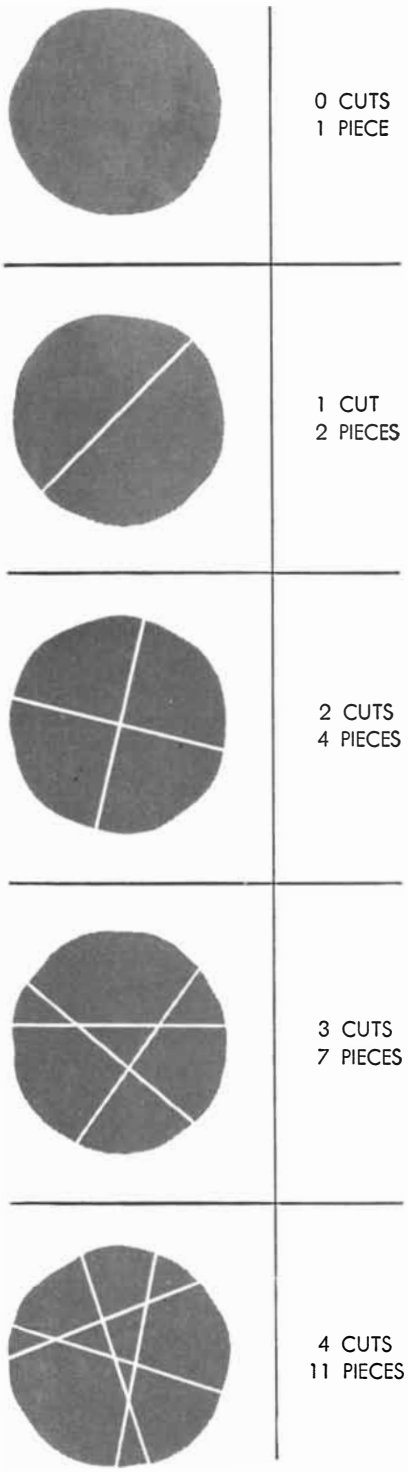
The formula is used only up to the point at which all further additions would be zero. For example, if applied to the pancake-cutting chart, the values of 1, 1, 1 are substituted for a, b, c in the formula. (The rest of the formula is ignored because all lower rows of the chart consist of zeros; d, e, f... therefore have values of zero, consequently the entire portion of the formula containing these terms adds up to zero.) In this way we obtain the quadratic function $\frac{1}{2}n^2 + \frac{1}{2}n + 1$.

Does this mean that we have now found the formula for the maximum number of pieces produced by n slices of a pancake? Unfortunately the most that can be said at this point is "Probably." Why the uncertainty? Because for any finite series of numbers there is an infinity of functions that will generate them. (This is the same as saying that for any finite number of points on a graph, an infinity of curves can be drawn through those points.) Consider the series 0, 1, 2, 3... What is the next term? A good guess is 4. In fact, if we apply the technique just explained, the row of first differences will be 1's, and Newton's formula will tell us that the nth term of the series is simply n. But the formula

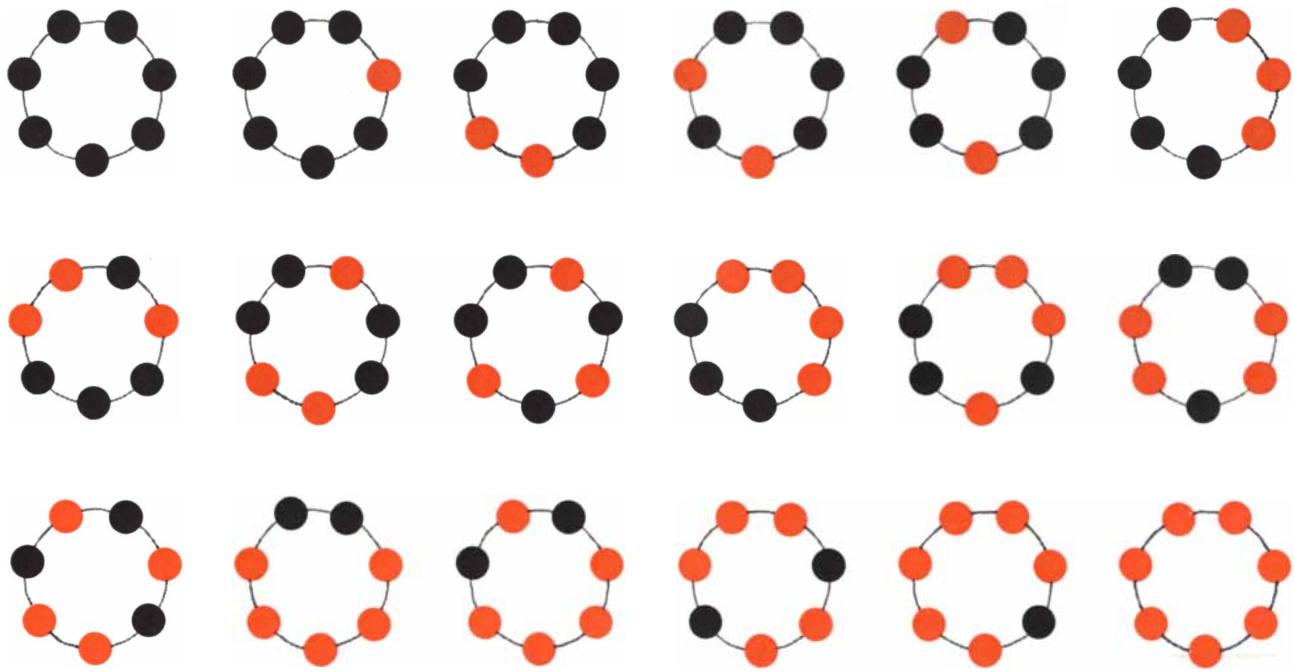
$$n+\tfrac{1}{24}n(n-1)(n-2)(n-3)$$

also generates a series that begins 0, 1, 2, 3... In this case the series continues, not 4, 5, 6... but 5, 10, 21...

There is a striking analogy here with the way laws are discovered in science. In fact, the method of differences can



The pancake problem



Eighteen different seven-beaded necklaces can be formed with beads of two colors

often be applied to physical phenomena for the purpose of guessing a natural law. Suppose, for example, that a physicist is investigating for the first time the way in which bodies fall. He observes that after one second a stone drops 16 feet, after two seconds 64 feet, and so on. He charts his observations like this:

0 16 64 144 256
16 48 80 112
32 32 32

Actual measurements would not, of course, be exact, but the numbers in the last row would not vary much from 32, so the physicist assumes that the next row of differences consists of zeros. Applying Newton's formula, he concludes that the total distance a stone falls in n seconds is $16n^2$. But there is nothing certain about this law. It represents no more than the simplest function that accounts for a finite series of observations; the lowest order of curve that can be drawn through a finite series of points on a graph. True, the law is confirmed to a greater degree as more observations are made, but there is never certainty that more observations will not require modification of the law.

With respect to pancake-cutting, even though a pure mathematical structure is being investigated rather than the behavior of nature, the situation is surprisingly similar. For all we now know, a fifth slice may not produce the 16 pieces predicted by the formula. A single failure of this sort will explode the formula, whereas no finite number of successes, however large, can positively establish it. "Nature," as George Polya has put it, "may answer Yes or No, but it whispers one answer and thunders the other. Its Yes is provisional, its No is definitive." Polya is speaking of the world, not abstract mathematical structure, but it is curious that his point applies equally well to the guessing of functions by the method of differences. Mathematicians do a great deal of guessing, along lines that are often similar to methods of induction in science, and Polya has written a fascinating work, *Mathematics and Plausible Reasoning*, about how they do it.

Some trial-and-error testing, with pencil and paper, shows that five cuts of a pancake do in fact produce a maximum of 16 pieces. This successful prediction by the formula adds to the probability that the formula is correct. But until it is rigorously *proved* (in this case it is not hard to do) it stands only as a good bet. Why the simplest formula is so often the best bet, both in mathematical and scientific guessing, is one of the lively controversial questions in contemporary philosophy of science. For one thing, no one is sure just what is meant by "simplest formula."

Here are a few delightful problems that are closely related to pancake-cutting and that are all approachable by way of the calculus of finite differences. First you find the best guess for a formula, then you try to prove the formula by deductive methods. What is the maximum number of pieces that can be produced by n simultaneous straight cuts of a flat figure shaped like a crescent moon? How many pieces of cheesecake can be produced by n simultaneous plane cuts of a cylindrical cake? Into how many parts can the plane be divided by intersecting circles of the same size? Of different sizes? By intersecting ellipses of different sizes?

Recreational problems involving permutations and combinations often contain low-order formulas that can be correctly guessed by the method of finite differences and later (one hopes) proved. With an unlimited supply of toothpicks of n different colors, how many different triangles can be formed on a flat surface, using three toothpicks for the three sides of each triangle? (Reflections are considered different, but not rotations.) How many different squares? How many different tetrahedrons can be produced by coloring each face a solid color and using n different colors? (Two tetrahedrons are the same if they can be turned and placed side by side so that corresponding sides match in color.) How many cubes with n colors?

Of course, if a series is generated by a function other than a polynomial involving powers of the variable, then other techniques in the method of differences are called for. For example, the exponential function 2^n produces the series 1, 2, 4, 8, 16... The row of first differences is also 1, 2, 4, 8, 16..., so the procedure explained earlier will get

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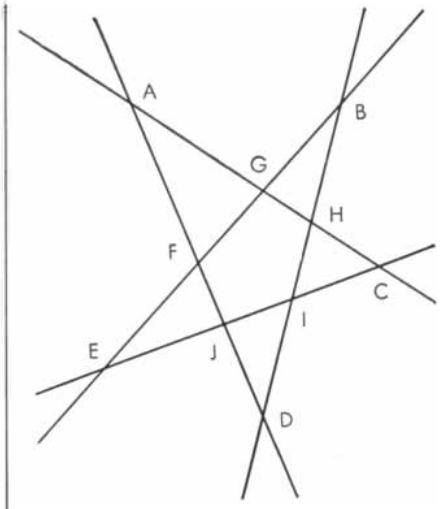
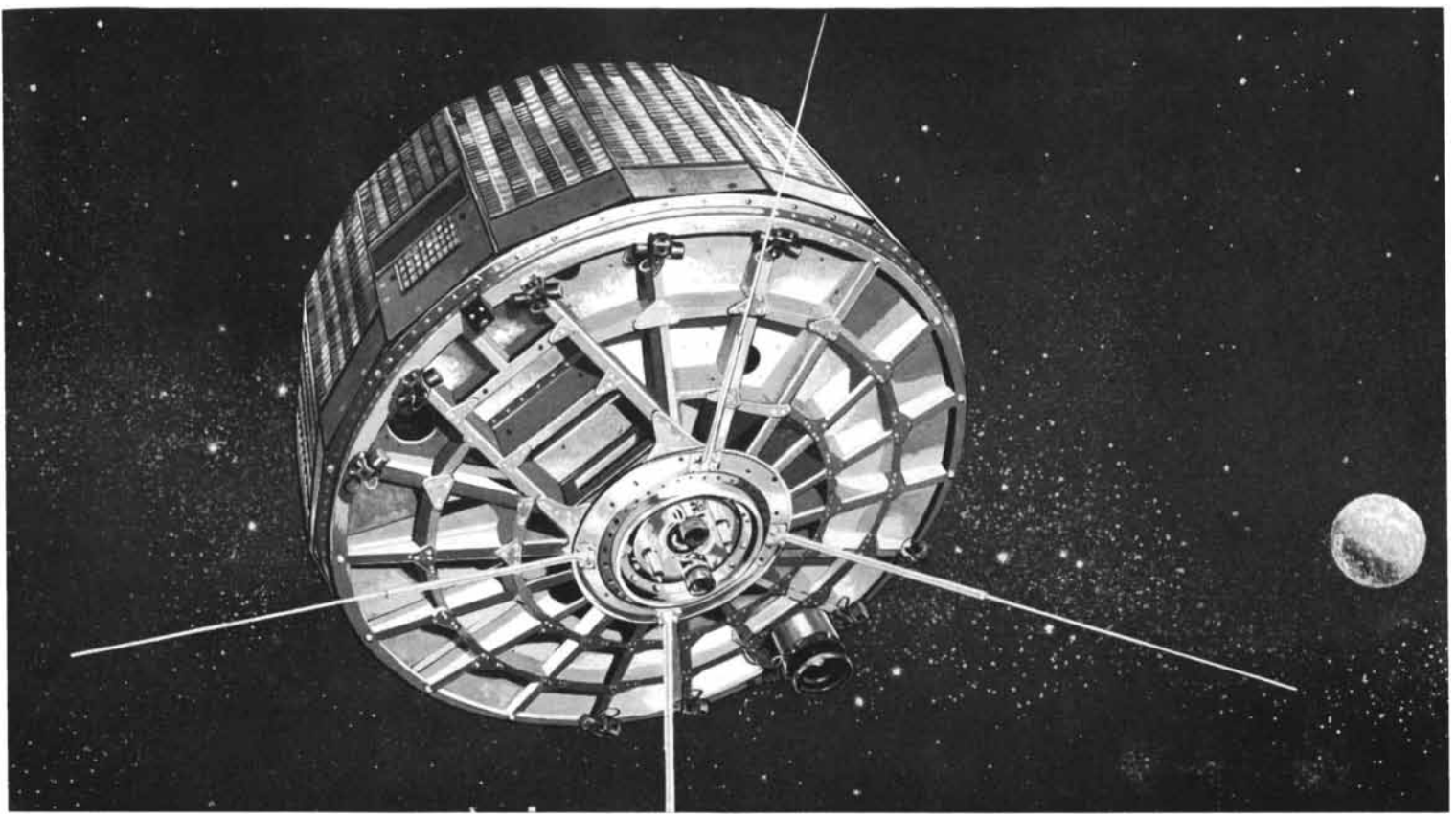


Five lines make 10 triangles

us nowhere. Sometimes a seemingly simple situation will involve a series that evades all efforts to find a general formula. An annoying example is the necklace problem posed in one of Henry Ernest Dudeney's puzzle books. A circular necklace contains n beads. Each bead is black or white. How many different necklaces can be made with n beads? Starting with no beads, the series is 0, 2, 3, 4, 6, 8, 13, 18, 30... (The illustration on page 138 shows the 18 different varieties of necklace when $n=7$.) I suspect that two formulas are interlocked here, one for odd n, one for even, but whether the method of differences will produce the formulas I do not know. "A general solution... is difficult, if not impossible," writes Dudeney. The problem is equivalent to the following one in information theory: What is the number of different binary code words of a given length, ruling out as identical all those words that have the same cyclic order of digits, taking them either right to left or left to right? I would be pleased to hear from any reader who knows of a reference for this problem or can shed any light on its solution.

