SCIENTIFIC AMERICAN

THE MOON ILLUSION

FIFTY CENTS

July 1962

Information is snowballing

IBM® is finding new ways of using computers to cope with the great volume of information that is piling up in science and business today.

One recent IBM development is a computer system that acts as an electronic traffic director for information. From the flood of reports, articles and books received by an organization, the new system selects and routes information to people according to their specific interests and needs.

In another area, IBM has developed a prototype information system that can store millions of document pages, yet is able to find and deliver a copy of any page within seconds. IBM scientists are also investigating new techniques for abstracting and indexing technical articles automatically.

New information-handling systems like these from IBM are urgently needed if scientists and businessmen are to make the best use of man's vast and growing store of information.

Garrett space radiator for manned and unmanned vehicles

Advanced solution to a heat transfer problem

Complex, long duration satellites and manned spacecraft must get rid of large amounts of heat produced by the vehicle's power, electronic or environmental equipment. Through unique fabrication techniques and know-how with exotic materials, Garrett-AiResearch is already building the first active (fluid cycle) radiator system for cooling manned and unmanned space vehicles.

Garrett is also developing heat transfer systems for applications from cryogenic temperatures to 2000 °F, using heat transfer fluids such as Coolanol 139, Freon 21, FC-75, mercury and alkali liquid metals including potassium, rubidium, sodium and cesium.

This critical development work is supported by more than a quarter century of Garrett heat transfer experience and is being put to extensive use in America's most advanced aircraft, missile, nuclear and space programs.

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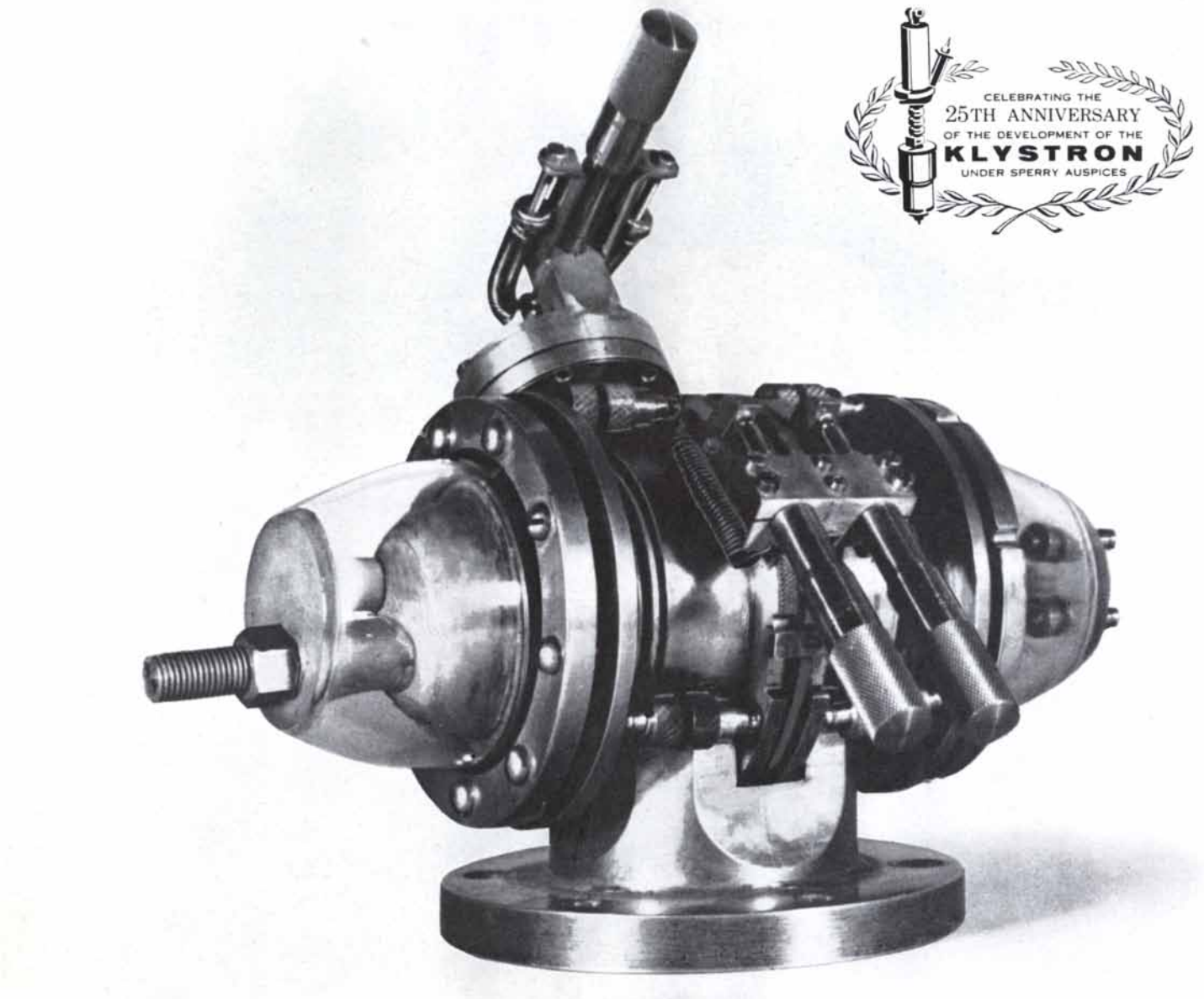

Early klystrons delivered only 5 to 10 W across a relatively narrow bandwidth. Today's Sperry klystron family blankets the spectrum at outputs from milliwatts to megawatts.

EXPERIENCE: how Sperry sets the pace in microwave tube competition

The invention that built a $110 million-a-year industry

This year is the 25th anniversary of the klystron. In 1937 the klystron became a reality under the auspices of Sperry research. Since that time, new Sperry developments have constantly expanded the microwave tube family's usefulness.

SPERRY ELECTRONIC TUBE DIVISION

SPERRY RAND CORPORATION
GAINESVILLE, FLA. / GREAT NECK, N. Y.

Established 1845 **SCIENTIFIC AMERICAN** July 1962 Volume 207 Number 1

ARTICLES

DEPARTMENTS

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THE COVER

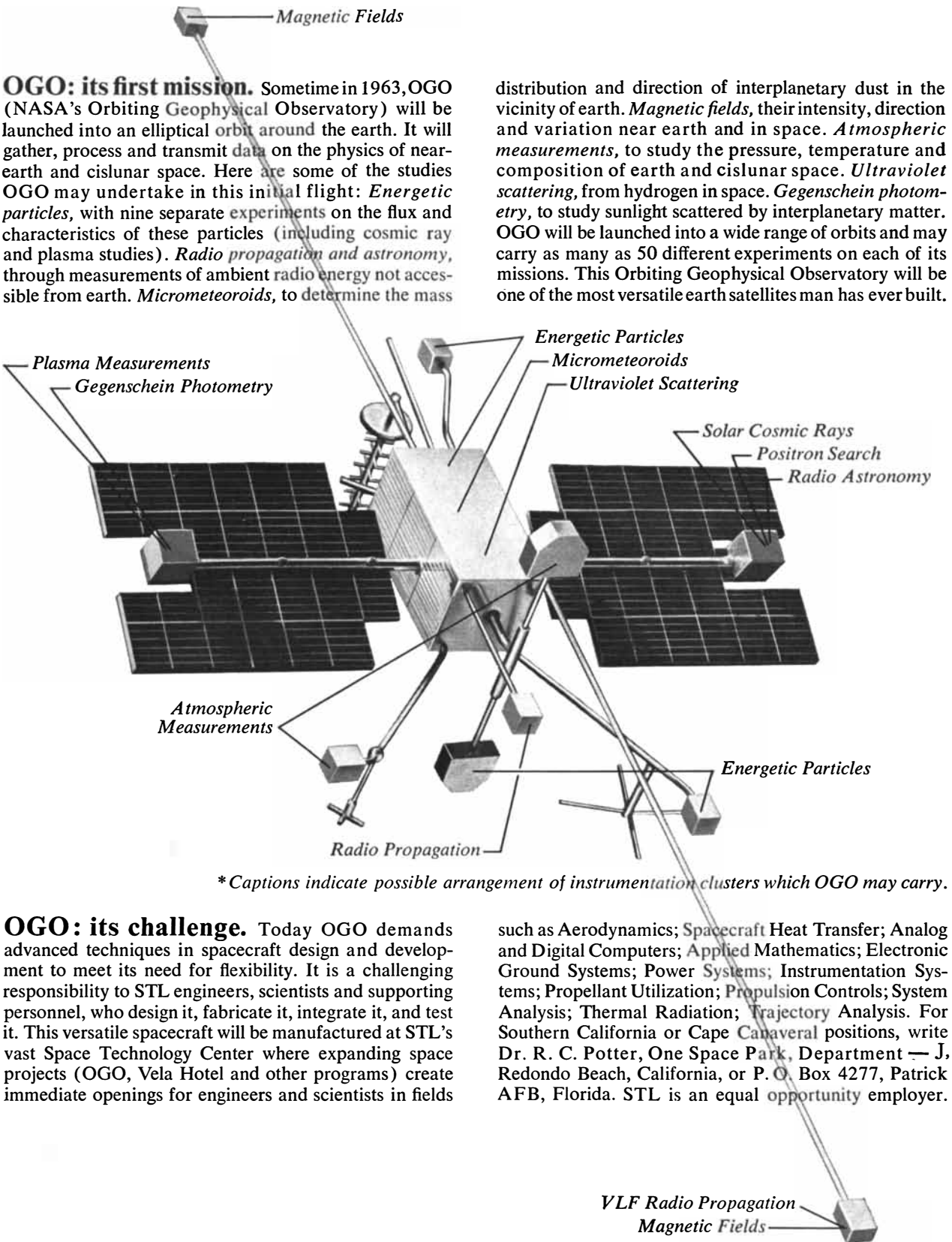
The photograph on the cover shows the moon rising over Yonkers, N.Y. In the foreground is the Hudson River. Everyone has observed that when the moon is near the horizon, it appears to be bigger than it does when it is higher in the sky. Why this is so is taken up in the article "The Moon Illusion" (page 120).