A much easier problem on which readers may enjoy testing their skill was sent to me by Charles B. Schorpp and Dennis T. O'Brien of the Novitiate of St. Isaac Jogues in Wernersville, Pa.: What is the maximum number of triangles that can be made with n straight lines? The illustration above shows how 10 triangles can be formed with five lines. How many can be made with six lines and what is the general formula? The formula can first be found by the method of differences; then, with the proper insight, it is easy to show that the formula is correct. Both formula and proof will be supplied next month.

"WEATHER EYE" IN SPACE



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THE AMATEUR SCIENTIST

Some diverting devices that apply the concept of negative resistance

Conducted by C. L. Stong

Of the several basic kinds of motion none suggests experiments more fascinating or varied than the class of sustained vibrations that can be explained by the concept of negative resistance. Examples of the class range from the heartbeat of animals to the pulsations of stars and include such man-made devices as the pendulum clock, the oboe, the pulse-jet engine and the transistor oscillator. Once the concept and the method of applying it have been grasped, many puzzling phenomena shed their mystery and the experimenter can design machines and processes of astonishing performance. R. Stuart Mackay, a biophysicist at the University of California, discusses some aspects of negative resistance and explains how to perform a number of experiments that demonstrate its application.

"Some of the most interesting effects in nature," he writes, "are cyclic or involve an oscillation. It is generally the case where sustained oscillations are observed that the result of an action is fed back to influence the further course of this action. In electrical devices sustained oscillations can occur only if the circuit includes some element that can function as a negative resistance, so that an increase in voltage across the element goes with a decrease in current through it [*see illustration at right*].

"Negatively sloping characteristics for alternating current and voltage can be generated either by inductances or capacitors, if their electrical characteristics depend on the magnitude of either the applied voltage or the current. An iron-cored choke coil can be made to react in this way. Many transformers also show the effect.

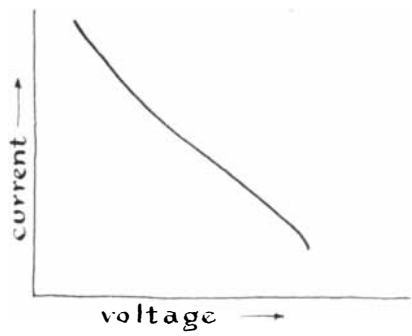
"In some respects a choke coil acts as the electrical counterpart of a flywheel, the inductance of the coil being analogous to the mass of the wheel. Similarly, the capacitor can function as an electrical spring, the capacity being analogous to the stiffness of the spring. When a choke coil and capacitor are interconnected, the combination exhibits the property of resonance, just as the balance wheel and hairspring of a watch tend to oscillate at a characteristic rate. Moreover, just as the rate of the watch can be altered by changing the mass of the wheel or the stiffness of the spring, so can the resonant frequency of the electrical circuit be adjusted by altering its inductance or capacity.

"The inductance of an iron-cored choke coil is related to the amount of magnetic flux that can be induced in the core by a current of given magnitude. For weak currents the amount of current in the coil and magnetism induced in the core are directly proportional. But the ability of the core to acquire magnetism is limited. The current can be increased to a point beyond which the magnetism fails to increase in proportion. At this point the core is said to be approaching saturation. Thereafter the inductance of the choke coil decreases as current in the winding increases.

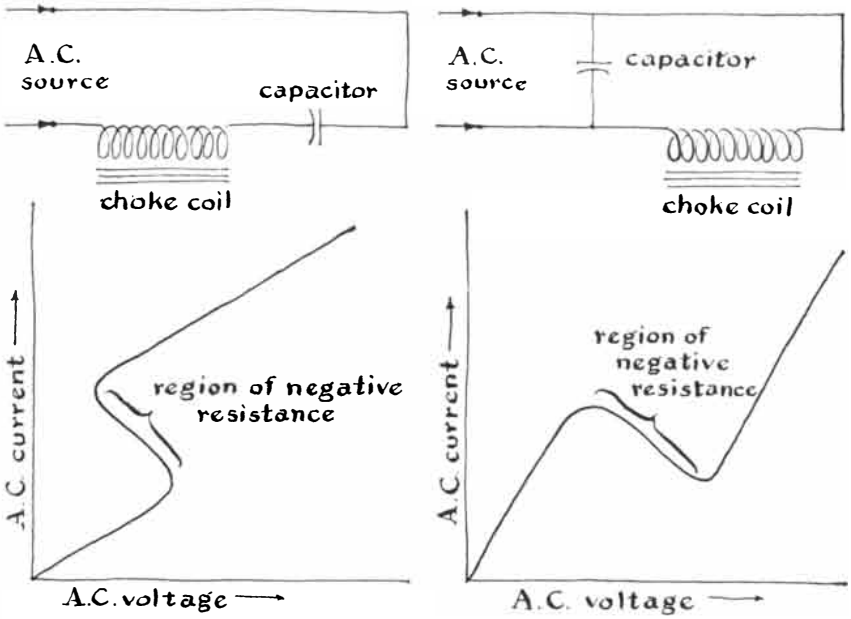
"When a choke coil is connected to a capacitor of such size that the combination resonates at a frequency of, say, 55 cycles per second, and the circuit is connected to a source of alternating current with a frequency of 60 cycles per second, the relationship between the current and voltage varies as shown by the curve at bottom left in the accompanying illustration [*top of next page*]. Initially the current increases in proportion to the voltage. Then, as the core approaches saturation, the inductance falls. Roughly speaking, this has the effect of tuning the resonant circuit closer to the frequency of the source, from 55 cycles toward 60 cycles. At resonance the circuit offers minimum resistance to the current. Consequently as resonance is approached the current increases and the voltage decreases. As the slope of the curve shows, this is a case of negative resistance (more precisely, in this special alternating-current example, negative impedance). Beyond resonance the voltage again increases with the current, and the slope of the curve reverses. Here it is assumed that the choke coil is connected in series with the capacitor, as shown at top left in the illustration. When the coil and capacitor are connected in parallel, the curve assumes the shape at bottom right in the illustration.

"If one now includes a component in the circuit that offers increasing resistance to the current when the current increases, the circuit will become unstable and oscillate. An ordinary tungsten filament incandescent lamp can be used as such a component. The resistance of these bulbs typically increases by a factor of 13 between 'off' and 'on.' To demonstrate the effect connect the primary winding of a transformer (used as a choke coil) in series with a condenser and an ordinary tungsten filament lamp. If all the values are properly adjusted, the lamp will flash on and off regularly every few seconds. The primary or input winding of a five-volt, 10-ampere filament transformer such as the Stancor No. P-6135 may be used as the choke coil. (The terminals of the secondary winding should be separated and taped.) A 100-watt incandescent lamp and a 12-microfarad paper capacitor (not electrolytic) are satisfactory. Inexpensive one- or two-microfarad surplus capacitors can be connected in parallel to make up the required 12 microfarads.

"It is convenient to be able to adjust the power-line voltage applied to the



The curve of a negative-resistance element

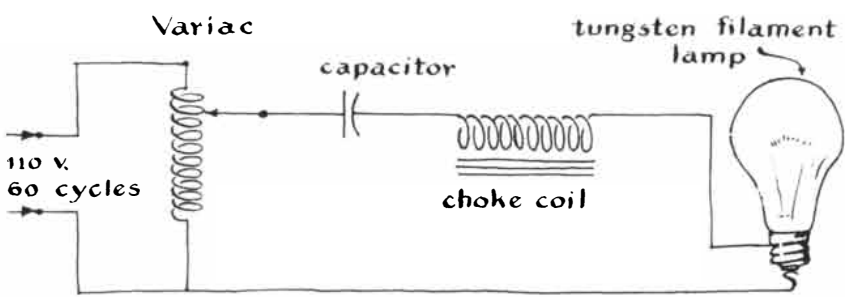


The behavior of two alternating-current devices incorporating a choke coil and a capacitor

combination by some sort of variable autotransformer such as a Variac [*see illustration below*]. The flashing rate of the lamp will depend on the 60-cycle line voltage; indeed, it is a sensitive indication of small changes in line voltage. Beyond the range of approximately five volts (about optimum) the lamp will remain either fully on or permanently off. (When working with series-resonant circuits, remember that the voltage across both the choke coil and the capacitor can be several times greater than the line voltage. Observe the usual precautions.)

"A comparable circuit that is relatively insensitive to changes in line voltage can be made by connecting two choke-capacitor-lamp combinations in parallel and placing a single capacitor in series with one of the power leads [*see diagram at left in illustration on page 146*]. If the components on the two sides of the parallel combination are approximately the same, the lamps will flash alternately in the manner of a railroad crossing signal. Up to four of these series combinations have been connected in parallel so that the bulbs flash in stable sequence. One combination has been in uninterrupted operation for nine years. The sequence of flashing is maintained by the relative resistance of the lamps. The most sensitive combination flashes first; then the current automatically switches to the lamp in the next most sensitive component and so on. By the time all the lamps have flashed on and off, the one that flashed first has cooled sufficiently to present the least resistance and therefore initiates another round of flashing. Incidentally, the transformers run abnormally warm but do not become dangerously hot.

"Two choke-capacitor-lamp circuits in parallel can be made to operate in other interesting ways, either by unbalancing one of the negative-resistance assemblies or by applying abnormally low voltage. If one of the capacitors is slightly larger than the other, for example, one of the bulbs will remain permanently lighted unless the circuit is disturbed. A brief disturbance can be introduced by connecting the unused secondary windings of the transformers by means of a quick-acting push button [*see diagram at right in illustration on page 146*]. Each time the button is momentarily depressed, the



An oscillating circuit made of a choke coil, a capacitor, an incandescent lamp and a Variac

In Navy's Polaris missile system—a major contribution to free world defense—it's a matter of "as the submarine goes, so goes the missile."

Navigation systems manager for this deterrent weapon, Sperry has evolved a system which provides the navigational accuracies required over the weeks and months a submarine is submerged. An inertial guidance system, double checked by a complex of instruments and master computer, not only guides the submarine and pinpoints its position, but telegraphs directly into the missile the exacting data needed to start it on its way. Thus has navigation been called the key to undersea firings: one degree error in the sub's heading means a 20-mile miss for the missile. General offices: Great Neck, N. Y.

Other Sperry contributions to deterrent weapons: precision acquisition, tracking and guidance radars for Navy's Terrier and Talos missiles; bomb-nav system for USAF's B-58; Army's Sergeant missile system; Sperry's Polaris submarine navigation simulator (main illustration).

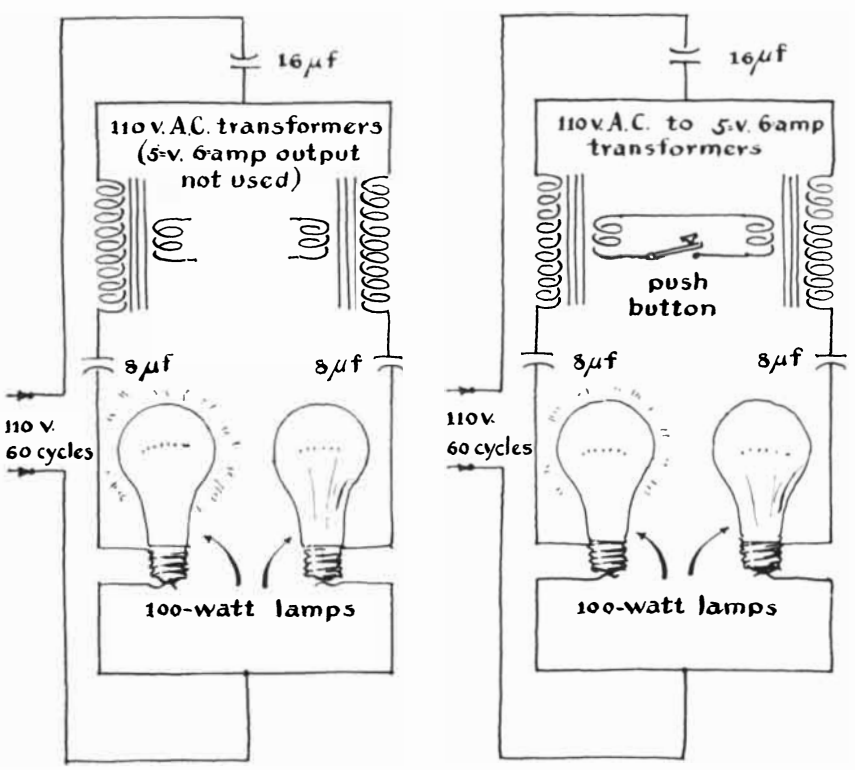
SPERRY

lamp that is normally on will go off for a fixed interval and the one normally off will go on—an action similar to that of a vacuum tube flip-flop circuit. At the end of the interval the circuit will flop back to its normal state. If the two halves of the circuit are balanced but the line voltage is very low, spontaneous switching will not take place. If the push button is operated when the circuit is in this state, however, the existing situation will reverse itself. The bulb previously off will go on and the bulb previously on will go off and stay that way.