THE ILLUSTRATIONS

Cover photograph
by William Vandivert

Page	Source
40–47	Alex Semenoick
48	Bunji Tagawa
50	Oscar Auerbach (*left*), Bunji Tagawa (*right*)
51	Oscar Auerbach
52–59	James Egleson
60–61	Perry W. Gilbert
62	Peter Stackpole
63	Peter Stackpole (*top*), Perry W. Gilbert (*bottom*)
64–66	John Langley Howard
67	Dade W. Thornton
68	Perry W. Gilbert and Steven D. Douglas (*top*), Perry W. Gilbert (*bottom*)
83–90	Irving Geis
96	Roman Vishniac
98–99	Hatti Sauer
100–101	Roman Vishniac
102–103	Hatti Sauer (*left*), David B. Ericson and Goesta Wollin (*right*)
104–106	Hatti Sauer
110–111	Thomas Prentiss (*top and bottom left*), Cecil E. Hall (*bottom right*)
112–116	Thomas Prentiss
121	William Vandivert
122–123	Bunji Tagawa
124	Bunji Tagawa (*top*), William Vandivert (*bottom*)
125–128	Bunji Tagawa
130	William Vandivert
132–133	David Linton
134	Bell Telephone Laboratories
135–142	James Egleson
147–152	Thomas Prentiss
157–162	Roger Hayward

OGO: its first mission. Sometime in 1963, OGO (NASA's Orbiting Geophysical Observatory) will be launched into an elliptical orbit around the earth. It will gather, process and transmit data on the physics of near-earth and cislunar space. Here are some of the studies OGO may undertake in this initial flight: *Energetic particles,* with nine separate experiments on the flux and characteristics of these particles (including cosmic ray and plasma studies). *Radio propagation and astronomy,* through measurements of ambient radio energy not accessible from earth. *Micrometeoroids,* to determine the mass distribution and direction of interplanetary dust in the vicinity of earth. *Magnetic fields,* their intensity, direction and variation near earth and in space. *Atmospheric measurements,* to study the pressure, temperature and composition of earth and cislunar space. *Ultraviolet scattering,* from hydrogen in space. *Gegenschein photometry,* to study sunlight scattered by interplanetary matter. OGO will be launched into a wide range of orbits and may carry as many as 50 different experiments on each of its missions. This Orbiting Geophysical Observatory will be one of the most versatile earth satellites man has ever built.



**Captions indicate possible arrangement of instrumentation clusters which OGO may carry.*

OGO: its challenge. Today OGO demands advanced techniques in spacecraft design and development to meet its need for flexibility. It is a challenging responsibility to STL engineers, scientists and supporting personnel, who design it, fabricate it, integrate it, and test it. This versatile spacecraft will be manufactured at STL's vast Space Technology Center where expanding space projects (OGO, Vela Hotel and other programs) create immediate openings for engineers and scientists in fields such as Aerodynamics; Spacecraft Heat Transfer; Analog and Digital Computers; Applied Mathematics; Electronic Ground Systems; Power Systems; Instrumentation Systems; Propellant Utilization; Propulsion Controls; System Analysis; Thermal Radiation; Trajectory Analysis. For Southern California or Cape Canaveral positions, write Dr. R. C. Potter, One Space Park, Department — J, Redondo Beach, California, or P. O. Box 4277, Patrick AFB, Florida. STL is an equal opportunity employer.

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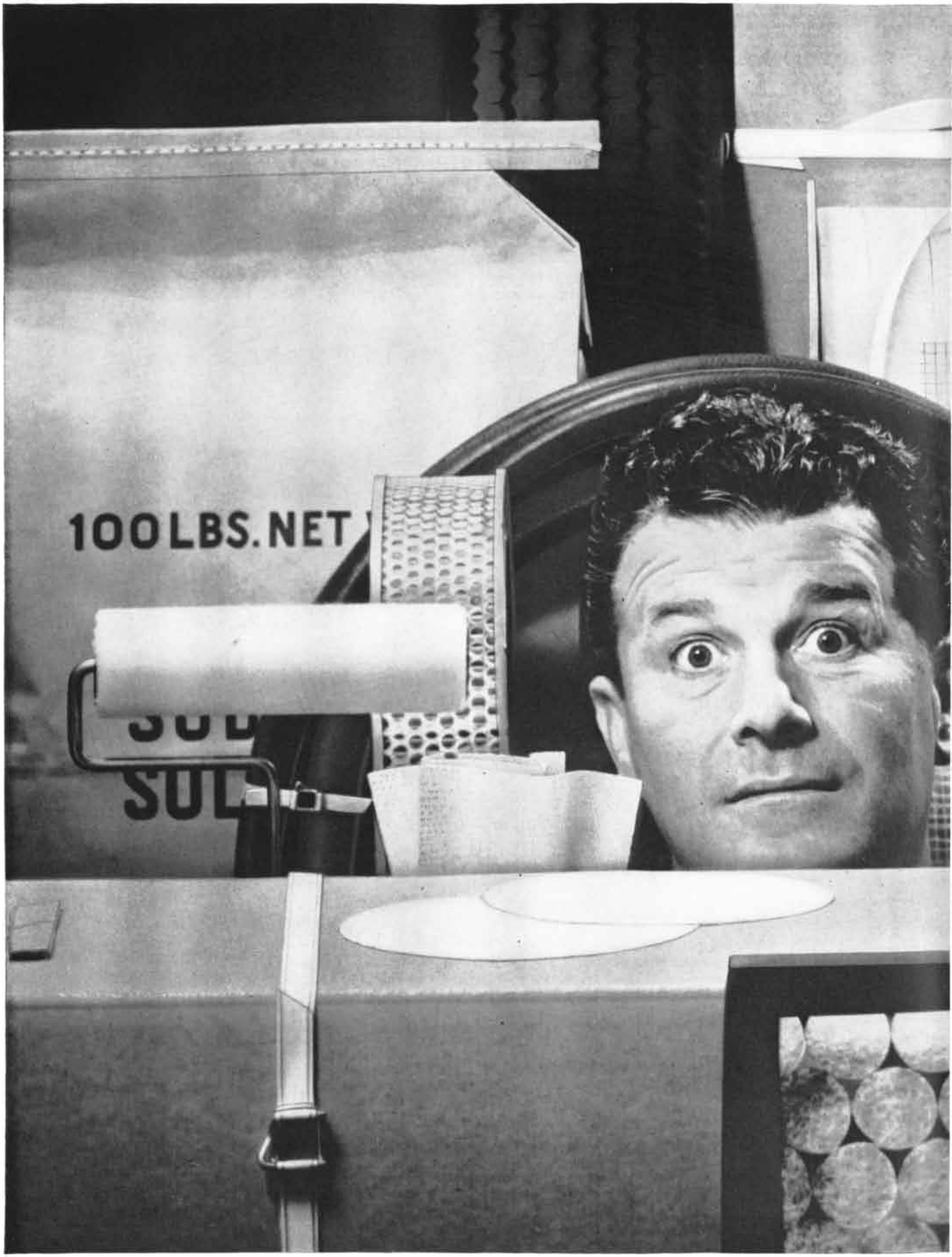

We're deep in your problems:

Today's Avisco rayons are providing economical answers to a lot of puzzlers in such areas as filtration, reinforcing and absorbency. In fact, the tremendous progress made in rayon technology has created fiber characteristics which economically solve mighty tough problems. Some of the important industrial uses of today's Avisco rayons are outlined below. They may provide the answers *you* have been looking for.

FILTER BETTER WITH AVISCO RAYONS Our fibers have a knack for providing efficient and economic filtration for such diverse fields as milk, liquor, lotions, paints, oils, water and air. The secret of this success is accurate control of the diameters, lengths and surface characteristics of Avisco fibers. These in turn mean precise control of flow rates, solid capacity and particle size. An important additional feature is the outstanding clarity of the filtrate.

REINFORCE ECONOMICALLY Excellent strength with minimum weight and bulk are obtained when Avisco rayons are used to reinforce products ranging from belting, tires, hoses, to corrugated board, papers, tear tapes and plastics. For example, extraordinary strong, tough belting fabrics are being woven with Avisco XL-I high-strength rayon staple. Conditioned tensile strength is up to 60% greater than an equivalent weight all-cotton fabric with less bulk. Fatigue life is actually 3 to 5 times greater.

NON-WOVENS BY WET OR DRY SYSTEMS We engineer Avisco rayons to meet the requirements of non-woven products ranging from lightweight tissues to heavy industrial fabrics. Their versatility is amazing and the many physical properties of Avisco fibers can be controlled so that non-wovens can obtain just the right softness, stiffness, porosity, absorbency, appearance, bulk, tensile and tear strength for a given end use.

A NEW IDEA IN MEDICINE The well-known "cotton ball" is turning to Avisco rayon to keep it softer and whiter, make it more absorbent, retain its shape wet or dry and to reduce linting to a minimum. And with all these advantages the rayon balls actually cost less than their cotton counterpart. Avisco rayon absorbs more and faster than any other fiber, is produced immaculately clean, and rayon has no static hazard. That's why surgical dressings, masks, bandages and many hygienic products are using Avisco rayon by the millions of pounds.

All this is our way of saying that there must be a product or process application for economical Avisco rayons in your field. We'll be glad to give you more information. Just contact the Industrial Merchandising Department of the American Viscose Corporation, 350 Fifth Avenue, New York 1, N. Y.

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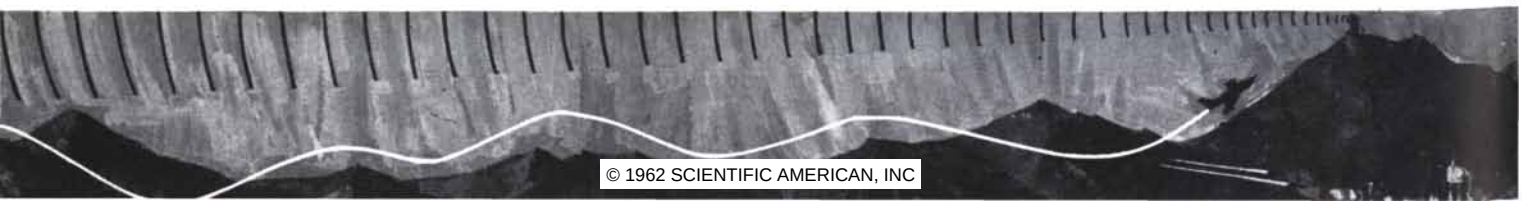
"TERRAIN AVOIDANCE" RADAR BOOSTS LOW LEVEL FLIGHT CAPABILITIES FOR HIGH-SPEED AIRCRAFT

General Dynamics|Electronics "terrain avoidance" radar is a low cost, compact system that enables high-speed aircraft to fly ground-hugging penetration missions and land on temporary fields in zero visibility weather. Designed for simplicity and low maintenance, the system offers the proven advantages of on-boresight, Ku-band radar and a single non-scanning antenna with no moving parts. Since the basic unit weighs 40 pounds and can be pod or nose mounted, it is especially suited to small high-speed aircraft or drones. Portions of the system can be added to aircraft already equipped with radar to provide terrain avoidance capability. For additional information, write General Dynamics|Electronics, Dept. C-59, P.O. Box 127, San Diego 12, Calif.

GENERAL DYNAMICS | ELECTRONICS GD SAN DIEGO



MATERIAL IN QUEST OF AN INVENTOR

Is there an inventor who can overlook the list of tempting (and profitable) new Dow epoxy resin developments?