"Small electric motors of the universal type draw progressively less current as they accelerate to full speed. In effect their resistance increases with time. Hence they can be used in a circuit characterized by negative resistance to induce oscillation. A small motor connected in series with the choke coil and a capacitor of appropriate size will accordingly turn itself on and off periodically. It must be remembered that the performance of these devices is influenced by line voltage. The voltage must be adjusted with a device such as a Variac for optimum performance.

"The experiments just described are all based on the negative impedance that is characteristic of a nonlinear choke coil and capacitor, plus a lamp (or motor), connected in series. It can also be shown that oscillatory behavior can be expected when the choke coil and capacitor are connected in parallel. To demonstrate this phenomenon, the paralleled units are connected in series with a resistance that decreases with increased temperature. Some thermistors will work in this application. An amusing experiment, though one rather difficult to perform, uses for the resistor a hot dog, one of the numerous substances in which electrical resistance decreases as temperature increases.

"A fascinating version of the well-known floating-ring experiment can be based on the property of negative resistance. In the classical version of the experiment a loose-fitting aluminum ring is dropped over a vertical solenoid that is energized by alternating current. When the power is switched on, the ring is lifted into the air. The alternating magnetic field of the solenoid opposes the alternating magnetic field set up around the ring by currents induced in the ring by the magnetism of the solenoid. In some experiments an extension rod of wood is added to the top of the solenoid as a guide to prevent the ring from flying away from the apparatus. The ring, restrained by the stick, then floats in the air. If the coil of the solenoid is resonated by a suitable capacitor, the current in the coil drops when the ring rises, thereby allowing the ring to fall back. But in falling back the ring inter-



Two oscillating circuits in which two choke-capacitor-lamp combinations are in parallel

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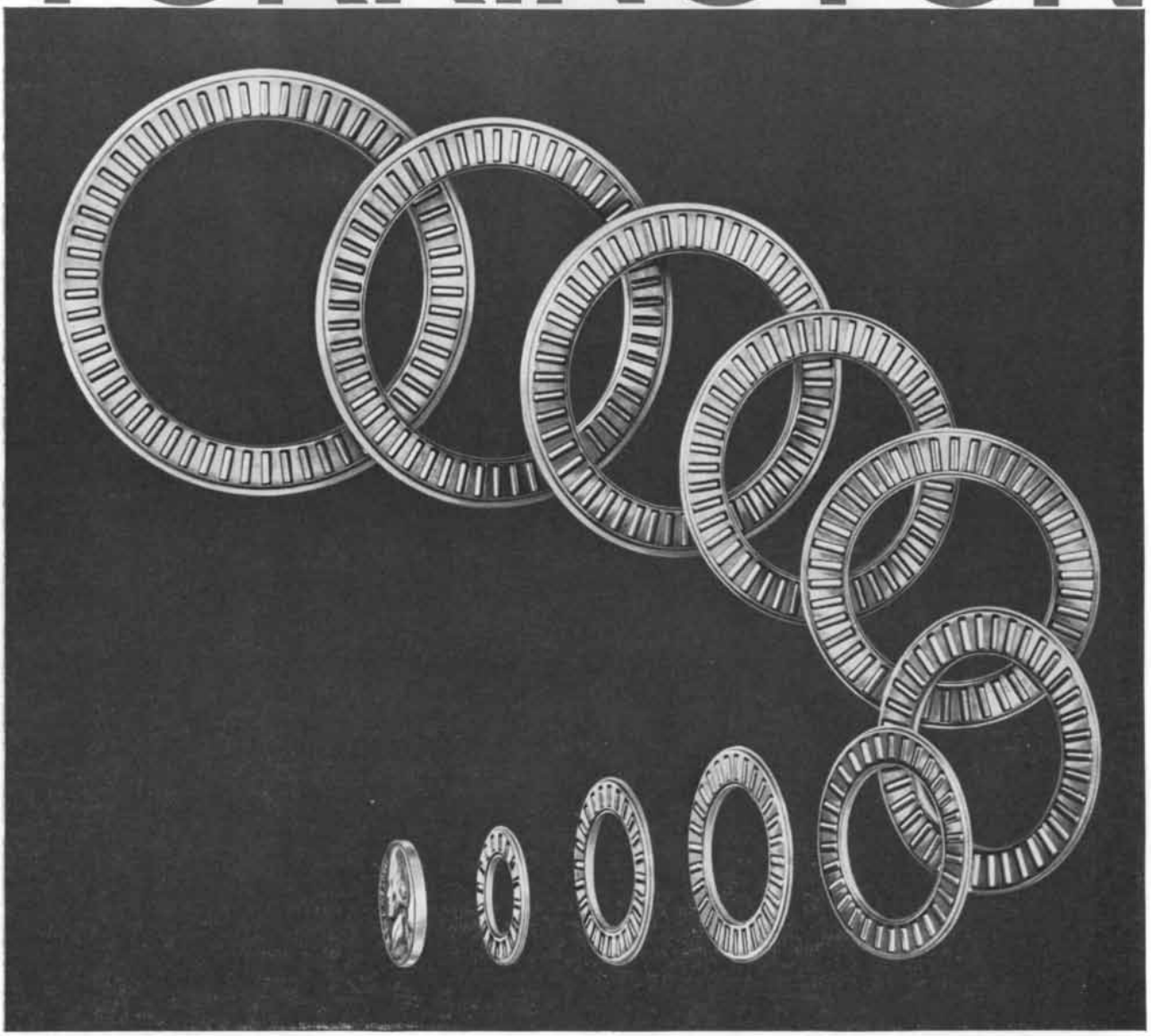

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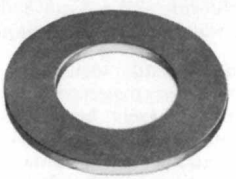

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Infrared Spectroscopic Studies of Molten Salts

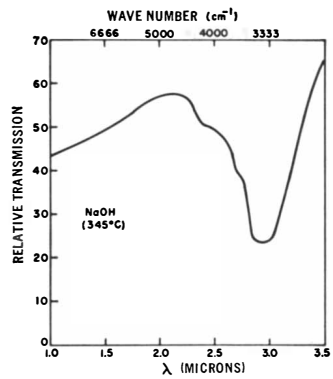
Of the three states of matter, solid, liquid and gaseous, the least is known about the liquid state. This is especially true in the field of molten salts. When a substance becomes molten, properties change drastically and certain change of state phenomena are unpredictable. New examination techniques are providing usable measurements and new insights in this field.

Solid and gaseous systems have been thoroughly studied and much classical data is available. Much less is known about the molten state and virtually nothing has been done in this field except for recent government-sponsored work on liquid coolants for nuclear reactors.

There is a large number of inorganic salts and their properties in a water solution are well documented. There is little knowledge, however, of their characteristics in the molten state. It is interesting to note that when used as a solvent each family of salts would represent a field of study as large as our presently defined field of inorganic chemistry.

Curious chemists have puzzled over molten salts for years. Why don't salts in the liquid state behave as a dense gas? Why does the liquid state depart from the usual law of like dissolving like? What principles of solution phenomena account for eutectics and ternaries? Why do almost identical crystal forms, such as sodium chloride and sodium hydroxide, have such widely separated melting points?

Until recently techniques did not permit laboratory experiments to answer these questions largely because salts at high temperatures become tremendously corrosive and no usable containers had been devised that would permit spectroscopic examination of salts in the molten state. Honeywell research scientists have recently developed a new apparatus in which a thin film of material under test is held in the interstices of a platinum gauze. The gauze is connected to an electrical circuit and heated to maintain the material in the liquid state at the desired temperature. The material itself, with no compensation for container material needed, can be examined above, below or at the melting point. Honeywell scientists, with this new technique, have been the first to apply infrared spectroscopy to liquid state measurements. Resulting data were somewhat surprising, but a check method using a highly polished gold container which reflects infrared after passage through the molten salt affirms the accuracy.



First Absorption Spectra of Molten (345°c) NAOH

This platinum screen technique permits the studying of infrared frequencies associated with the stretching and rocking motions of molten-salt molecules. It also allows a direct measurement of the changes in frequencies of a system as it goes through the melting point. It is a qualitative tool for determining what species of material are present, what changes or reactions occur and why certain mixtures melt at the temperatures they do.

It is known that the X-ray diffraction patterns for sodium chloride and sodium hydroxide are quite similar, bonding energies are fairly close, yet the melting points are 500°C apart. Our data indicate that this is because melting does not involve a complete dissociation of the crystal structure into single molecules or ions. Rather it seems that a quasilattice structure results wherein some dissociation occurs, but cybotactic groups retain structure and are dispersed in the dissociation medium. Sodium hydroxide retains a structure upon melting and thus melts at a lower temperature than sodium chloride which dissociates to a much higher degree upon melting.

Infrared absorption spectra taken below, at and above the melting point reveal another interesting phenomena. Sodium hydroxide in the solid state is not hydrogen bonded. Upon melting it forms hydrogen-bonds which then break as it is heated further. This is evidenced by shifts in the absorption bands. As a result of a series of such spectroscopic examinations, preliminary explanations of phenomena not previously understood are emerging.

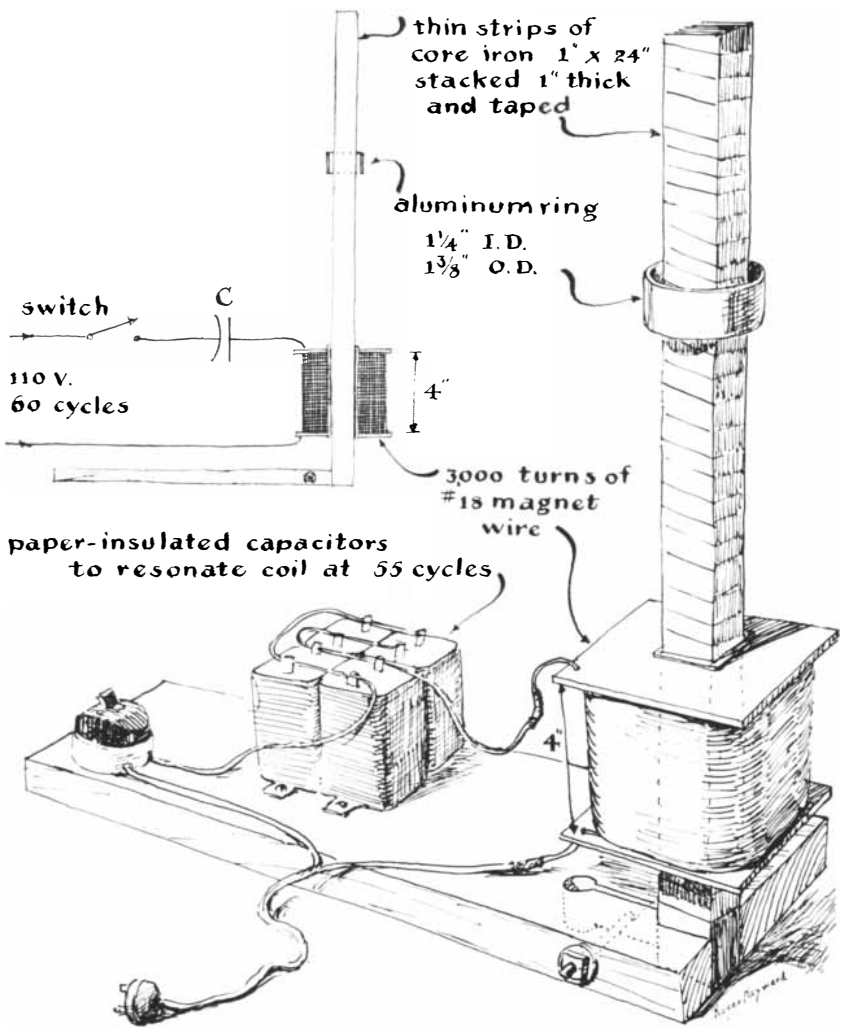
With additional knowledge being uncovered by Honeywell's and other laboratories, molten salts will most certainly be put to important uses. Several interesting things already present themselves. A storage battery could be charged in the liquid state, cooled to the inactive solid state and upon remelting would supply power instantaneously. A switch or other device would be open and inactive in the solid state but would become closed when melting was induced by a heat source. Electrical power could be generated by a combination of fused salts used as thermocouples. More importantly, scientific curiosity alone compels us to explore this vast new field of chemistry.

If you are engaged in scientific work involving molten salts and would like to know more of Honeywell's research in this field, you are invited to correspond with Dr. D. A. Olsen and Mr. L. J. Hallgren, Honeywell Research Center, Hopkins, Minnesota. If you wish a current paper on Honeywell's techniques in molten salt spectroscopy, write Honeywell Research, Minneapolis 8, Minnesota.

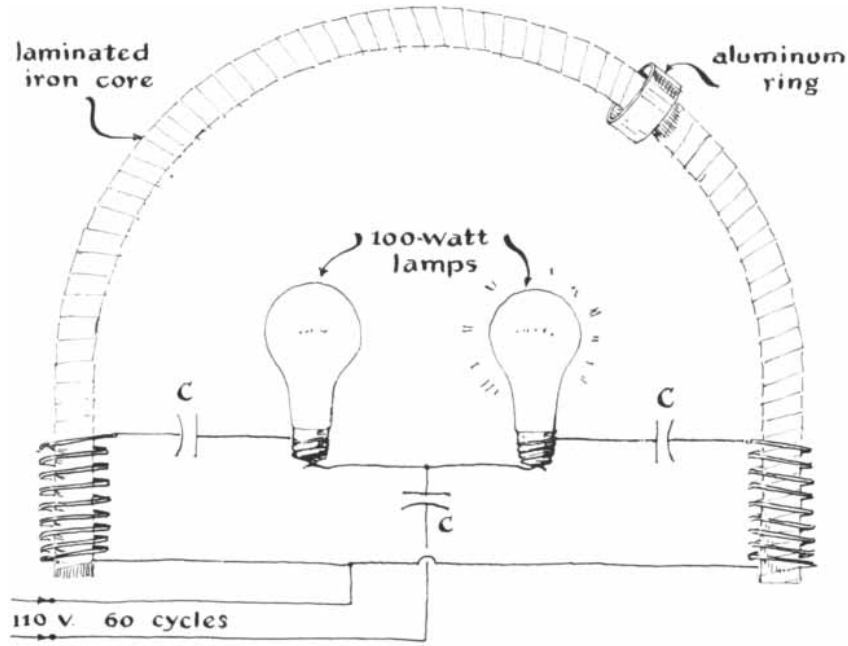
acts electrically with the coil (shifts the current across the region of negative resistance) and the current increases, initiating another cycle. Thus without using breaker points or other mechanical switching devices the floating ring can be transformed into one that dances. A display unit of this type that was designed for operation from a 110-volt, 60-cycle power line used a core two feet long made of thin iron laminations one inch wide and stacked one inch thick [*see illustration below*]. The core extended below a coil four inches long and wound with approximately 3,000 turns of No. 18 wire. The ring, which slid up and down the 14-inch length of core above the coil, was a one-inch length of aluminum tubing. An eight-microfarad capacitor is about right. The ring continuously jumps up and down the full two-foot length of the core. A more elaborate version of the apparatus that is less sensitive to changes in line voltage can also be made [*see illustration on next page*].

"Another interesting oscillatory effect is observed when an iron pendulum bob is suspended directly over a coil that is similarly connected in series with an appropriate capacitor and energized by alternating current. If conditions are right, the iron bob will vibrate above the coil. This experiment has been described in 'The Amateur Scientist' as a method of keeping a Foucault pendulum in motion without the use of an escapement mechanism, either electrical or mechanical [see 'The Amateur Scientist'; June, 1958].

"Interesting oscillators need not be electrical in nature. An automatic Cartesian diver provides an illustration. Normally this charming toy consists of a small inverted vial, filled partly with water and partly with air, that floats in a larger bottle of water. Pressure applied to a diaphragm that closes the top of the large bottle compresses the air above the water. This pressure is transmitted through the water to the air inside the small vial, compressing it. The conse-



A solenoid device that makes an aluminum ring oscillate up and down



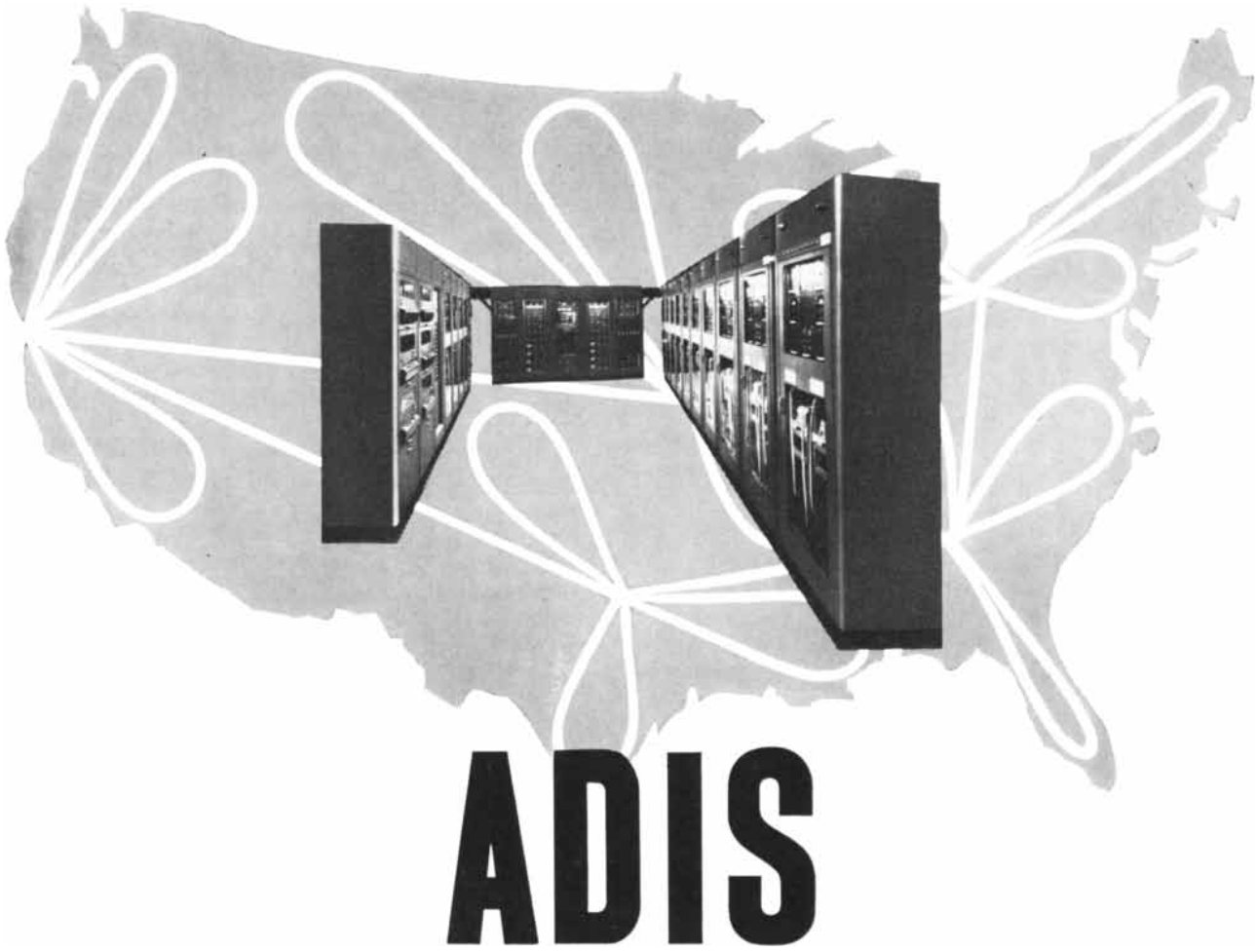
A device in which the lamps alternately flash and the ring oscillates back and forth

quent loss of buoyancy causes the vial (the "diver") to sink to the bottom of the larger bottle. Removal of pressure reverses the process, and the diver rises. If the size of the air bubble is carefully adjusted, the diver can be made so sensitive that it will respond to the small change produced by squeezing the glass wall of the outer bottle. The diver can be made automatic by including a small drop of some volatile liquid in the air bubble of the vial and then either warming the bottom of the outer bottle or cooling its top. In either case the diver will sink; as it descends into warmer water the bubble expands, increasing the buoyancy of the diver. This makes the diver rise, whereupon cooling initiates a new cycle. One can either cool the top of the outer bottle with a piece of ice or warm the bottom slightly by any convenient source of heat. (A 60-watt lamp bulb that has been coated with carbon in a smoking flame works well.) In every case the initial buoyancy of the diver must be adjusted until it is on the verge of sinking. This can be done easily by adding or removing a little air from the diver with a pipette bent into a hook at the lower end for reaching up into the diver. The diver can be a two-inch length of quarter-inch glass tubing and will be most stable if a small bulb is blown at the sealed end [*see top illustration on page 152*]. Any one of a number of volatile liquids can be used in the air bubble. Ether works well but eventually dissolves in the surrounding water. Petroleum ether is preferable.

"The sustained motion of the diver is due in part to the appreciable time required for it to change temperature. If the heating and cooling were instantaneous, the diver would take a position at the center of the outer flask and stay there, because any tendency to rise would immediately be counteracted by decreasing buoyancy. By introducing a time delay what otherwise would be a depth regulator is converted into an oscillator or heat engine. It is often observed in scientific experiments that regulators or servo devices oscillate if a time delay is introduced into the system —that is, if there is a delay in forwarding a signal from the output to the input of the feedback system.

"It is interesting to observe in the case of the Cartesian diver moving in a region of nonuniform temperature that the size of the bubble increases as the diver moves down into a region where the water pressure is also increasing. That is to say, the volume increases rather than decreases with increasing pressure. This corresponds exactly to the increase in current that accompanies the decrease in voltage in electrical negative resistance. In most electrical situations current increases with voltage.

"Another delightful oscillator can be bought in toy stores or made at home. It consists of a small metal boat that is powered by a boiler equipped with a pair of tubes that act as jets at the stern. When a candle is placed under the boiler, one soon hears a putt-putt sound and the boat is driven steadily forward. The alternate formation and condensation of steam draws water into the boiler



ADIS

Communications breakthrough

New Teletype Automatic Data Interchange System (ADIS) now enables the Federal Aviation Agency to interchange aviation weather data coast-to-coast ten times faster than ever before.

With this new electronic message switching system, the FAA effects a major advance in the speed, scope and flexibility of its weather communication service—which supports all civil and extensive military aviation in the United States.

Nucleus of the system is a series of five Interchange Centers, located in Kansas City, Cleveland, Atlanta, Fort Worth and San Francisco. Each of these acts as a clearing house for a number of area circuits, or outlying "loops," collecting data from observation points on these loops and providing the area circuits with data from other parts of the country.

Teletype electronic communications equipment at the Interchange Centers carries out an automatic program of sequentially calling data-originating stations, classifying messages by priority, selecting only those weather items wanted at regional stations, and delivering them to the area circuits—while maintaining the ability to handle emergency traffic when required.

Ultra-fast communication between Interchange Centers is provided by Teletype punched tape equipment operating at 850 words per minute, utilizing the DataPhone concept. Stations on outlying loops are equipped with Teletype Model 28 page printer and punched tape units. Speed-conversion equipment permits automatic interoperation between the national circuit and the local loops. Thus the new system, which serves some 2,400 locations, can report weather conditions from any part of the country in a matter of minutes.

The FAA, through the years, has followed a program of continually upgrading its facilities to meet the needs of the nation's growing air traffic. Teletype Corporation is proud of its part in providing communications equipment for this vital service.

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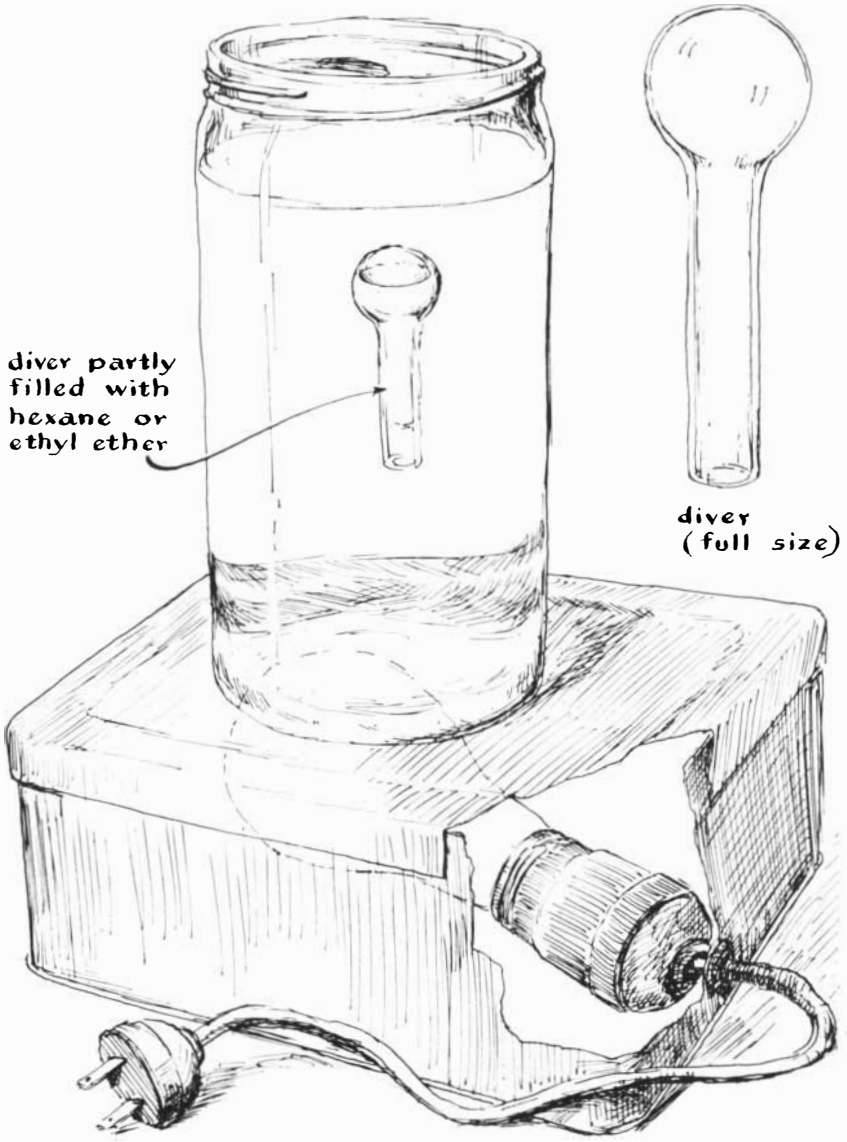
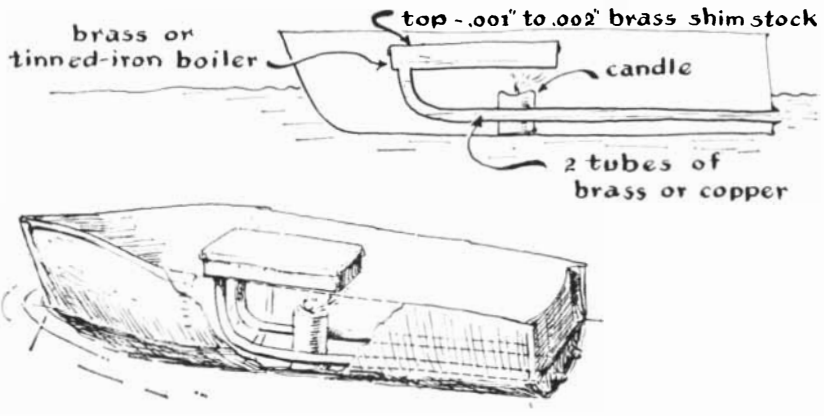


A device in which a Cartesian diver oscillates up and down



A little boat that is driven by alternately sucking in water and expelling steam

and shoots it out. If the top of the boiler is flexible, the sound is quite loud. At first thought it may seem amazing that sucking in water and then blowing it out could drive the boat steadily ahead rather than first pulling it back and then pushing it forward. Two effects account for the forward motion of the boat. First, water is drawn in from all directions at the stern but is ejected almost straight backward. This imparts a net forward component of momentum to the boat. The second effect is caused by the shape of the tubes. When water is shot out of an L-shaped tube, the bend is driven forward. The principle is demonstrated by Hero's aeolipile, the earliest known jet motor. When water or gas is drawn into an L-shaped tube, however, the tube is not pulled backward.