As a start, consider the possibilities of an extremely pure epoxy resin with a viscosity of 4,000—6,400 cps, and color 1 max. It is an essentially pure diglycidyl ether of bisphenol A from which we've eliminated troublesome high polymer fractions. Then, there are flame-retardant brominated epoxies that also give top physical and electrical properties. And an epoxy novolac with high (even for an epoxy) chemical resistance and temperature stability up to 500° F.

All Dow epoxy resins have extremely high adhesion and low shrinkage during cure; resistance to thermal and mechanical shock, toughness, chemical inertness, moisture resistance and outstanding electrical properties. Another feature common to all—dependable quality control. That's because we make all the ingredients that go into our epoxies (even most of the ingredients that go into the ingredients).

You have the problems, we have the epoxies . . . many types. Why not see if they can help in your development work? Samples available. Write us, c/o Coatings Sales Dept. 1642EQ7.

THE DOW CHEMICAL COMPANY DOW Midland, Michigan

MEASURE. RECORD. ANALYZE.

(It sounds easy when you say it fast.)

It used to be that data acquisition was as simple as looking at a dial or a glass thermometer. No more. The entire data handling process itself has become more and more complicated and demanding. Because of this, it has become increasingly prudent to call for expert advice when you have a challenging problem—or even a routine one, for that matter—in the field of data handling. We believe the examples cited below bear out this practical wisdom.

• •

"LONG DISTANCE" DIAGNOSIS. In experimental tests in Birmingham, Alabama, electrocardiograms are being "dialed" by special telephone hook-up directly from patients in one hospital and automatically charted on a Honeywell Visicorder direct-writing oscillograph at another hospital across town for immediate interpretation and diagnosis. The success of these experiments, conducted by the Memorial Institute of Pathology, with the Birmingham Baptist Hospitals and engineers of Honeywell collaborating, demonstrate the feasibility of transmitting and recording, even thousands of miles distant, practically any type of physiological data which can be sensed electronically. Thus the knowledge and ability of medical specialists can be made available to physicians and their patients in any part of the country.

• •

GET DOWN TO THE ELEMENTS. This was the assignment recently handed to Honeywell engineers by a midwestern manufacturer of scientific instruments. That is: determine the various elements in a hydrocarbon mixture: carbon, hydrogen, oxygen, nitrogen, sulfur, and so on. For some time, gas chromatographs have been used to determine the percentage of components of a gaseous mixture—methane, butane, ethane, hexane, propane, and other hydrocarbon compounds. Starting with this instrument and its Honeywell strip chart recorder, adding a mass spectrometer, and feeding the signals into a multichannel Visicorder oscillograph, a time-correlated record of the various component elements of a gaseous mixture was readily obtained. Since few recorders can keep up with the speed of a mass spectrometer, an extremely wide range of galvanometric sensitivities had to be provided to measure the wave lengths of the various elements. In practice, the assembly works with speed and precision, doing instantaneously analytical work that previously took hours of laborious laboratory time.

• •

ELECTRONIC "SLIDE RULE" FOR STEEL MILLS. In the basic oxygen steelmaking process, a heat of steel is produced very quickly, and the charge for the next batch must be calculated as the current one is being poured. If the mix is off, the steel may not reach the proper temperature by the time the furnace is tapped, and the whole batch has to be reblown. If the narrowly limited tapping temperature range is exceeded, the steel has to be cooled down. In either case, it's costly, and seriously interferes with production schedules. The proper proportion of charge ingredients—raw steel, scrap, scavengers, etc.—can be figured out empirically on a slide rule, but even the best human calculations are too slow to keep up with the furnaces. Honeywell engineers designed for Jones & Laughlin Steel Corp. a special analog computer that determines instantly the proper charge formula for a specified end temperature.

• •

CLINICIAN TURNS REPORTER. In the treatment of Parkinson's disease and other musculomotor disorders, it would be most helpful if the therapist could accurately measure cogwheel rigidity (muscular resistance) before and after treatment. Working with Duke University Medical Center, Honeywell field engineers and university physicians devised a two-channel amplifier that measures the angle of the patient's arm and reports muscular resistances while the arm is being rotated through an arc. A two-pen Honeywell recorder forms an integral part of this system, and furnishes the hospital a permanent strip chart record for further study and evaluation.

• •

You will find that a combination of experience, equipment, and engineering competence offers a unique capacity for coping with the complete range of data handling problems—acquisition, reduction, computation and analysis, and presentation. If you would like to enlist Honeywell's cooperation in solving yours, call your nearby Honeywell field engineer or write Industrial Products Group, Minneapolis-Honeywell, 4412 Wayne Avenue, Philadelphia 44, Pa.

Honeywell

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LETTERS

Sirs:

I have read with interest Martin Gardner's discussion of the difficulties of communicating the local definition of right and left to the inhabitants of a distant planet ["Mathematical Games"; SCIENTIFIC AMERICAN, May]. The conclusions he reaches are perfectly sound, except that the statement of the problem was not sufficiently restrictive to eliminate some "trick" answers. The difficulty is that he allows physical entities, i.e., radio waves, as the carriers of information. Two possibilities immediately suggest themselves.

The first involves the transmission of signals from three separated points, with a suitable time lag between transmissions. If the extraterrestrials are able to resolve the three points, the sequence of signals will define a direction of rotation about the beam direction that defines a vector product and thus a right-handed co-ordinate system. If we invoke a suitably turbulent atmosphere for Planet X, this method can probably be ruled out.

A more difficult method to rule out would be the use of a circularly polarized radio wave, whose direction of polarization immediately defines right-handedness. An atmosphere that reduces a polarized radio wave to complete randomness is hard to imagine.

The result of this discussion is the fol-

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lowing: If we are allowed to send only information to the inhabitants of a far-off region, there is no way to tell them which is their right hand (allowing for the possibility of antimatter). On the other hand, there does not seem to be a way to send information except by the use of physical entities, and as soon as these are introduced their properties allow the distinction to be made.

VICTOR KORENMAN

Jefferson Physical Laboratory
Harvard University
Cambridge, Mass.

Sirs:

Many readers have written to point out loopholes in the way the problem of communicating "left" and "right" was stated. The intention was to restrict the communication to language, transmitted by a pulsed code, in which case the only way to send a definition of handedness to another planet in the galaxy is by sending information about the parity-failure experiments.

MARTIN GARDNER

Dobbs Ferry, N.Y.

Sirs:

Having read the note entitled "First Inducer" in your department "Science and the Citizen" [SCIENTIFIC AMERICAN, April], I feel there are a few errors that should be corrected.

1. This is not the first time that a substance has been found that induces the formation of specialized tissues in embryos. Embryological literature is filled with the isolation and identification of specific chemical "inducers."

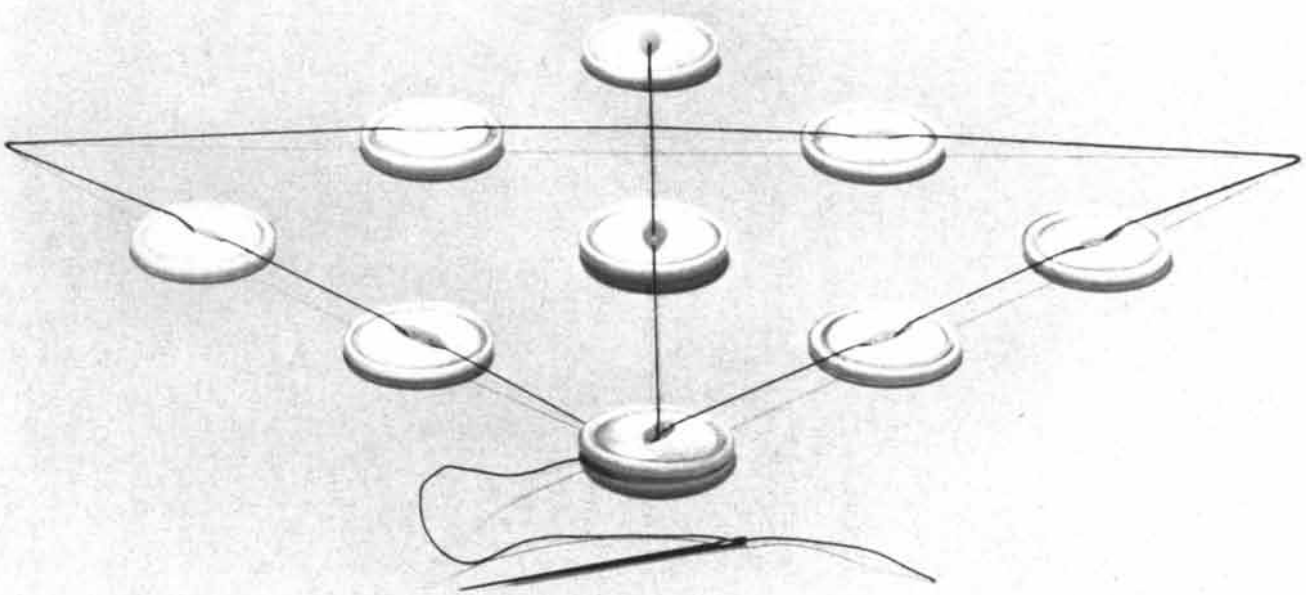
2. The discovery that the ventral half of the spinal cord would stimulate the formation of cartilage in embryonic somites was made by Howard Holtzer 11 years ago, not by Holtzer and Lash two years ago.

3. The fraction you speak of as having inducing activity has not been fully characterized. There is absolutely no evidence that the active agent in our fractions is a nucleoprotein.

JAMES W. LASH

Department of Anatomy
The School of Medicine
University of Pennsylvania
Philadelphia, Pa.

ACHPHENOMENON



For the first moment, the elements are seen separately. Then suddenly, insight arrives. The structure is seen as a whole. With just four straight lines it is possible to bisect all nine dots, the pencil never leaving the paper. What happened? A Flash Experience. Aha! Achphenomenon.

The courage to go outside the confines of the original pattern resulted in an optimal solution. This talent to think in new directions is a quality we look for in engineers. If you're sometimes dissatisfied with traditional concepts and look for a chance to exercise your creative impulses, send a resume to Mr. Don F. Krause, Manager Professional and Scientific Staffing. Expect a prompt reply.