"All these oscillators require that some energy be fed from the output back to the input through a system that introduces time delay. Moreover, this signal must act in a direction that reinforces the output. Signals that are fed back in opposition to the output stabilize the system, and the result is known as negative feedback. Negative feedback is found in nature as well as in man-made devices such as high-fidelity amplifiers. In animals negative feedback helps to stabilize muscle action.

"Biologists can perform surgery on a jellyfish to display a system that has delay, amplification and feedback, and which transforms the animal into a biological oscillator. In a normal jellyfish a controlling impulse is discharged from a central control point into the nerve network that stimulates an over-all contraction of the jellyfish 'bell' to produce a swimming stroke. But consider what happens when the center of the jellyfish is excised and a point on the outer ring of the nerve network is stimulated. The impulse is transmitted around the ring in both directions, initiating muscle contraction until the opposing actions cancel on the other side of the bell. If a point on the ring is squeezed, the impulse is blocked. Stimulation to the right of this point will start an impulse propagating around to the right. If at some time before this impulse arrives back at the starting point the block has been removed, the impulse will be propagated past the starting point and go around for another trip. In fact, the wave of action will continue to travel around the ring for a week or more if the jellyfish is merely left sitting in a pan of sea water. The characteristic time delay in this case is represented by the interval required for the transmission of an impulse around the ring."

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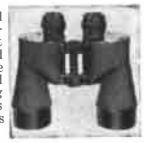

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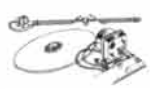

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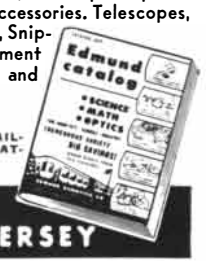

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BOOKS

About the rich lore of games played on boards and tables

by James R. Newman

BOARD AND TABLE GAMES FROM MANY CIVILIZATIONS, by R. C. Bell. Oxford University Press ($5).

Games are second nature to man. A sophisticated form of play, they may be older than tools. Games mirror man's interests, his concerns, his ingenuity, his curiosity, his desires, his aggressions, his loneliness, his sociability. This book describes many of the principal games which have been played by different peoples at different times. Bell, a British surgeon, has studied the fascinating subject for years and has assembled his own valuable collection of boards, pieces and other paraphernalia. He deals with six basic forms: race games, war games, positional games, *mancala* games, dice games and domino games.

In Korea men have for centuries played cross-and-circle race games. *Nyout,* in which the pieces are called horses and are moved according to the throw of four wooden dice, is a favorite; a similar game was played 11 centuries ago in Mayan cities and was taken up later by North American Indians. *Patolli,* a cross game, was a gambling pastime of the Aztecs, but Christian priests destroyed the native records and manuscripts; no Aztec description survives. Mexicans also played *patolli,* and as they rubbed the five beans between their hands and threw them on the mat they invoked their god of sport and gambling, shouting "*Macuilxochitl!*"; this is harder to pronounce but perhaps more effective than "Baby needs a new pair of shoes." That splendid, enduring game pachisi, invented in India, was played by the lowly and the exalted alike. Akbar, a reigning serenity, played it on huge courts made of inlaid marble; he sat on a dais, surrounded by his courtiers, in the center of the court, and 16 comely young slaves from the harem, wearing appropriate colors, moved about the red and white squares as directed by the throws of cowrie shells. (I fancy pachisi to be a game of skill because many years ago, before we were married, my wife and I played it often, the loser to pay for theater tickets, and I usually won. Our markers were colored disks rather than slaves.) Baggara Arabs play a spiral race game called Hyena, the board being a spiral groove traced in the sand, marked by holes along the course; each player has a marker which represents his mother. A related form is the Royal Game of Goose, which was imported into England from the Continent in the 18th century. Women and girls in southern India who, when the rice is nearly ripe, spend days in the paddy frightening away the birds, play a square-board race game, *thayyam,* using the ground as a board, little sticks for pieces, and tamarind seeds, which are cubical in shape, as dice.

Excavating at Thebes, Lord Carnarvon found in a tomb of the Late Middle Kingdom (2000 to 1788 B.C.) an ivory-topped gaming board used in the Palm Tree Game, also known as the game of Dogs and Jackals. At Ur, Sir Leonard Woolley uncovered a Dogs and Jackals board, probably made by the Assyrians about 700 B.C., with some of the gaming pieces still inserted in it. Other such boards have been dug up in Mesopotamia and in Palestine, some beautifully made of ivory and gold; some humbler, of baked clay. Today's cribbage boards, which can be bought in most game shops, are strikingly similar to the Dogs and Jackals scoreboard and thus apparently have "a lineage reaching back to the board from Thebes."

Even older are the race games of the backgammon group. Woolley found five such boards, their squares differently decorated, in the royal tombs at Ur; the date is about 3000 B.C. A simple specimen has little disks of shell with red or blue centers set in bitumen; these covered the wood and formed a background. A more elaborate board is covered with an incrustation of shell plaques inlaid with lapis lazuli and red limestone and divided by lapis lazuli strips. The boards are hollow and inside them are black and white counters and six pyramidal dice (three for each player), with two of their four points dotted with inlay. For many centuries Sumerians, Egyptians and Arabs played variations of this game.

A very popular member of the group, often referred to in the literature, was the Roman *ludus duodecim scriptorum*—the game of the 12 lines. On the back of a silver mirror made in the second or third century B.C. and found in Palestrina is an engraving of a youth and a maiden, both partly undressed and sitting in front of a gaming table. Considering the state of their clothes and the fact that there are no pieces shown on the table, the game they are playing is uncertain. Bell suggests the board game had only just begun, and the youth does look as if he is about to throw a die. Next to the half-naked maiden, however, appears the word *devincamted,* which may be translated "I believe I have beaten you." Very puzzling. At any rate, an archaeologist who examined the mirror concluded that although its style was Greek, it was Roman, and that the game portrayed was the original form of *ludus duodecim scriptorum.* Later this form was replaced by a more elaborate 36-space game, which came to be played on every street corner and in every inn in Rome, and by Romans in other parts of the world. A board made of buff-colored pottery was found at Holt in Denbighshire; it apparently belonged to a soldier of the 20th Legion stationed on the marches of Wales in the first half of the second century A.D.

The commonest form of the board consisted of three horizontal lines, each split into 12 spaces. The spaces might be circles, squares, letters, crosses, monograms, even erotic symbols. Cubical dice were used, three for each player. The lowest throw, three aces, was known as *canis;* the highest throw, three sixes, was called by Cicero *venereus.* To prevent cheating the dice were thrown into a *fritillus,* or *pyrgus,* a wooden tower about a foot high which had a little spiral staircase inside. Though all gam-

bling games were forbidden by law except during the Saturnalia, the laws were laxly enforced and under many emperors were entirely disregarded. Gambling at *ludus* became a mania. Nero, who could be relied on to do things in big style, played at stakes up to 400,000 sesterces (about $17,000) a point, and Commodus went the whole way simply by turning the imperial palace into a casino, with amorous diversions to relieve the tensions of gambling. That one did not have to be an emperor to play *ludus* is proved by a tavern wall-painting found in Pompeii, preserved under the lava of Vesuvius. This shows a pair of the *hoi polloi* about to square off in a fight over their game, with the innkeeper, acting as his own bouncer, pushing them into the street and shouting, "*Itis foras rixsatis!*" ("Get out if you want to fight!").

Like pachisi, the backgammon-type games have had a long history and have waxed and waned in popularity. A well-known variant, *tabula* (Tables), replaced *ludus* in fashionable circles and was played for more than a thousand years. The *Codex Exoniensis,* a collection of Anglo-Saxon verse given to Exeter Cathedral by Leofric, the city's first bishop, about A.D. 1025, contains the first English reference to Tables. Two lines run "*Hy twegen sceolon/Taefle ymsittan,*" which means "These two shall sit at Tables." A magnificent medieval board used for Tables, which served as a reliquary in the church of St. Valentine in Aschaffenburg, had plain points made of red-veined oriental jasper, adorned points overlaid with inlaid pieces of split rock crystal, and beneath them small terra-cotta figures painted in green, red, yellow, blue and white tints on a gold ground. "They represented partly twin-tailed sirens, partly dragon-like monsters, centaurs, and battles between beasts and men." The Church has always known how to choose and how to use its treasures, regardless of their object or origin.

A *tabula*-like game called Chasing the Girls, using a simple plank as a board, with wooden strips for points tacked to it, is still played, Bell tells us, in remote parts of Iceland. *Nard,* "a favourite game of the Arab world" and also played throughout Asia, is of the backgammon family. In the 17th century a new variant of *nard* appeared in Europe and enjoyed "a tremendous revival." In England the game was called backgammon, in Scotland gammon, in France *tric-trac,* in Germany *puff,* in Spain *tablas reales,* in Italy *tavole reale.* Again, just before World War II, "there was a craze for backgammon among the intellectuals, especially the London literary set," but now the pastime is in eclipse. Perhaps space travelers will revive it.

War games make a large and ancient group, the basic theme of which, involving threats, attacks, strategies, encirclements, captures and the like, is more imaginative than that of the race games. A board for the war game *alquerque* was found cut into the great roofing slabs of the temple at Kurna in Egypt, which was built about 1400 B.C. Its descendant, called *quirkat,* was played by the Arabs and brought by the invading Moors into Spain. The pieces were moved from point to point along a marked line and could jump hostile pieces (as in checkers), thereby removing them from the board. The Spaniards brought the game to the New World and the Indians modified it, one form being the Game of the Stone Warriors, which had 168 squares and could be played by two or four players.

Most famous in this category is the chess group. At one time in ancient India there was a race game called *ashtapada* which was played on a board of 64 squares. About the fifth century A.D. the board became host to a new game called *shaturanga,* a battle between four armies each under control of a rajah and each containing four corps: infantry, cavalry, elephants and boatmen. This was the youth that was father to chess. Pawns represented the infantry, a ship the boatmen, a horse the cavalry, an elephant the elephants (what else?) and a human figure the rajah. As it is today, it was a cerebral game, but dice were also used in profound recognition of the fact that chance so often rules human affairs. A rajah's throne could be seized, opponents could be "despoiled," a throne could be regained, a rajah could be "rescued," empires could be built, there was a "concourse of shipping," pawns could be "promoted" to horse or elephant, there were "privileged pawns" (a "chivalrous courtesy towards a weak adversary"), and a game could be drawn when a player had lost all his pieces except his rajah and was considered to have fought "to an honourable peace." At an early date in Hindu culture gambling was forbidden; dice were therefore eliminated from *shaturanga.* Each force was reduced to a single army and the game for four players became a game for two. This is why the pieces in modern chess (with the exception of the king and queen) are duplicated. Moreover, the kings were reduced to the rank of prime ministers, their power of movement was halved and they became weak pieces. With other changes *shaturanga* was transformed into the early medieval variety of chess: *shatranj.*