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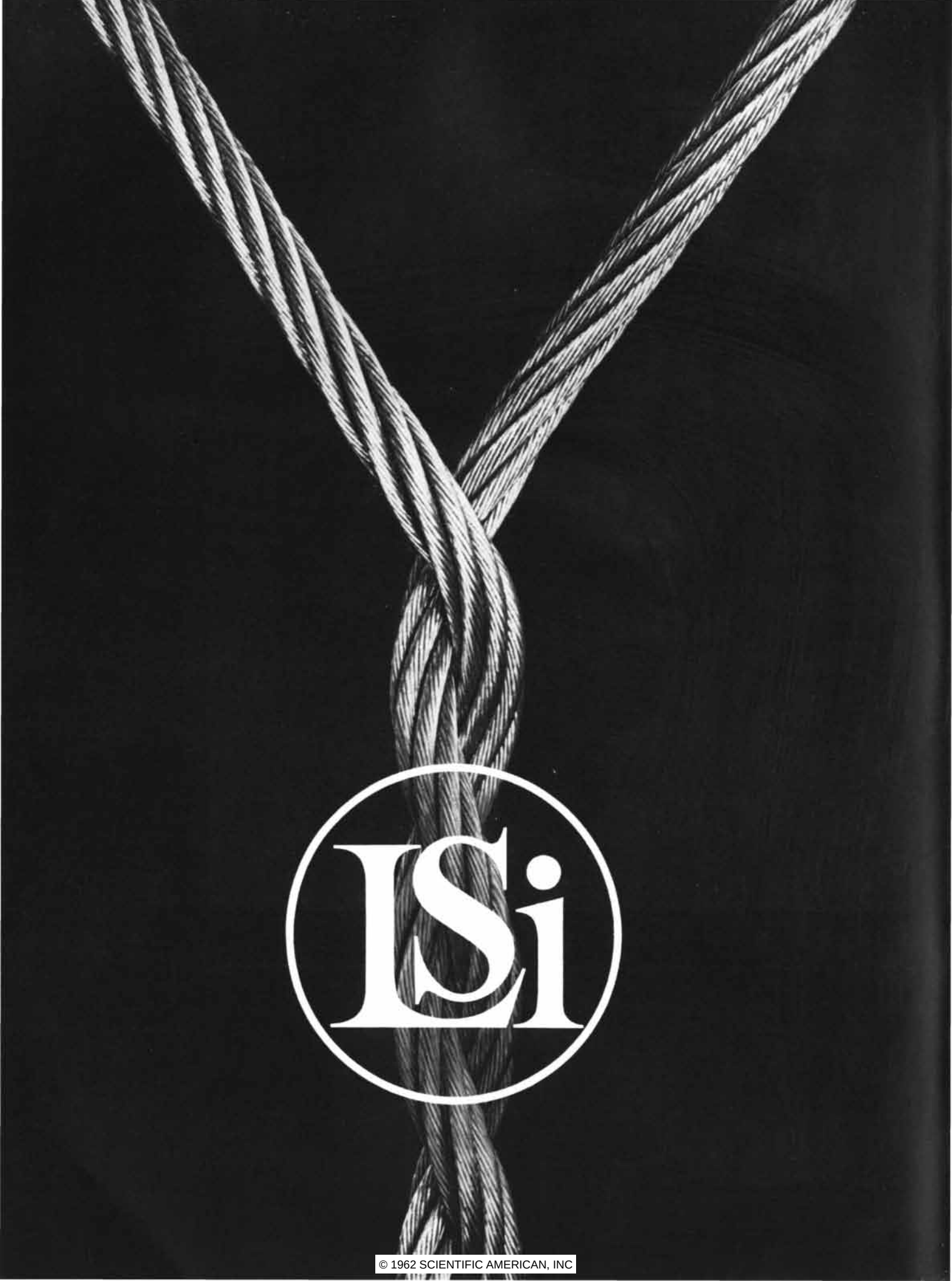

Dirt in...dirt out

Films from ethylene do the trick. Protecting the white crispness of a new shirt, or keeping grimy soil-builders in good condition—plastic packaging sets new standards in efficiency, appearance and sales appeal. Clothes stay cleaner, fertilizers drier, hardware brighter, foods fresher. These new films, polyethylene and polyvinyl chloride, come from ethylene—a Gulf Petrochemical. Ethylene, too, is basic to many leaders in today's growth markets. It's part of the styrene in synthetic tires, part of the alcohol in carefree lacquers. From its oxide comes the glycol for antifreezes and plasticizers. And ethylene is only one of Gulf's many quality petrochemicals that end old processing problems, and begin excitingly new products. If you're in chemicals, see how you can put new profits into your product and your customers' with Gulf Petrochemicals. Write our Sales Office at 360 Lexington Avenue, New York 17, N. Y. for details on Ethylene, Benzene, Cumene, Cyclohexane, Oxo Alcohols, Propylene, Propylene Trimer and Tetramer, Sulfur, Toluene. **Gulf Petrochemicals for that certain quality**

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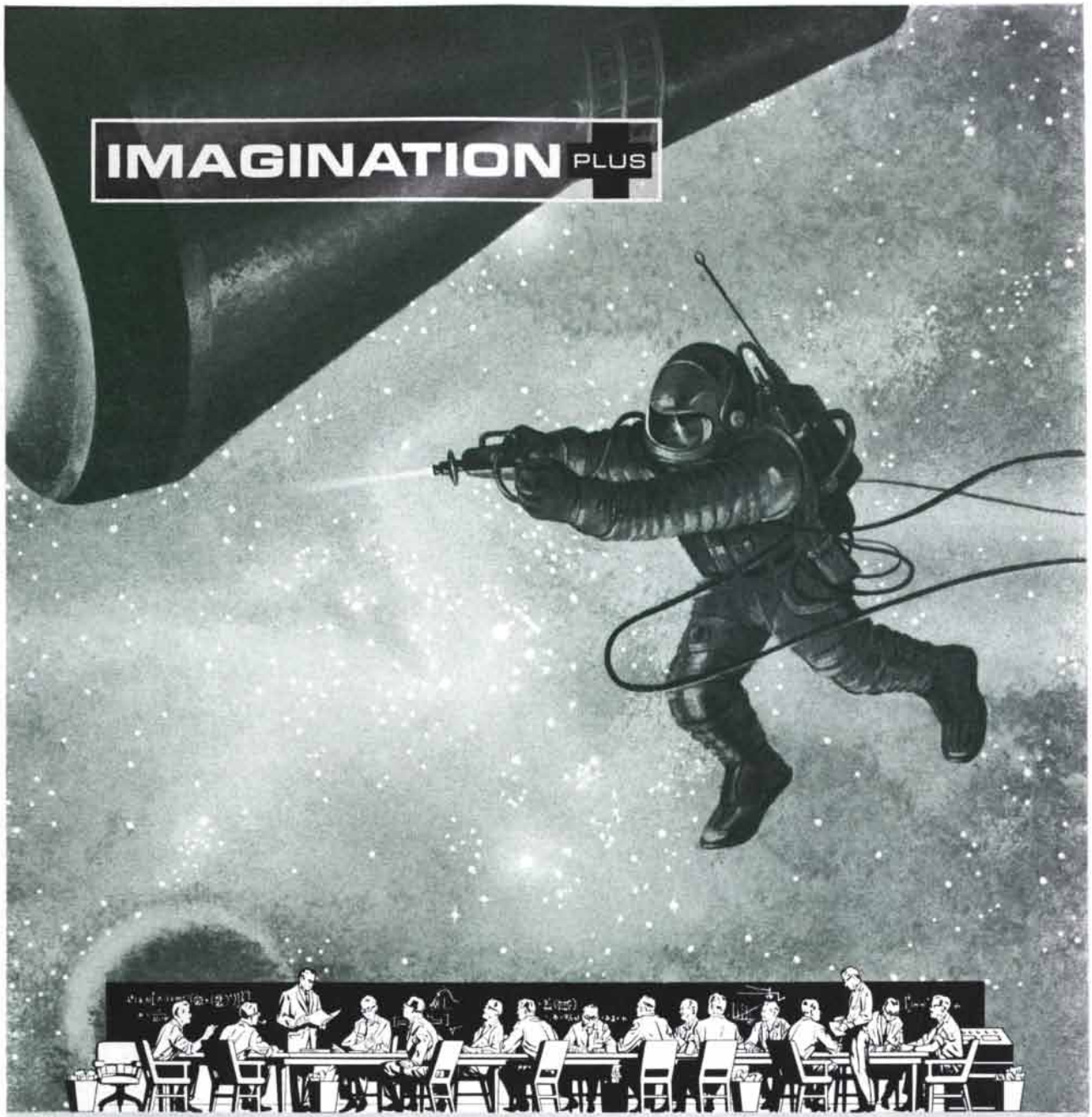

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For information on how Bendix-Pacific's "imagination plus" can go to work for you in any of these fields, write or call Bendix-Pacific Division, North Hollywood, California.

Bendix-Pacific Division

THE Bendix CORPORATION

You have one week to balance this

Walk down this Farmall tractor assembly line and you'll see 50 distinct products in the making. All tractors, but all different. Some farm, some industrial. Diesel, gasoline, LP and high altitude engines. Different transmissions, different hydraulic systems, different steering mechanisms. Different accessories. To suit the customer.

You'd think this would make line balancing a problem. But it doesn't—not with an IBM Computer helping out. Production line balancing with an IBM Computer has helped International Harvester's Farmall Works shave one to two weeks off the task. They now balance the line for a complete schedule change in less than a week.

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■ The computer starts the assignment process, determines the best set of jobs for one operator, prints out the detailed information.

■ As all jobs in one zone are assigned, the computer reads in the job data for the next zone, repeating the process until the line is balanced.

IBM®
DATA PROCESSING

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JULY, 1912: "The Australasian Antarctic Expedition under Dr. Mawson has not only proved the existence, over a distance of some 1,200 miles, of Wilkes Land, which has been a bone of contention between American and European geographers for 70-odd years, but also has landed two parties on it: one under Mawson himself nearly at the east end of this coast, at Point Alden in the eastern part of Adelie Land; the other under Mr. Wild about 1,200 miles farther west, in the part of the coast that was named Termination Land by Wilkes and that has hitherto been either ignored or marked with a note of interrogation on all European maps. Besides these two parties in Antarctica the expedition landed five men at Macquarie Island, where a wireless telegraph station was installed."

"Some very successful experiments have been made with wireless telegraphy for aeroplanes at Chartres in France, using a biplane mounted with the new type of transmitter designed by M. Rouget. The aeroplane started from the aerodrome at Chartres with the inventor on board, piloted by Frantz. In all, a flight of about 100 miles was made around the country, with 30 miles as the greatest distance from the center. A small wireless post had been set up at the aerodrome and the army officers thus kept in touch with the flyer. The antenna at the ground post was less than 100 feet long and was stretched at a height of 30 feet. The officers could take all the observations made by the pilot en route, and the signals were quite clear. On the aeroplane the apparatus used an antenna wire about 100 feet in length, hanging down from one end."

"In the late Henri Poincaré we had a genius of the first order, a man whose accomplishments in his chosen sphere earned him a foremost place among his contemporaries. By many competent authorities he was considered to have been the greatest mathematician of our day. Poincaré was a well-known figure in Parisian society and was by no means the retired mathematical recluse of popular imagination. He was a member of the French Academy of Literature, an extraordinary honor for a scientific man, and a member of a great number of scientific societies in various countries. His published works embrace nearly every branch of pure and applied mathematics. His work in dynamical astronomy is of great value. Among other things, he has made contributions to the famous problem of three bodies that are of the first importance. In general function theory he has created a new type of functions."

"The third Boston Aeroplane Meet, which was held from June 29 to July 7, had a pall thrown over it at the close of the third day by the sudden death of its manager, Mr. W. A. P. Willard, and Miss Harriet Quimby, America's best-known aviatress. The accident occurred at the close of a 20-minute flight to the Boston Light and back. Miss Quimby had almost reached the field and was at a height of about 1,000 feet when the machine made a sudden dip, and her passenger, who had been seated in the rearmost of the two tandem seats, was thrown out of the machine and came hurtling to the earth. For a moment the pilot managed to right her machine, but the next instant it dived vertically and almost turned upside down, the result being that she too was thrown out, in spite of the strap that she had placed across the fuselage just in front of her waist. Miss Quimby, it will be remembered, was the first woman to fly across the English Channel, a feat that she performed on April 16 last."

Scientific American.

JULY, 1862: "This war has proved that the United States have more military resources, and can put into the field greater armies, than any nation on earth. It has proved that the United States Government has no friends among the governments of Europe, and furthermore that it needs none. It has proved that the genius and mechanical skill of American inventors is as remarkable in war as it is in peace."

"The 'Department of Agriculture,' incorporated by a late act of Congress, is to go into immediate operation. Isaac Newton, Esq., of Pennsylvania, the head of the recent agricultural department of

NEWS FROM
BELL LABORATORIES

A simple, highly sensitive microwave amplifier

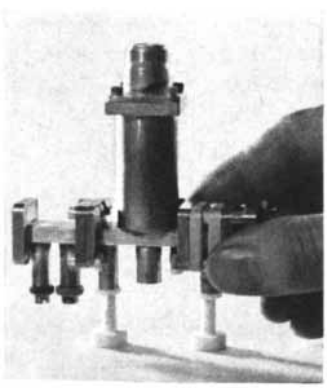
Bell Laboratories engineers have developed an extremely sensitive parametric amplifier which approaches the maser in sensitivity. Both will be used in experiments with Telstar, the Bell System's experimental communications satellite.

Heart of the parametric amplifier is a newly developed semiconductor diode with very low intrinsic noise. Previously, the sensitivity of such amplifiers at microwave frequencies was severely limited by the unwanted noise generated in their diodes. The new diode, no bigger than the eye-end of a needle, solved this problem.

Our engineers also devised new circuitry to stabilize precisely the output of the klystron (microwave generator) supplying power for the amplifier. To reduce further the intrinsic noise of the amplifier, they immersed the diode and its circuits in liquid nitrogen, utilizing a new cooling arrangement which economically maintains a low temperature for many days without attention.

The new amplifier fills a need in the communications field for a simple microwave amplifier of high sensitivity in applications for which the higher sensitivity of the maser does not justify its additional complication.

Bell Laboratories' Michael Chruney adjusts waveguide assembly (in circle) housing the diode. After adjustment the entire parametric amplifier will be immersed in liquid nitrogen in dewar at left. The new amplifier operates at 4170 megacycles (center of band) and provides an almost flat gain of 38 db over a 50-megacycle band with a noise figure of approximately 0.6 db.



Close-up of the waveguide assembly, in which Bell Telephone Laboratories' newly developed diode is located.

Heart of amplifier—a hermetically sealed gallium arsenide diode—is compared with eye of average-sized sewing needle.

BELL TELEPHONE LABORATORIES

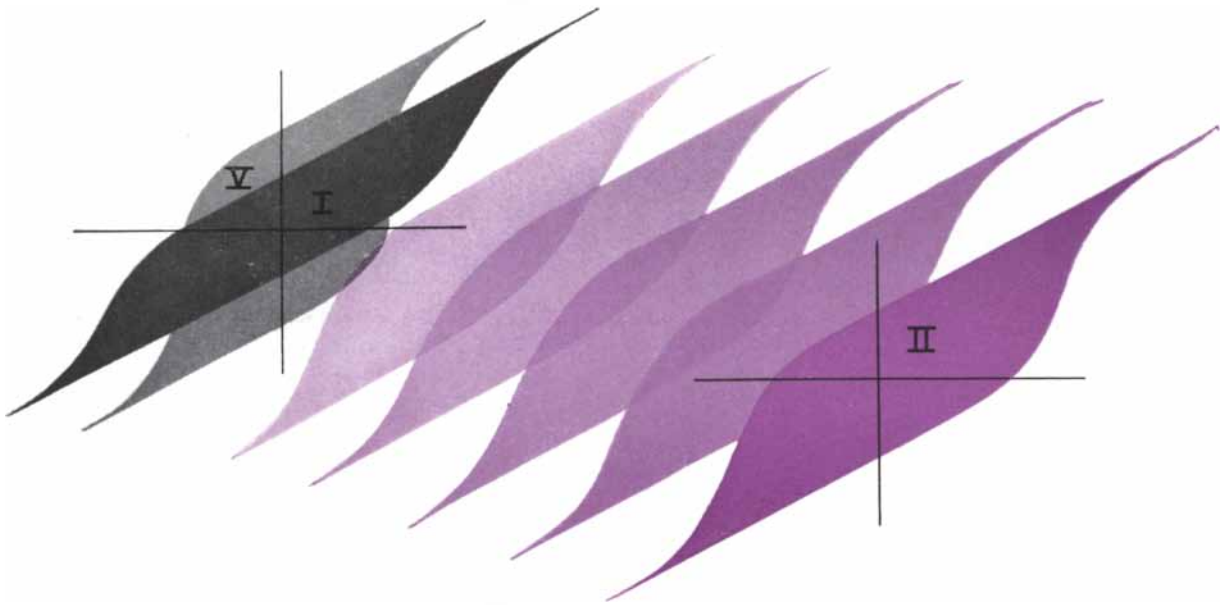
World center of communications research and development

the Patent Office, is the commissioner under the new law. Richard C. McCormick of New York will fill the position of chief clerk. The department is in accordance with the suggestion of the President in his annual message, and the establishment of a distinct bureau or department devoted as a leading purpose to the agricultural interest has been discussed more or less for the past 20 years."

"The most effectual means of preventing dogs biting, and thereby communicating rabies, seems to be muzzling them; and M. Renault, the distinguished veterinarian, in a communication to the Academy of Sciences states that the assertion that muzzling dogs, by the constraint it produces, is itself a cause of rabies is utterly unsupported by any well-established facts. On the other hand, he points out the results that have been obtained in Berlin from a general and permanent muzzling of all dogs not tied up at home. A tax had already been imposed with no diminution of the number of cases of hydrophobia, when in 1854 the muzzling was ordered and strictly executed on all dogs not tied up. From the year 1845 to 1853 inclusive 278 cases of rabies (nearly 20 per annum) were verified at the Berlin Veterinary School; whereas from 1854 to 1861 inclusive only nine cases have occurred, and none of these since 1856. The conclusions that M. Renault draws from these facts are that spontaneous rabies is of very rare occurrence, and that permanent and general muzzling of dogs is a highly efficacious means of preventing the propagation of the disease."

"Colt's Armory at Hartford now employs about 1,100 men, and the pay roll amounts to nearly $50,000 a month. The value of the machinery and tools in the old armory is placed at about $500,000. An additional building is now being erected that will double the size and capacity of the establishment."

"Returned prisoners from the South state that, as far as they saw and heard, the cultivation of cotton is almost entirely suspended in those States that used to produce that staple. In the early part of the present spring cotton planting was commenced, but it was suppressed by proclamations by the governors of the cotton States, who enjoined the planting of corn instead. The consequence is that no more cotton is planted than will suffice for seed for an ensuing crop; but instead of the deposed monarch King Cotton, King Corn wields the scepter."



we probed material mutations . . .

discovered a low-cost motor magnet

The fantastically expanded use of small electric motors, in both battery-operated and plug-in devices, gave our research people a challenge — and an opportunity. The project — come up with a lower cost, yet efficient ceramic magnet material for a DC motor field. ■ Using our unique materials research experience, we varied the techniques involved in the development of our original INDOX® ceramic magnet materials; experimented with different firing temperatures, environments, and cooling rates; applied special manufacturing techniques to obtain production quantities comparable to laboratory samples. ■ The result — INDOX II, a mutation of our INDOX I and INDOX V materials having the low-cost advantage of the first and the superior magnetic characteristics of the second. INDOX II has a residual induction (B_r) of 2700 gauss; coercive force (H_b) of 2250 oersteds; intrinsic coercive (H_{ci}) of 2800 oersteds and peak energy product (B_dH_d) of 1.65 x 10^6 max. When used to replace wound fields in DC motors, INDOX II reduces cost, improves efficiency, lowers heat losses, cuts noise, reduces motor size and weight. ■ Indiana General engineers are happy to place their magnetic experience at your disposal — from designing new permanent magnet materials to building complete memory systems for logic storage. **Call or write for free booklet, "This is Indiana General"** to Indiana General Corporation, Valparaiso, Indiana.

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Sophisticated orbiting biomedical capsules • Lunar probes • Interplanetary exploration programs • A space rendezvous system • Nuclear and other advanced propulsion systems • Communications satellite systems

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Pheidippides was the forerunner

The marathon was included in our modern Olympics in honor of Pheidippides (or Philippides) who, legend says, died about 490 B.C. after racing some twenty-three miles to Athens from the plains of Marathon. There, the Athenians had just routed the forces of Darius, king of Persia, in one of the decisive battles of the world.

The victory itself was in large part due to Pheidippides. Earlier, he had raced the 150 miles from Athens to Sparta in forty-eight hours to enlist Spartan aid, thereby becoming forever a part of "the glory that was Greece."

Today's defenses require that communication be a matter of seconds rather than days. That's why so many early warning systems depend upon REL tropospheric scatter radio which—with the speed of light—leaps oceans, desert sands, and Arctic wastes. That's why you *can depend upon REL to solve your telecommunication problems.*

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New approaches to problems in technical measurement...

Minute electrical impulses previously unstudied or undependable as information because they were buried in high amplitude background noise take on new significance when they are put through the CAT computer. A four-input, digital computer of average transients, the CAT picks repetitive signals out of noise (even when ratios are as low as 1:100), stores them in its memory, averages them and displays the averaged signal for analysis — or sends them on to readout devices. This singular research instrument is the development of Mnemotron Corporation, a subsidiary of Technical Measurement Corporation.

The CAT computer shows promise in many applications in biological and physical research. For instance, it is used to measure and compare simultaneously evoked responses from different regions of the brain . . . to obtain time histograms of nerve action potentials . . . to single out faint communication signals for identification. The CAT can be used virtually anywhere that "signal-in-a-haystack" conditions exist.