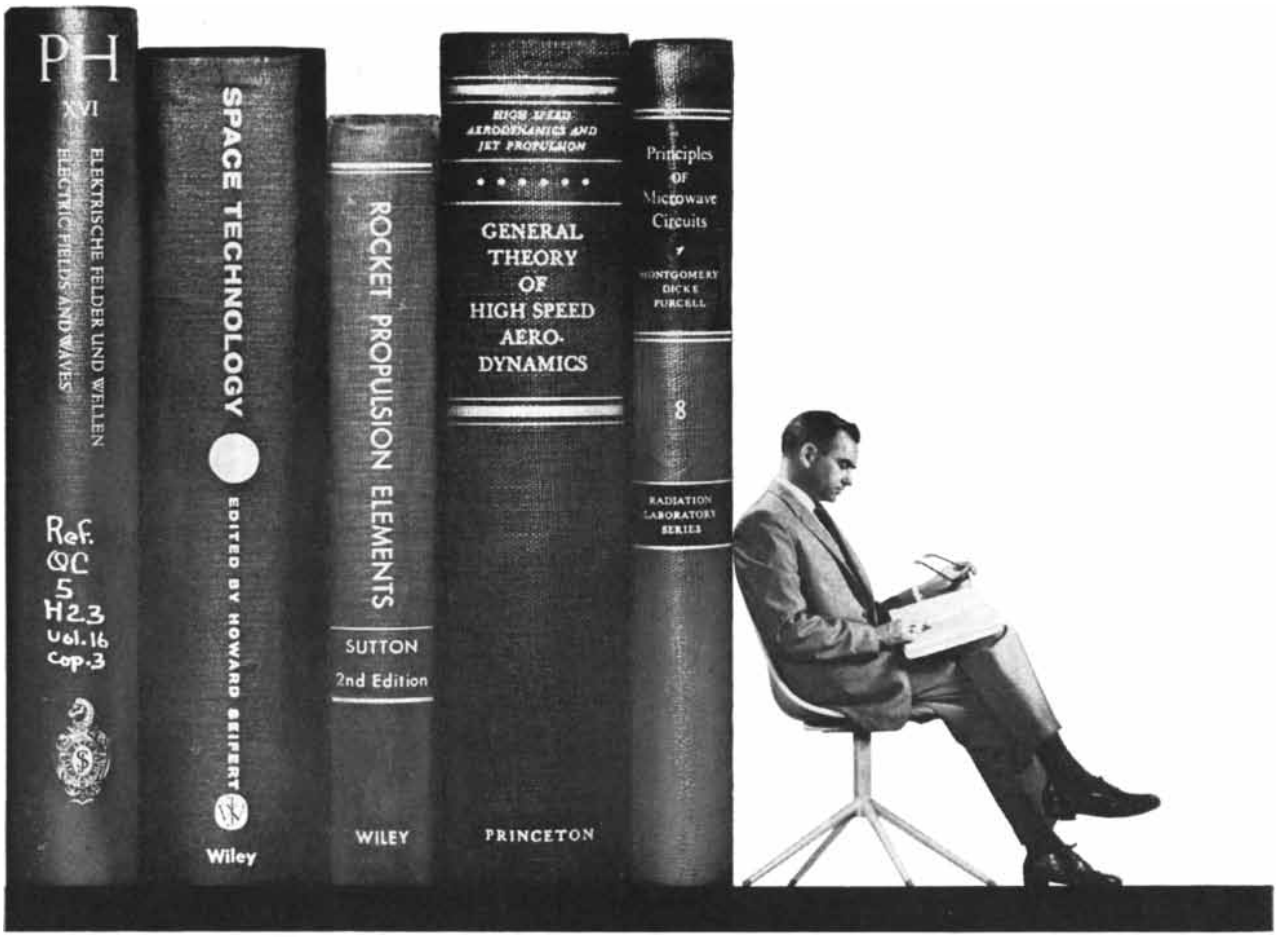
This game became known to the Arabs, to the Byzantine court, to the Greeks (soon after A.D. 600), to the Muslims of India and finally to Europe—perhaps first in Charlemagne's court via Spain, perhaps via the Crusades. If the Knights of the Cross indeed learned chess from the Arabs, it is more than likely that on their return home the game would have reached every castle in Christendom.

The game evolved slowly; Caxton's *The Game and Playe of the Chesse,* printed in Bruges in 1474, described European medieval chess, which differed little from the *shatranj* of the Crusades. Among the exotic forms were "great chess," played by Tamerlane (28 pieces on a side, board of 112 squares); circular, or Byzantine, chess, which had four "citadels" where a piece had sanctuary; the Courier Game, played after the 13th century in Germany, which had couriers (they moved like the modern bishop), jesters with cap and bells and sages with long beards in addition to the regular pieces; the Maharajah and the Sepoys, in which one player has a single piece—the maharajah—which can move as a queen or a knight, and the other player has a full set arranged in the normal way; Chinese chess (*siang k'i*), which has generals, mandarins, horsemen, chariots, cannon, elephants, and in which the board of regular size is bisected by a "river"; the Jungle Game, with lions, tigers, panthers, dogs, cats, rats and other fauna.

Draughts, another celebrated game, was invented in France about A.D. 1100. At first there was no compulsion rule—one did not have to capture an enemy piece in take—but in the 16th century the rule was introduced, the name of the game being changed from *le jeu plaisant de dames* to *jeu forcé.* There are English, Italian, Turkish and Polish versions.

Miniature battles between unequal forces, in which the smaller force has a piece with special powers, are exemplified by the *tafl* group of games of northern Europe: Fox and Geese, *tablut* (the Swedish king is the central figure), the Saxon *hnefatafl.* Cows and Leopards (the leopard—one player has two—can kill a cow; the other player has 24 cows, but they can only imprison the leopard) is a similar game. *Tablan,* a running-fight game played in India, uses dice sticks; a related Central American Indian game, *puluc,* has corncobs for pieces.

Everyone is familar with some of the



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games of position: Noughts and Crosses, for example, also called ticktacktoe, and other three-in-a-row and five-in-a-row pastimes. But these are in effect poor relations of the Chinese *wei ch'i,* otherwise known as *i-go,* or simply Go, "one of the great intellectual games of the world." Of my own knowledge I vouch for the truth of the assertion that Go is a harder and subtler game than chess.

Go is played on an 18-by-18 board. The pieces, which are called *tze,* are discoid, black or white and about the size of a nickel, and are placed on the 361 points, not on the squares. There are two players, each moves in turn, and the object is to control as many of the points as possible. When a group of enemy pieces is surrounded, that is, cut off from contact with an empty point (in orthogonal, not diagonal, directions), the points are credited to the encircler, and the surrounded troops become a "dead mass." It is a game of great elegance; the obvious is never stressed. For example, if a batch of troops is clearly to be surrounded, they are regarded as "dead," the *coup de grâce* (to use an old Chinese expression) is not given, and the players simply turn their attention to another part of the board; similarly, an "impasse" is left alone, this being a configuration where an empty point is surrounded partly by white pieces, partly by black, in such a way that if either player enters a man his opponent could capture the entire group.

Oriental scholars, says Bell, have devoted years to the study of Go. Philosophies of strategy and tactics have been elaborated; players are rated in nine grades and handicapped according to skill; there are five points of etiquette and courtesy (*e.g.*, when an opposing piece is within one move of being captured, "it is usual to tap the board with a *tze*"). Go is first mentioned in Chinese writings about 625 B.C. A century later it was taken to Japan, where, as in Cathay, skill at Go was until the 20th century "a strong recommendation to promotion," corresponding "as an index of mental ability to a university degree in a standard subject in the West." Confucius advised the idle rich to play *wei ch'i* "rather than allow their minds to stagnate." Apparently not even Confucius had been able to prevent this.

I shall pass over the *mancala* group (games in which pebbles, balls or other counters are arranged in rows of small depressions in a board) and turn to an ancient and still vigorous favorite. The Sumerians played at dice, as did the Etruscans. Dice with the opposite sides adding up to seven—as with any self-respecting pair of bones—have been found in England in the prehistoric earthworks of Maiden Castle. Tacitus described the Germani in A.D. 99 as practising dice play "soberly, and quite as if it were a serious business, with such hardihood in winning and losing, that, when they have nothing more left, they stake their freedom, and their person on the last cast of the die." Dicing spread throughout England in the 12th and 13th centuries. Among the English, who respect liberty, a man could not dice away his freedom, but he could lose everything else. A 14th-century manuscript illumination shows two players, one stark naked, the other reduced to his shirt. The dice game called hazard was not confined to low taverns. King Olaf of Norway and King Olaf of Sweden met at Konungahella in Norway in A.D. 1020 to decide the ownership of the isolated district of Hising. They agreed to throw dice for the prize. The story is that Olaf of Sweden threw two sixes, smiled and said it wasn't worth the other Olaf's while to throw. He then threw two sixes. The Swede rethrew and produced another pair of sixes. Then Olaf of Norway banged down the dice, throwing one six and splitting the other cube in two so that seven pips turned up. "Norway gained the district and the kings parted at the end of the meeting staunch friends." I don't believe it.

Of dice games there is no end. Heads and Tails is a kind of dice game. It was played by Nero, who used crooked coins (one of which has been found), and by Edward II of England, who managed to lose eightpence at the game (which he had to borrow from Henry, his barber) to Monsieur Robert Wattewille. (In those days a sheep cost threepence.) Thirty-six and Pig are examples of games using six-sided dice; only one die is used, the object being to score a certain number of points. A popular Mexican gambling game is *barbudi,* which consists of throwing two dice from a cup to achieve certain winning number combinations, *i.e.*, 6:6, 5:5, 3:3, 6:5. The lingo is as well known to us as it is to the Mexicans: the player rolling the dice is called the shooter, and he who bets that the shooter will not make winning points is the fader.

The game of hazard has had a long life. In Chaucer's *The Pardoner's Tale* occur the lines: "In Flaundres whilom was a compaignye/Of yonge folk that haunteden folye/As riot, hasard, stywes, and tavernes..." But not only the yonge folk of the 14th century played it: among gamblers in the 17th and 18th centuries it had become a passion and it survived

in a modified form in the game called craps. Here a nice little point (of semantics, not craps) arises, for the game Bell calls craps, which he describes as being "widely played" by U.S. and Canadian troops in World War II, is not quite the game we all know by that name. Bell's craps is a refined sort of thing in which two dice are thrown from a cup by one of the players known as the caster. He first throws a "main point," which has to be a 5, 6, 7, 8 or 9 (other throws are disallowed and he must throw until one of these comes up); then a "chance point," which has to be a 4, 5, 6, 7, 8, 9 or 10. Main and chance points having been determined, he now continues to throw until he either duplicates the chance point, when he wins the stakes on the table, or the main point, when he loses them. But note that when the caster is throwing to fix the chance point, he loses the stakes if he throws an "out": 12 is out if the main point was 9, 7 or 5; 11 is out if the main point was 9, 8, 6 or 5; a throw of 2 or 3, known as "crabs," is out regardless of the main point. Another feature, called "nicks," provides the caster with an outright win if in his chance throw he duplicates the main point. I cannot quite see this game played in the alley around the corner and I am rather impressed with the elegant inclinations of U.S. and Canadian troops.

A hazard player of the 18th century who deserves to be remembered was William Crockford, the son of a fishmonger. Crockford relinquished this peaceful trade for the joys of gambling. The joys fluctuated, but when "Crockey," as he was called, was not contemplating hanging or drowning himself because of reverses, he did pretty well. At one session lasting 24 hours he won 100,000 pounds from two noble lords named Thanet and Granville, a Mr. Ball Hughes and two other gentlemen. What the losers did to themselves after this disastrous sitting is not known, but Crockey built himself a splendid gambling palace in St. James's Street, London, where exquisite suppers were served gratis and where the celebrities of England, from the Duke of Wellington to the youngest ensign of the Guards, and other magnificoes such as Prince Talleyrand, Count Pozzo di Borgo, Prince Esterhazy and the Duke of Palmella came often between midnight and dawn to see and be seen, to enjoy, in the words of a contemporary reporter, "brilliant sallies of wit, the most agreeable conversation, the most interesting anecdotes, interspersed with grave political discussions and acute logical reasoning on every con-

ceivable subject," and to win (or lose) a little (or a lot) at hazard. "In the playroom might be heard the clear ringing voice of that agreeable reprobate, Tom Duncombe, as he cheerfully called 'Seven' and the powerful hand of the vigorous Sefton in throwing for a ten. Who that ever entered that dangerous little room can forget the large green table, with the croupiers, Page, Darking and Bacon, with their suave manners, sleek appearance, stiff white neck-cloths, and the almost miraculous quickness and dexterity with which they swept away the money of the unfortunate punters when the fatal cry of 'Deuce ace,' 'Aces,' or 'Sixes out' was heard in answer to the caster's bold cry of 'Seven,' or 'Nine,' or 'Fives the main'...." It was not the same cry as that heard by the reformed gambler John Philip Quinn from a Negro on the Mississippi steamboat *City of Chester:* "Come seven or eleven" and "Chill'en crying fo' bread," but the game, called craps (or the Negro's Game), was merely a simplified version of hazard. Bell says that craps is a dull game, the only attraction of which is money. It had not occurred to me that gambling had any other end in view.

After hazard everything is anticlimax, but perhaps a few more dice games should be mentioned. Among three-dice games I note Buck Dice and Martinetti; among five-dice games, Drop Dead, and Ship, Captain, Mate and Crew; among six-dice games, Sequences; among 10-dice games, Twenty-six; among games using 15 or more dice, Aces; among games with special dice, Bell and Hammer (picture cards appear) and Liar Dice (poker faces on the cubes instead of dots); and finally, among Chinese dice games, Strung Flowers (the dice are like dominoes) and Put and Take (where the die is a six-sided teetotum with instructions on each side, such as "Take one," "Take all," "Put 2").