As with the CAT, all Technical Measurement Corporation instruments represent progress in the realm of technical measurement. In nuclear research, for instance, the TMC family of pulse analyzers include the only 256-channel system with a choice of seven plug-in logic circuits; the most portable 400-channel pulse height analyzer available, and the world's first production 4096-channel time-of-flight analysis system. In telemetry, another TMC subsidiary, Telemetrics, Inc., provides reliable ground station equipment for military and space exploration installations.

If you are interested in the remarkably wide application possibilities of the CAT, write the Mnemotron Corporation, Pearl River, N.Y. If your problems are in the realm of nuclear research or telemetry, contact Technical Measurement Corporation, North Haven, Connecticut.

TMC **TECHNICAL MEASUREMENT CORPORATION**
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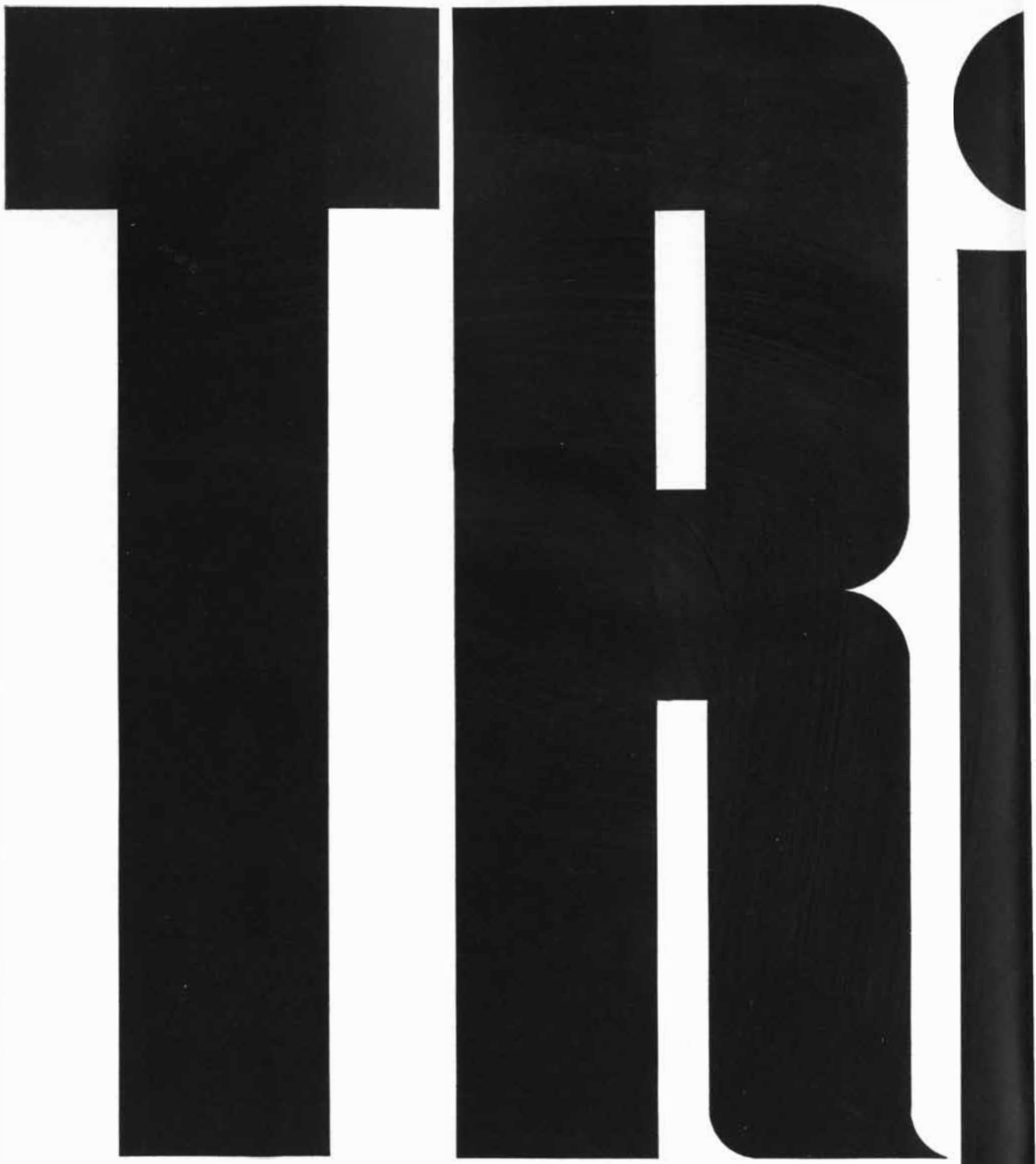
Salvation for small signals lost in high background noise



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THE AUTHORS

E. CUYLER HAMMOND ("The Effects of Smoking") has since 1946 been director of the Statistical Research Section of the American Cancer Society. Hammond received a B.S. from Yale University in 1935 and an Sc.D. from Johns Hopkins University in 1938. He was associate statistician in the division of industrial hygiene of the National Institutes of Health until 1942; as a major in the Army Air Force from 1942 to 1946 he served first as chief of the statistics department of the School of Aviation Medicine at Randolph Field in Texas and later as assistant chief of the statistics division of the Office of the Air Surgeon in Washington. Hammond, who has been studying the effects of smoking for more than a decade, was professor of biometry and director of statistical studies in the graduate school of Yale University from 1953 to 1958.

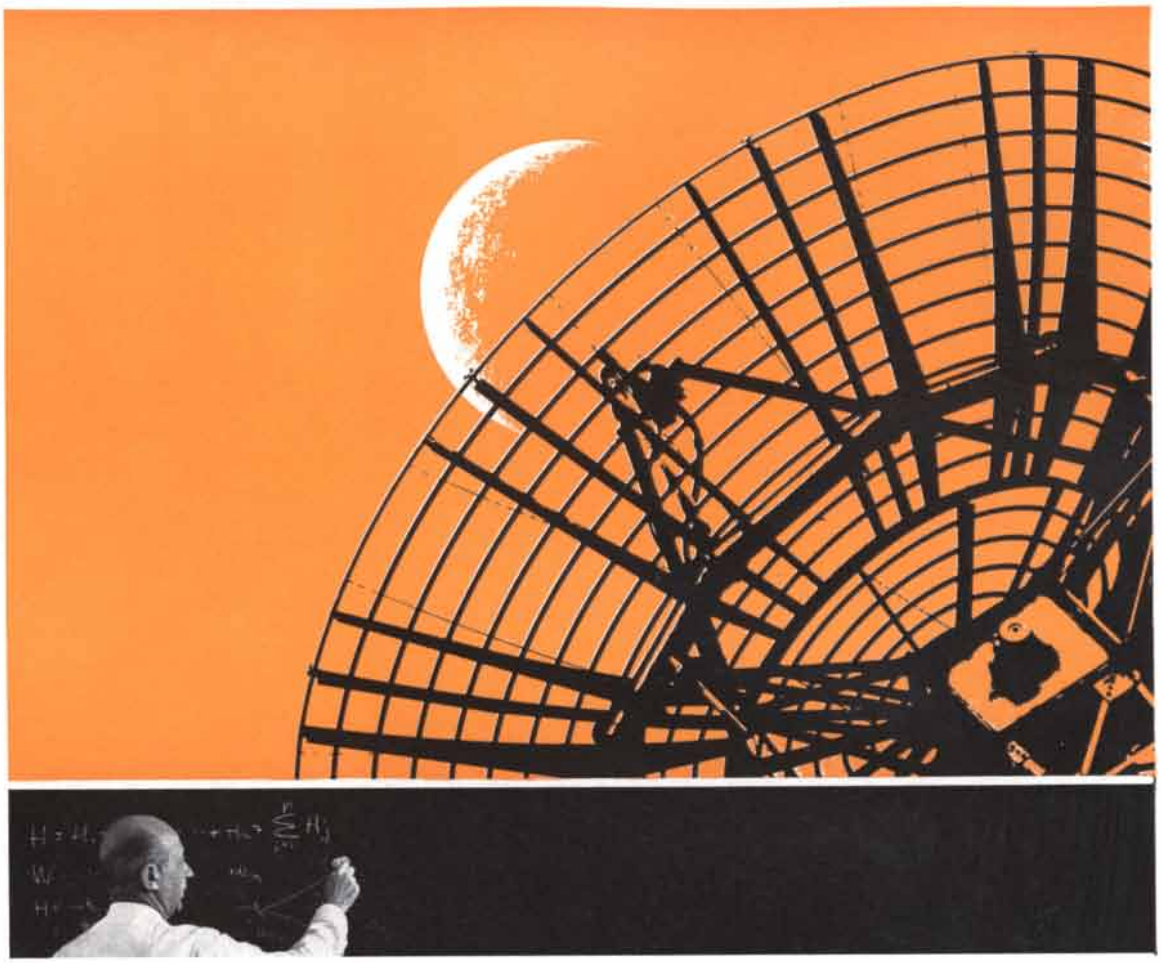
DON L. ANDERSON ("The Plastic Layer of the Earth's Mantle") is research fellow at the Seismological Laboratory of the California Institute of Technology. He took a B.S. in geology and geophysics at Rensselaer Polytechnic Institute in 1955. In 1956 he joined the Arctic Studies Section of the Air Force Cambridge Geophysics Research Directorate. Anderson has led six expeditions to Greenland to study the elastic properties of sea ice. His theoretical work on this material later proved pertinent to the study of the earth's mantle. Anderson received his M.S. and Ph.D. from Cal Tech and is currently investigating the properties of the crust and upper mantle.

PERRY W. GILBERT ("The Behavior of Sharks") is professor of zoology at Cornell University and chairman of the Shark Research Panel of the American Institute of Biological Sciences. Gilbert, whose research on sharks spans the past 20 years, acquired an A.B. at Dartmouth College in 1934 and a Ph.D. in zoology at Cornell in 1940. His work has taken him to Maine, Florida, the Bahamas and the Marshall Islands. The locales of his shark research this summer are Durban, South Africa, and Sydney, Australia.

JOHN F. BROWN, JR. ("Inclusion Compounds"), is an organic chemist at the General Electric Research Laboratory in Schenectady, N.Y. Brown obtained an Sc.B. at Brown University in 1947, did graduate work in physical and organic chemistry at the Massachusetts Institute of Technology, receiving his Ph.D. in 1950, and went to General Electric the same year. From 1956 to 1961 he was manager of the Reaction Studies Unit at General Electric. Brown's interest in enzyme models and techniques for controlling synthetic reactions led him to study inclusion compounds.

DAVID B. ERICSON and GOESTA WOLLIN ("Micropaleontology") are respectively a geologist and a student of social problems who spends part of his time in deep-sea research. Ericson has been on the staff of the Lamont Geological Observatory since its founding in 1949. He studied petroleum geology at the Massachusetts Institute of Technology, where he received a B.S. in 1931, and at the California Institute of Technology, where he acquired an M.S. in 1933. Ericson prospected for oil in the U.S. and Asia Minor until 1946, when he went to the Woods Hole Oceanographic Institution to study marine sediments. In 1947 he accompanied Maurice Ewing, director of Lamont, on the latter's first expedition to the Mid-Atlantic Ridge. Since then he has devoted himself to the study of the sediment cores raised by Ewing and his associates. Wollin, a native of Sweden, studied at Hermods College and the University of Lund, is consultant to the National Council on Crime and Delinquency and research associate at the Lamont Geological Observatory. After almost a decade of newspaper reporting, Wollin came to the U.S. in 1942 to join the Army. During the next three years he served in Army Intelligence and participated as a paratrooper in the invasions of Normandy and Holland. He was a free-lance writer for Swedish newspapers from 1945 to 1950, when he went to Lamont. Wollin, who holds an M.S. from the New York School of Social Work at Columbia University, joined the National Council on Crime and Delinquency in 1960.

ROBERT L. SINSHEIMER ("Single-stranded DNA") is professor of biophysics at the California Institute of Technology. Sinsheimer took his degrees at the Massachusetts Institute of Technology, receiving a Ph.D. in 1948. During the period from 1942 to 1946 he was research associate in the Radiation Laboratory at M.I.T., where he was engaged in the design and flight-testing of air-borne radar. Before going to Cal Tech in 1957 he had been a member of



YOU'VE SEEN THE MOON...NOW LISTEN

Lately we've been talking and listening to the moon to learn more about communications. And talking to the solar system we've learned a lot of other things. We've learned to track a missile plunging through space three times faster than a rifle bullet. Our Atomic Clock (it will vary but one second in 1500 years) will help in space navigation, where a split-second time error can throw spacecraft thousands of miles off course. We've developed the capabilities to solve almost any space problem including guidance, detection, telemetry, even building the spacecraft itself. / One notable accomplishment is Station KF2 XBR (2299.9 MC on the dial), the first radio station licensed for experimental radio transmission into space leading to commercial use. Together with a unique transportable space communications center developed by ITT, to be located in Brazil, it will be an integral part of NASA's coming RELAY communications satellite program. And ITT companies in New Jersey and London will be using this station to communicate by bouncing signals off the moon. Working together on project Moon Bounce, ITT scientists around the world have learned much to advance the art of communications for the benefit of people everywhere. / International Telephone and Telegraph Corporation, World Headquarters: 320 Park Ave., New York 22, New York.

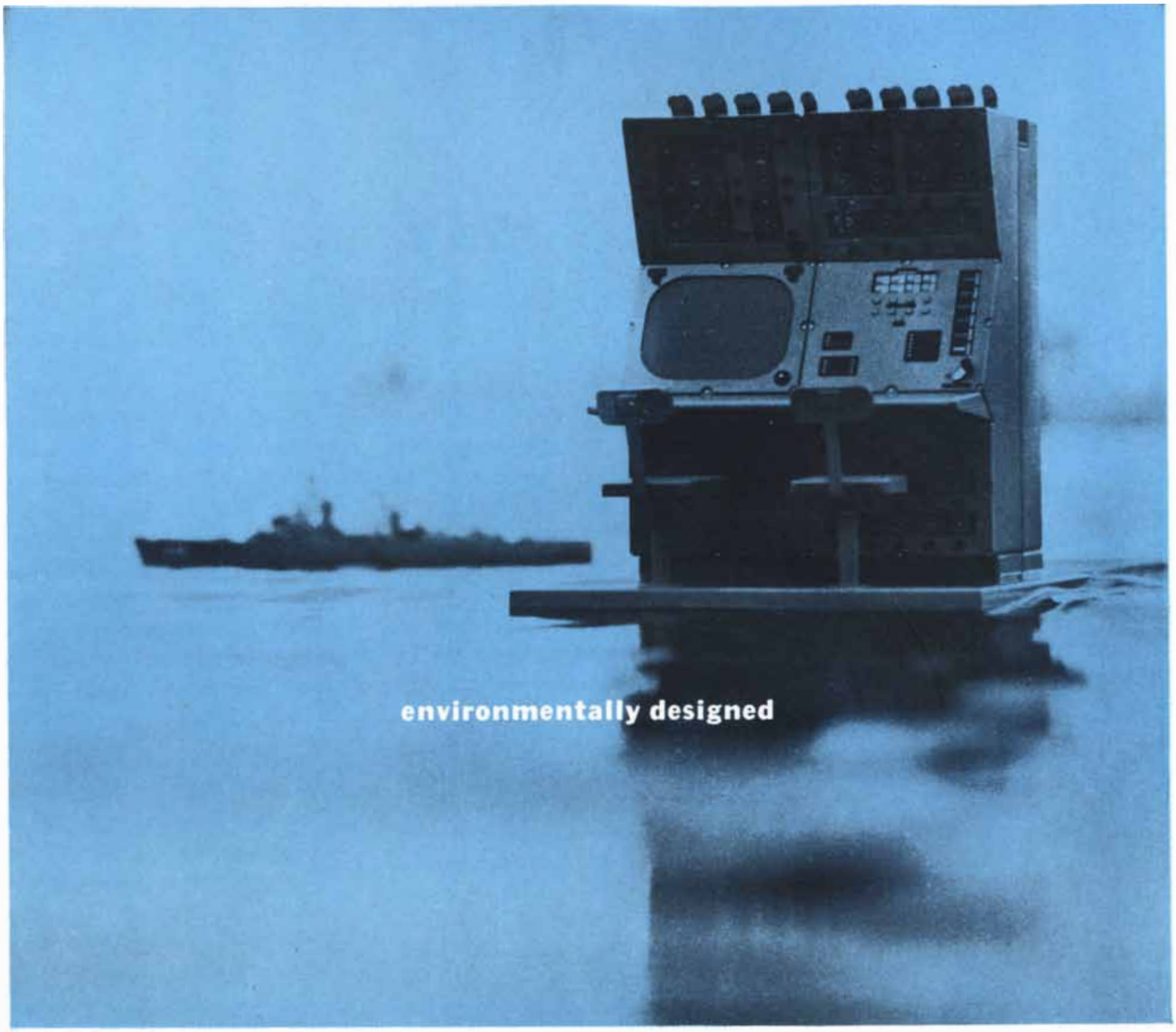
worldwide electronics and telecommunications ITT

the physics department at Iowa State University since 1949. Sinsheimer is an editor of the *Journal of Molecular Biology*.

LLOYD KAUFMAN and IRVIN ROCK ("The Moon Illusion") are respectively Section Head for Human Factors in the Systems Group of the Sperry Rand Corporation and professor of psychology at Yeshiva University. Kaufman took his B.A. at San Diego State College in 1950, joined Sperry Rand in 1952 and received his M.A. and Ph.D. degrees from the New School for Social Research in 1957 and 1961. Also a visiting member of the Yeshiva faculty, Kaufman is at present engaged in research on visual-search and detection problems for the Federal Aviation Agency as part of its collision-prevention program. He began his collaborative study of the moon illusion with Rock (in which they consider themselves equal partners) in 1956, when the latter was teaching at the New School for Social Research. Rock studied psychology at the College of the City of New York and acquired his Ph.D. from the New School in 1952. In 1959 he went to the Graduate School of Education at Yeshiva as chairman of the department of psychology. Last year he moved to the department of experimental and clinical psychology.

H. S. FEDER and A. E. SPENCER ("Telephone Switching") are respectively a member of the technical staff of the Electronic Switching Division and a supervisor in the Military Communications Systems Engineering Center at the Bell Telephone Laboratories. Feder took his B.S. in electrical engineering at the College of the City of New York in 1944 and joined the Bell Laboratories in 1946, having worked in the meantime for the Western Electric Company and at the Los Alamos Scientific Laboratory. He received an M.S. in electrical engineering from Rutgers University in 1960 and is currently doing research on the "time division" telephone system discussed in the present article. Spencer obtained a B.S. in electrical engineering from Drexel Institute of Technology in 1951. He went to the Bell Laboratories the same year, where he is engaged in the design of communications systems.

MARSHALL D. SAHLINS, who in this issue reviews Robert Ardrey's *African Genesis*, is assistant professor of anthropology at the University of Michigan. Sahlins wrote the article entitled "The Origin of Society" in the September 1960 issue of SCIENTIFIC AMERICAN.



. . . out of 22 years of ASW fire control system engineering

This is the ASROC fire control computer, symbolically afloat. In reality, this computer directs the fire of the U.S. Navy's antisubmarine rocket weapon system. It is the latest of eleven major Librascope contributions to ASW dating back to 1940. More than 80% of the Underwater Fire Control Systems in the Navy's Antisubmarine Surface Fleet today were designed and/or built by Librascope. Subsurface, surface, air and space, Librascope computers pace man's expanding mind. Send for "Librascope ASW Achievements 1940-1960."

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Be fussy

Two things determine whether or not a particular printed circuit connector is "right" for your application:

1. How the printed circuit board mates with the connector, and

2. How the connector connects to the rest of the system.

Take mating, for example. Besides having the correct number of contacts, a printed circuit connector must hold the board securely whether the board happens to fall at the high or low end of thickness tolerances.

IT TAKES THREE

These considerations convinced Amphenol engineers that no single contact design could satisfy the requirements of a wide range of applications. So they designed three contacts that will.

One, used in Prin-Cir* connectors, looks a lot like a tuning fork with lips. The circle lip design makes contact overstressing or "setting" impossible —even after repeated insertions. The contact's long spring base also enables it to accommodate boards that range in thickness from .055″ to .073″, while doing an excellent "wiping" job.

EASY DOES IT

But not every application requires the Prin-Cir "bite." For this reason, Amphenol engineers designed connectors with ribbon contacts that mate with a gradual wedge-like force. In blind mating applications, gradual mating makes the feeling of *correct* mating unmistakable. (Just the thing when your equipment may eventually be maintained by less-skilled and less-concerned personnel.) Ribbon contact wedge action also makes it possible for connectors using these contacts to accept the same wide range (.055″ to .073″) of board thicknesses as do Prin-Cir connectors.

Finally, advances in micro-miniaturization (like Amphenol-Borg's Intercon® pre-fabricated circuitry) meant that tinier-than-ever-before connectors were needed. Amphenol's answer was the Micro-Min® receptacle and printed circuit board adapter. Micro-Min contacts are actually tiny springs of beryllium copper wire, formed in a precisely designed arc to assure firm circuit board retention. This unique design makes it possible to space contacts on .050″ centers and crowd 19 connections into a little more than an inch of space.