The last major category in Bell's arrangement consists of domino games. A domino, which is nothing more than a little tablet representing the throw of two dice, is said to be a Chinese invention. Dominoes seems a gentle game, which many remember playing as children with Grandfather or a favorite aunt. The Chinese forms include Fishing (*tiu ü*), which uses two sets; Disputing Tens (*tsung shap*); and Collecting Tens (*k'ap t'ai shap*), a not so gentle gambling game in which many sets of dominoes are used. Ma-jong, a form of dominoes very popular a few decades ago, has been dated to the time of Confucius, but it is probably only about 150 years old. There are many variations and no sovereign rules, one code being as acceptable as another. A genuine Chinese set has tiles made of pieces of bone or ivory, backed with bamboo or even mother-of-pearl or jade, and is likely to be quite expensive. The tiles are called dragons, winds, birds, flowers, seasons and reflect the poetic and aristocratic features of Chinese culture. Dice are used to determine the order of play; the tiles are shuffled; the clinking of the ivory pieces is known as the "twittering of the sparrows"; each player (there are four) builds a wall 17 tiles long and two high which represents a wall of a city, and these are then joined to make a square, the space left at the corners permitting the entry of the "devils of ill-luck" ("More realistically it allows a possibility of cheating"). Less poetic are the gambling aspects of the game, which Bell characterizes as "vicious." The details of play are complicated and need not be considered. European dominoes, bingo, Domino Crib, the Matador Game, Cyprus and Tiddle-a-Wink (which is the call of the first player to play his last tile, who then gets a point for each spot in his opponent's hand, as in gin rummy) are among other species of the domino family.

Bell concludes with a chapter on the making of boards and pieces, which contains, as do other chapters, many excellent illustrations. An appendix presents a number of brief biographies of Bell's predecessors from as-Suli (about A.D. 920), a descendant of a Turkish prince of Jurjan who was the foremost chess master of his day and wrote a book on the subject, to H. J. R. Murray (1868–1955), the greatest of the chess historians. In the group is the 19th-century architect and archaeologist Edward Falkener, author of the classic *Games Ancient and Oriental and How to Play Them*, which I mention because it has recently been reprinted by Dover Publications. Falkener's book, written 70 years ago, is full of inaccuracies but is equally stuffed with interesting, out-of-the-way information about such pastimes as *senat*, played by the Egyptians, the *hiera gramme* of the Greeks, magic squares, Polish and Turkish draughts, the Knight's Tour (on the chessboard) and *ashta-kashte*, like *chausar* and *chauput* a variant of pachisi.

Games of the few, games of the many, games for gentlemen, games for harpies, games for thinkers, games for fun, games for gamblers and for desperate men, games that have vanished like Archaeopteryx and games that have adapted and are still flourishing, games even for timid lookers-on: life, in short, played out with

little dummies, a benign distraction in a dangerous world.

Short Reviews

THE VOICE OF THE DOLPHINS, by Leo Szilard. Simon and Schuster, Inc. ($3). To the late Sir Edmund Whittaker's six postulates of impotence (*i.e.*, things one cannot possibly do, such as exceed the velocity of light) another might be added: it is impossible not to admire the mind of Leo Szilard. He is endlessly ingenious, sometimes prophetic, sometimes profound and altogether unquenchable. As a nuclear physicist, biophysicist, pioneer of information theory (a not widely known paper of his published in the 1920's suggests the link between entropy and information), chemist, radiologist, he needs no introduction to readers of this magazine. Nor has his part been forgotten as an associate of Enrico Fermi in achieving an atomic-chain reaction, as a central figure in getting Albert Einstein to write his fateful letter to President Roosevelt, as a fighter for civilian control of atomic energy and, in more recent years, as an indefatigable mover and shaker for world peace. Szilard, as many a Government nabob has learned, is not afraid to speak his mind, and he has a disagreeable way of getting to the point while others are still muddling around in the pudding. In this volume of short science-fiction stories he appears in a role that is new, yet not entirely new. Science fiction is for him a new venture, but the castigation of morals, the exploding of pretensions, the deadpan satire on behalf of humane ends—all of which characterize the tales—are familiar exercises for Szilard. He is practiced at proposing outrageous ideas which are either not so outrageous as they first seem or deliberately outrageous in the nature of a *reductio ad absurdum*. The title story, which takes advantage of the current flap about the intelligence and teachability of dolphins, is a political fairy story set at the end of this century. A group of dolphin consultants advise the scientists of the Biological Research Institute in Vienna (set up in 1963) how to keep the world from committing suicide. Since men are both quarrelsome and dull it takes the dolphins about a quarter of a century to get their views across, but at last disarmament is achieved. Another story describes the world a hundred years from now: most of the problems we face today, including the economic headaches, have not yet been solved, but men have learned how to give injections so that they can "withdraw from

life" into a "*statu dormiendi*" for as long as they like. Millions of unemployed avail themselves of this temporary exit, Congress having in 2025 passed a "Withdrawal Act" authorizing the use of Federal funds to help the unemployed catch a few years' sleep until the current economic depression passes. In "Report on 'Grand Central Terminal' " visitors from another planet find life extinct on earth and attempt to reconstruct our habits from the remains. Most puzzling are the lavatory facilities in Grand Central, with the pay-as-you-enter cubicles, some of the locks on the cubicles being filled with metal "disks." Since the facilities in private homes are not so protected, the visiting scholars hypothesize that the Grand Central setup was part of a "ceremonial act" connected with "the act of deposition in *public places*." The stories are well written, with a true ear for official jargon and the like. The political satire, however, gets heavy-handed at times, and Szilard's penchant for the wayward and bizarre gets him into trouble—amateurish literary trouble and half-baked-thinking trouble. Still, there are very nice things in this little book. Only recently—and absurdly belatedly—the author was elected to the National Academy of Sciences. This book would scarcely have earned him the accolade, but it is an amiable *jeu d'esprit* by an admirable man.

A Hole in the Bottom of the Sea, by Willard Bascom. Doubleday & Company, Inc. ($4.95). Straight down as well as straight up: these are the directions of two of the major research efforts of the 1960's. Straight up is vastly more expensive than straight down but not necessarily more fruitful or absorbing. A small group of U.S. scientists have for some time been planning to make a hole in the bottom of the sea. The Mohole Project, as it is called, will drill five or six miles down at some point on the ocean floor; cores of the earth's mantle and overlying sediments are to be brought up and studied by geologists, paleontologists, oceanographers and other specialists. It is their hope that the information obtained from the cores will cast much light on the history, structure and composition of the earth. Bascom, an oceanographic engineer, has written an interesting and highly instructive story which goes much beyond the Mohole Project itself. He traces the history of the project, describes the science fiction which has grown up around the idea of piercing to the center of the earth, explains what men have learned from rocks and what they still hope to learn, tells about the methods that have been used to explore the crust with gravity, and leads the reader agreeably through primer courses in seismography, oceanography, modern oil-well drilling and so on. The author writes well and his enthusiasm for a variety of scientific and technical matters from terrestrial magnetism to drilling bits and kelly rigs is effectively imparted to the reader. Illustrations.

Science since Babylon, by Derek J. de Solla Price. Yale University Press ($4.50). Both the title of this volume and its price are more spacious than the contents justify. The book itself consists of five public lectures given at Yale in 1959, treating various topics in the history of science with which Price has had direct "research experience"; the discourse runs to 150 pages, illustrated with half a dozen simple graphs. Thus the admission comes pretty high. The performance, however, is not without interest. The author deals with what he calls certain "crises" in the growth of science. He considers the work of the Babylonians and the Greeks, when our own civilization "started to become scientific, thereby setting it apart from all other cultures"; celestial clockwork in Greece and China, which represented the crossover of science from pure thought to technology; the "Renaissance roots of Yankee ingenuity"—that is, the beginnings of the practitioner movement by clockmakers, practical teachers, working artisans, instrument makers, who, while not so celebrated as their contemporaries Galileo, Gilbert, Harvey and Newton, nor as deserving of celebration, nevertheless made essential contributions to scientific advance both by their artifacts and by their creation of a climate and circumstances favorable to experimental science. A fourth lecture deals with "mutations" of science, the transition from classical theories of the 19th century to the revolutionary breakthroughs of the 20th; here Price describes the delightful nonsense of René Blondlot's discovery of N rays—a French riposte to Roentgen's X rays—for which achievement he received a great prize from the French Academy, though it was already known when M. Poincaré bestowed the award that N rays were products of radioactive imagination rather than of the whirling ferment of matter itself. The book also treats of the "diseases of science," by which Price means the contemporary superabundance of literature, man-power shortages, increasing specialization and the deterioration in quality of what passes

for research. He hints at, but unfortunately does not explicitly touch upon, the grave question of social responsibility in science.

LIVING FISHES OF THE WORLD, by Earl S. Herald. Doubleday & Company, Inc. ($12.50). Three hundred or so million years ago fishes were the most advanced animals on earth. The descendants of that golden age are some 25,000 species and various other organisms, including ourselves. This well-written, informative book with 300 illustrations (145 in color) is about the marvelously diverse life of oceans, lakes and streams: hagfish and sharks, skates, rays, bichirs, sturgeons, gars, herring, bony tongues, mormyrids, Bombay duck, gulper eels, pirate perch, opahs, squirrelfish, John Dorys, bass, dolphins, grunts, croakers, scats, wrasses, electric stargazers, Moorish idols, snake mackerel, gobies, dragonets, blennies, cucumber fish, labyrinth fish, phallostethids, threadfins, flying gurnards, ragfish, clingfish, midshipmen, sea robins, lobe-finned coelacanths, sea moths—and all their relatives. Fishes are remarkably adaptable forms and as hard to describe as to catch. Not all fish have scales; not all spend most of their time in the water; not all have gills; not all have fins. What manner of strange creatures these are, what makes a fish a fish, how they have adapted themselves, the tremendous variation in their sensory apparatus (*e.g.*, mormyrids and knifefish inhabiting muddy waters use electric organs to bounce discharge impulses off unseen objects) are among the details in this recent volume of the "World of Nature" series. Recommended.

GALILEO GALILEI ON MOTION AND ON MECHANICS, translated and edited by I. E. Drabkin and Stillman Drake. University of Wisconsin Press ($5). This volume comprises Galileo's *De Motu,* written about 1590, now for the first time translated into English (I. E. Drabkin), and *Le Meccaniche,* written about 1600 and here translated for the first time since 1665 (Stillman Drake). *De Motu* deals with motion and acceleration; its approach is based largely on hydrostatic analogies and is under the strong influence of Archimedes. Acceleration of a falling body is regarded as an "external accident" and does not persist; the inertial concept is not stated. *The Mechanics,* a small treatise Galileo wrote 40 years before the *Two New Sciences* for the instruction of his private pupils at the University of Padua, deals, as Drake states, almost exclusively with the analysis of simple machines, a topic

omitted from the *Two New Sciences* except for a brief discussion of the lever.

RELATIVITY: THE GENERAL THEORY, by J. L. Synge. Interscience Publishers, Inc. ($16.50). A sequel to the author's monograph on the special theory of relativity, reviewed in these columns several years ago, this book is characteristic of Synge in its geometrical approach, its originality and its felicitous, relaxed and agreeably ironical style. "There are," he writes, "heavy calculations in the book, but there are places where the reader will find me sitting on the fence, whistling, instead of rushing into the fray." Synge breaks into the heart of questions which many another mathematical physicist would be too reverent or conventional or scared to tackle, and he doesn't mind saying he doesn't know when he doesn't know. One must turn to Oliver Heaviside or one or two other physicists of a now vanished age to find the same spirit and temper, the same sense of proportion. A superior book.

MASTERPIECES OF GREEK ART, by Raymond V. Schoder, S.J. New York Graphic Society ($12.50). A beautifully illustrated survey of the whole field of 2,000 years of Greek art, from an inlaid 16th-century B.C. Mycenaean gold dagger to a second-century A.D. statue of a smiling faun, including jewelry, vases, architecture, coins, mosaics, glass and cameos, terra cottas, paintings. Supporting text, chronological charts, bibliographies, 112 color plates. An elegant book.

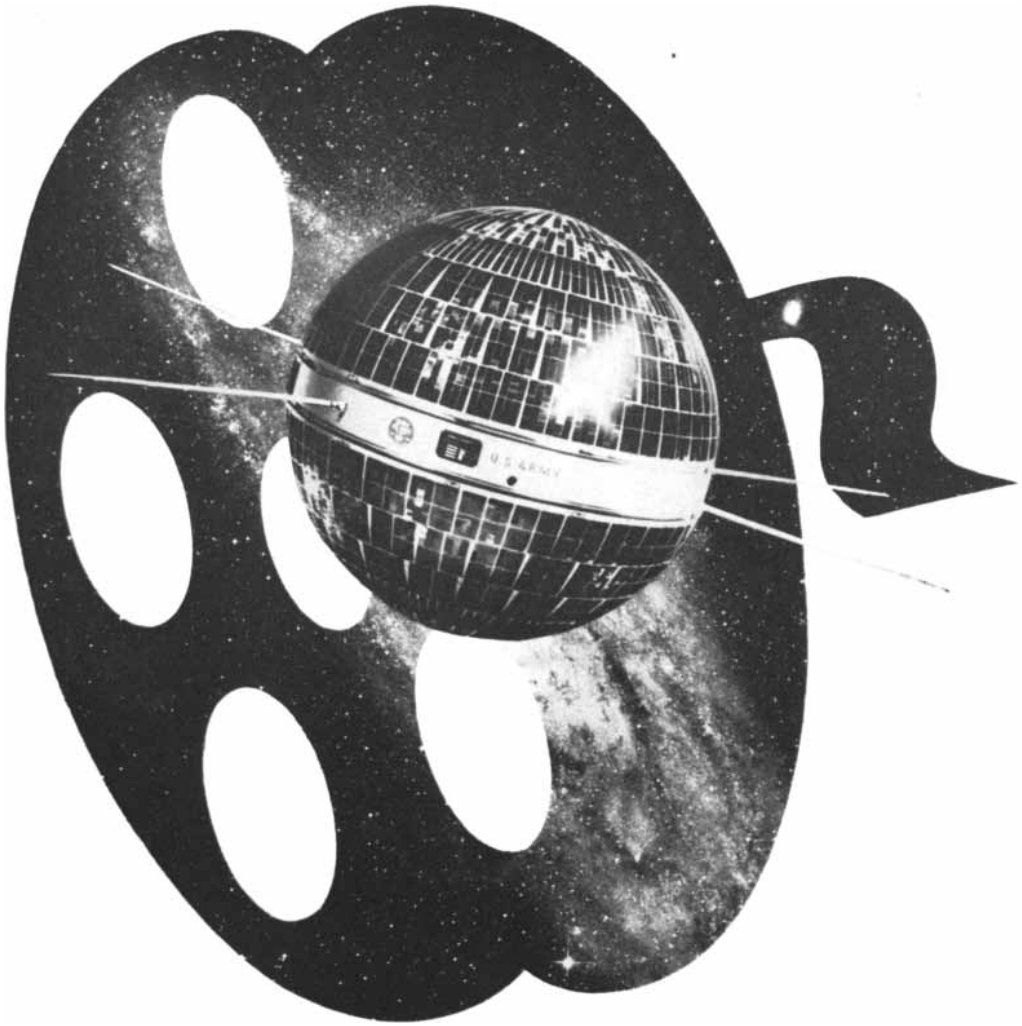
HANDBOOK OF PHYSIOLOGY, SECTION I: NEUROPHYSIOLOGY, VOL. III, edited by John Field. The Williams & Wilkins Company ($20). The most recent section of a comprehensive handbook, the first volume of which was reviewed in these columns two years ago. It includes articles on sensory discrimination, the neural basis of learning, emotional behavior, perception, memory, speech, psychosomatics, cerebral circulation, neural metabolism, the chemical architecture of the central nervous system and the abnormalities of neural function.

A HISTORY OF METALS, by Leslie Aitchison. Interscience Publishers, Inc. ($30). This amply designed, well-stocked, attractively illustrated book is a "biography" of a family of substances which have over the millenniums attained an almost unquestioned supremacy over the materials used by man. Told as a continuous narrative, the story begins with the primitive use of gold and native copper and concludes with the bizarre, portentous and revolutionary use of uranium as a fuel. The approach is general rather than academic; the specialist will find less in this book than will the average reader interested in the history of technology; but, except for the steep price, the book will appeal to readers in every category.

ENERGY IN THE AMERICAN ECONOMY, 1850–1975, by Sam H. Schurr and Bruce H. Netschert, with others. The Johns Hopkins Press ($12.50). A thorough, scholarly, enlightening account of the supply and demand of U.S. energy resources from 1850 to the present, with an estimate of prospects over the next 15 years. The authors deal with energy use in the past and its relation to economic growth, the probable future of coal, oil, water power, gas and atomic energy, the implications of change in the country's position from an exporter to an importer of fuels and related questions. The analysis is supported by a large number of factual tables and statistical analyses. A solid, impressive performance, which economists and other specialists will find invaluable.

THE ENCYCLOPEDIA OF MICROSCOPY, edited by George L. Clark. Reinhold Publishing Corporation ($25). Better evidence can scarcely be found of the enormous specialization of modern science than the appearance of this solid and valuable reference handbook, a cooperative undertaking consisting of more than 140 specially written articles by experts from a dozen countries, dealing with no less than 28 kinds of microscopy. Methods and instruments include autoradiography, chemical microscopy, electron microscopy, electron-mirror microscopy, field-emission microscopy, flying-spot microscopy, metallography, optical microscopy, ultraviolet microscopy, X-ray microscopy, resinography, the television microscope, polarizing microscope, ultrasonic-absorption microscope. Many diagrams and photographs, and bibliographies.

THE FOURTH DIMENSION SIMPLY EXPLAINED, introduced and edited by Henry P. Manning. Dover Publications, Inc. ($1.35). In January, 1909, "a friend of *Scientific American*, who desired to remain unknown," gave the publishers $500 to be awarded as a prize for the best popular explanation of the fourth dimension. Two hundred and forty-five essays were submitted and judged by Henry P.



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Manning of Brown University and by S. A. Mitchell of Columbia University. The prize-winning essay and a number of others thought to be of merit were collected and published in 1910. This paperback is a reissue of the earlier volume. Several of the essays are illuminating, ingenious and amusing.

Notes

A Modern Introduction to the Family, edited by Norman W. Bell and Ezra F. Vogel. The Free Press of Glencoe, Illinois ($7.50). A collection of 51 articles and essays on the sociology of the family: its relations to external systems, internal processes of the family, family and personality.

A Treatise on the Higher Plane Curves, by George Salmon. Chelsea Publishing Company ($4.95). A reprint of the third edition of a well-known 19th-century work, intended as a sequel to Salmon's noted treatise on conic sections.

Pioneers in Criminology, edited by Hermann Mannheim. Quadrangle Books, Inc. ($7.50). Articles on, among others, Cesare Beccaria, Jeremy Bentham, Isaac Ray, Henry Maudsley, Cesare Lombroso, Gabriel Tarde, Hans Gross, Émile Durkheim.

The Skeleton Key of Mathematics, by D. E. Littlewood. Harper Torchbooks ($1.25). A fine introduction to complex algebraic theories by a leading British mathematician. Paperback.

X-Ray Microscopy, by V. E. Cosslett and W. C. Nixon. Cambridge University Press ($15). A comprehensive account of the use of X-ray microscopy in research on, among other things, plant and animal tissue; metallurgy and mineralogy; the technology of paper, fibers and fabrics.

Impact, by Werner Goldsmith. St. Martin's Press, Inc. ($17.50). A reference book on the theory and physical behavior of colliding solids, for workers in the fields of applied mechanics and in certain areas of applied mathematics and physics.

Introducing Geology, by D. V. Ager. Faber and Faber (30 shillings). A clear, well-written primer on the earth's crust: its evolution and its present features. This book is directed to British readers and oriented to their landscape, but it will profit any beginner. Good illustrations.

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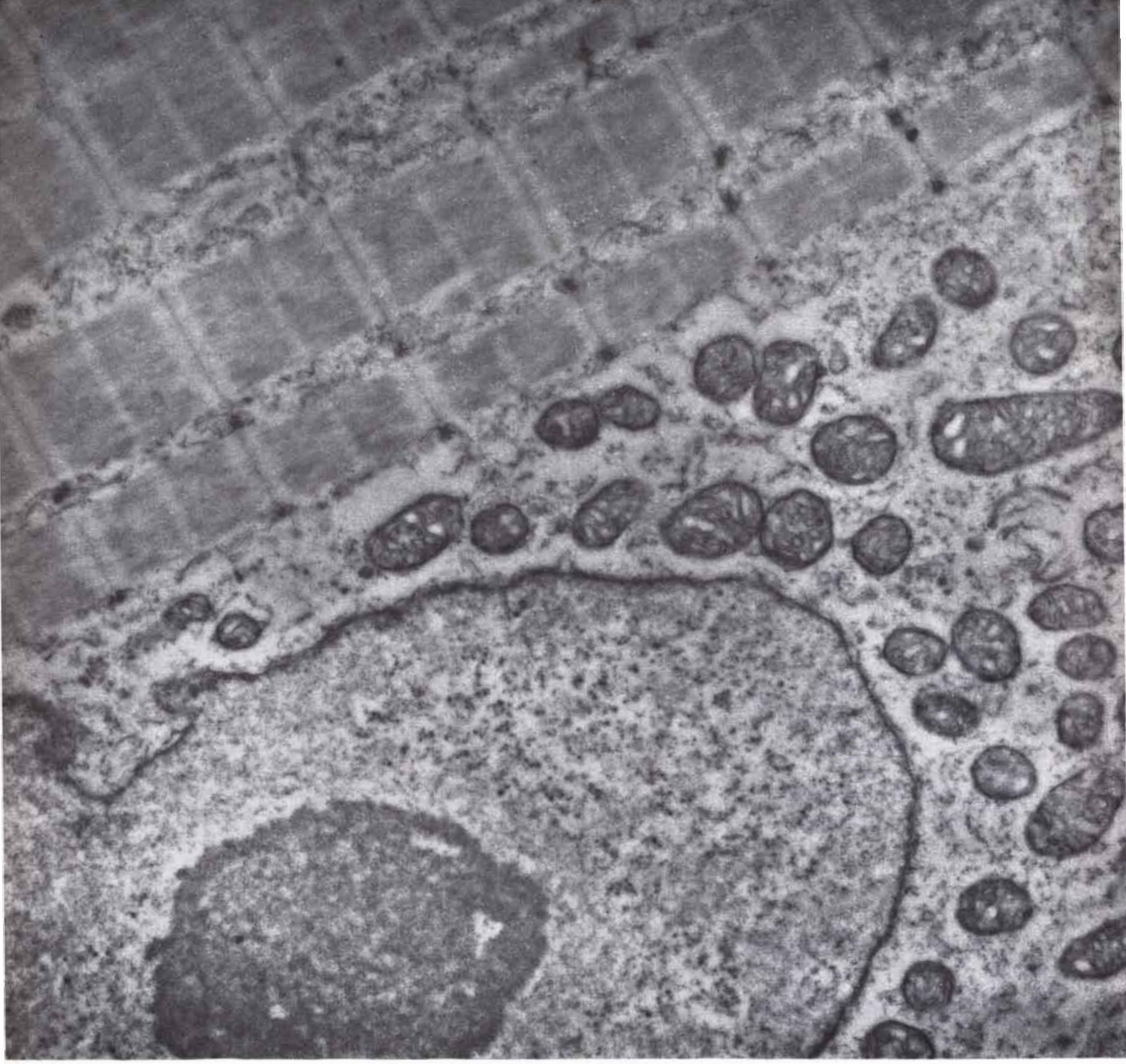

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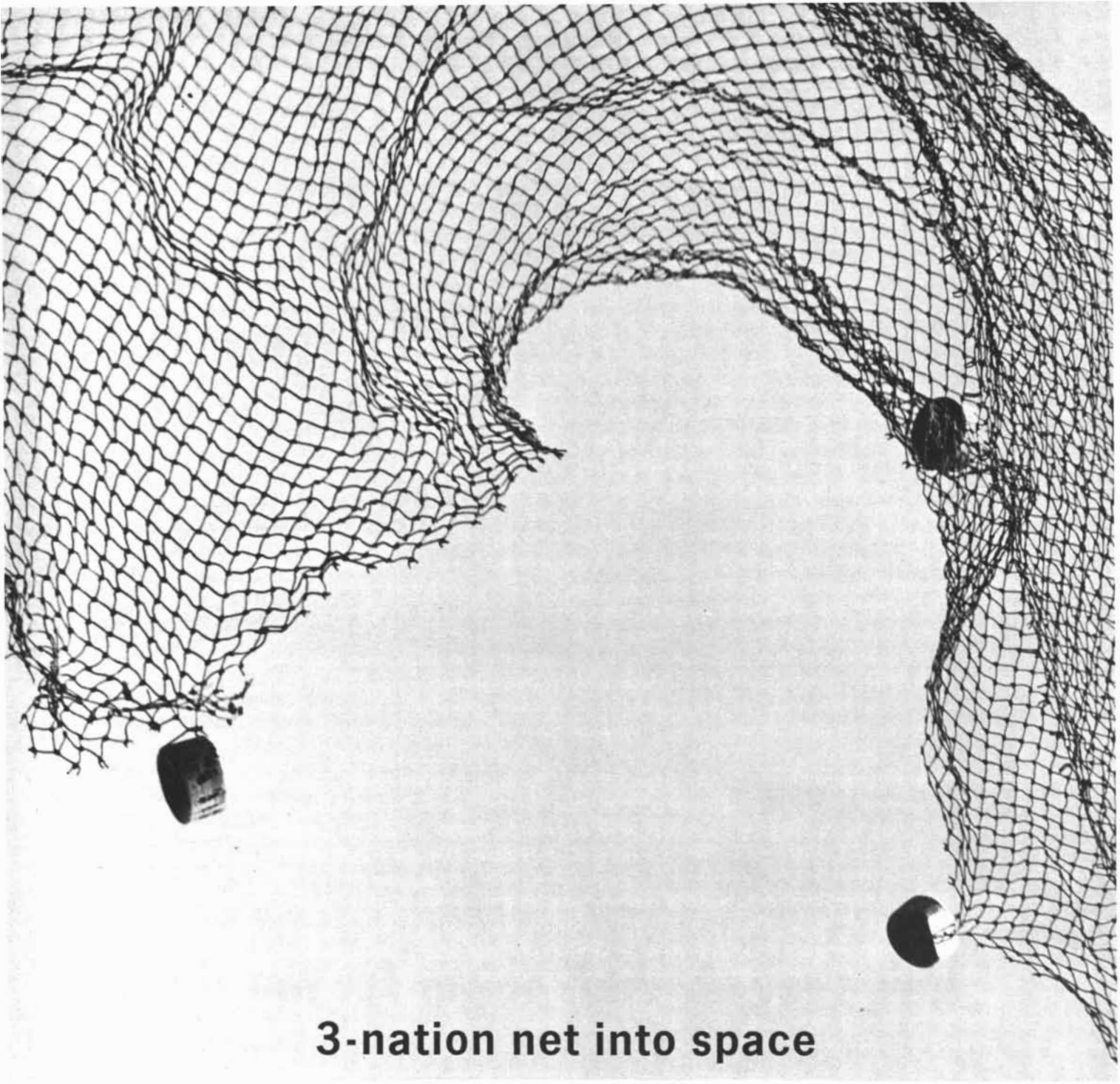

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