TERMINATIONS COUNT, TOO

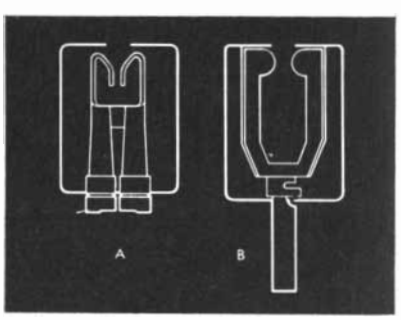
"How to connect connectors to the rest of the system" also merits a good deal of consideration. In some cases, hand soldered terminations will do just fine. In others, higher volume requirements call for high production rate methods like dip soldering and wire-wrapping. Some engineers prefer taper pin terminations.

Our printed circuit connectors are available with contact tails designed for each of these termination methods. In addition, adapters are available for use in connecting printed circuit boards at right angles to each other or in modular arrangements. We make printed circuit connectors with hermetically sealed contacts — still others with coaxial contacts.

Take your choice.

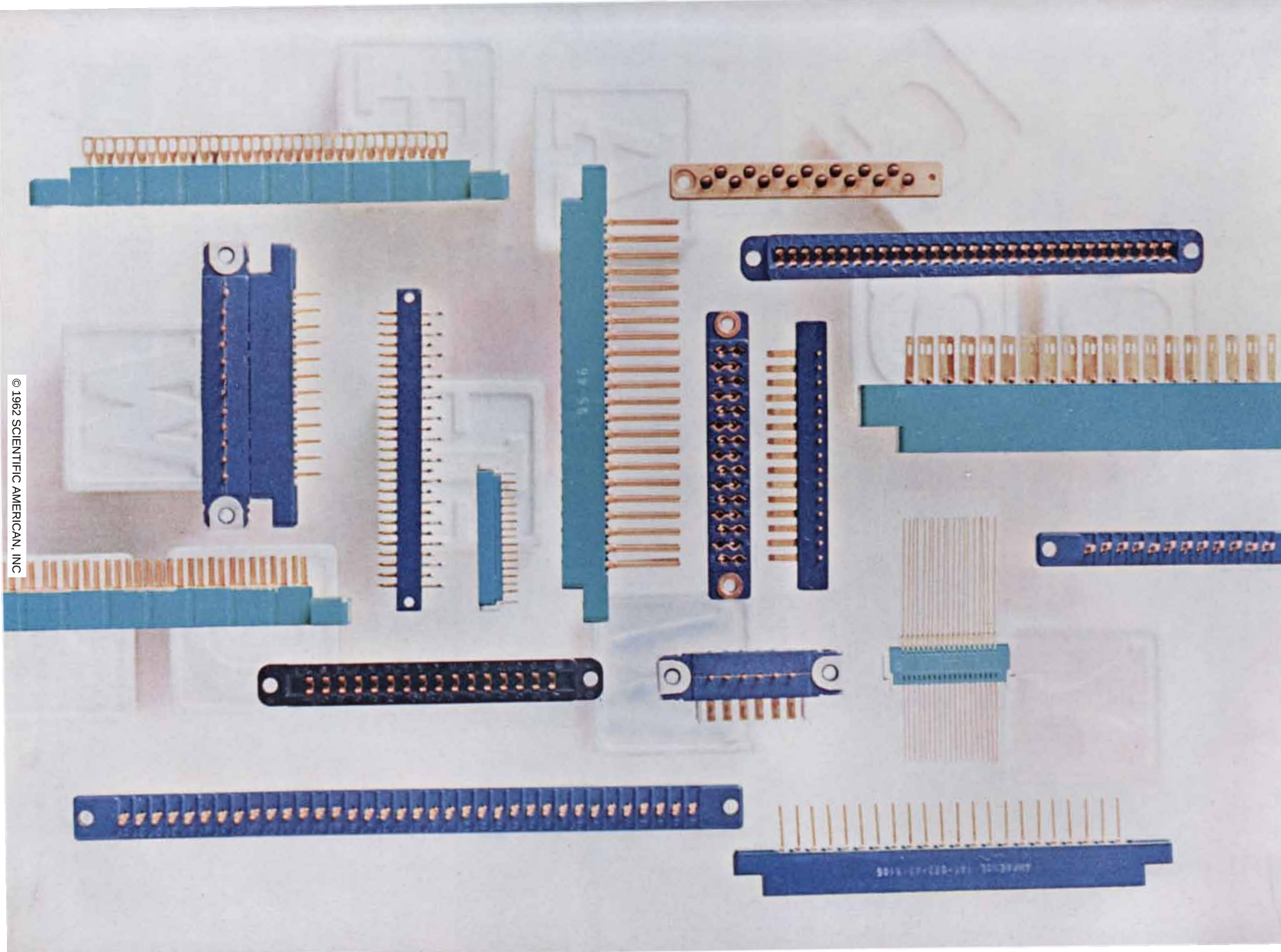
Any Amphenol Sales Engineer or authorized Amphenol Industrial Distributor will be happy to discuss printed circuit connectors (ours) with you. Or, if you prefer, write directly to Dick Hall, Vice President, Marketing, Amphenol Connector Division, 1830 S. 54th Avenue, Chicago 50, Illinois.

*T.M. Amphenol-Borg Electronics Corp.



Wedging action of Amphenol ribbon-type (A) and long spring base of Amphenol Prin-Cir connectors (B) assure firm printed circuit board retention, whether board happens to fall at low (.055″) or high (.073″) end of thickness tolerance.

AMPHENOL **Connector Division** / Amphenol-Borg Electronics Corporation



WHO KEPT THE HYDROQUINONE OUT OF MRS. MURPHY'S ROAST?

Meats, as well as other foods, have an eager affinity for unpleasant-tasting esters, inhibitors, and catalysts that remain unreacted in some polyester resin molded plastics.

A meat packer was searching for reinforced plastic processing trays that positively would not contaminate the meats being processed and delivered. In addition, the trays had to fully resist the hot cleaning solutions he used.

The tray manufacturer began using a new Glidden polyester resin formulation. Trays molded of this resin have shown no exudation of harmful materials and no warping or crazing even after two years of hard usage and severe sterilization.

1 Complete "wetting" of glass reinforcing fibers by Glidden Glidpol resin is shown in the enlarged photograph at top. Incomplete "wetting" (lower photograph) creates capillaries for entrance of cleaning solutions and food juices into body of molded plastic parts.

2 To make certain that commercial dishwashers and heavy-duty detergents will not faze, craze, nor warp trays made of Glidpol resins, molded samples are subjected to this supertest. Simulating two years of normal washing and sterilizing, the test is a 48-hour immersion in 2% trisodium phosphate solution.

3 In production on tray manufacturer's press, Glidpol quickly impregnates glass fiber mat, cures in less than two minutes to a craze-free, chemically inert plastic with flexural strength up to 50,000 psi.

4 After official tests, Glidpol has been accepted for use in contact with specific food products, including meat, fish, and poultry. Extraction tests show that no food-contaminating substances exude from products molded of this Glidpol resin.

If your product requires a finish, a coating or a resin, Glidden is ready to work with you. To obtain the formulation best suited to your product and application methods, write or phone:

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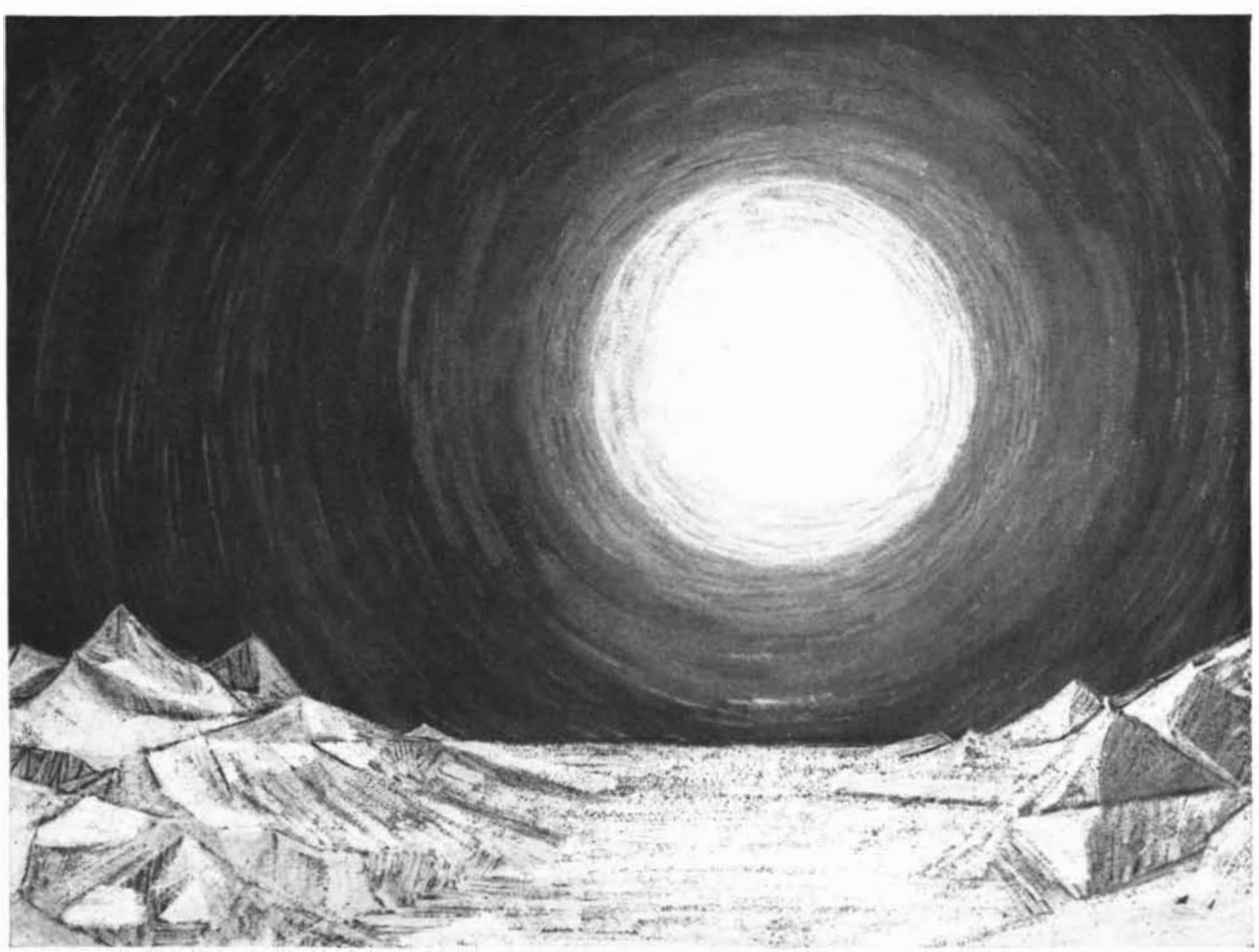
THE YEAR OF THE QUIET SUN

...AND WHAT DOUGLAS IS DOING ABOUT IT

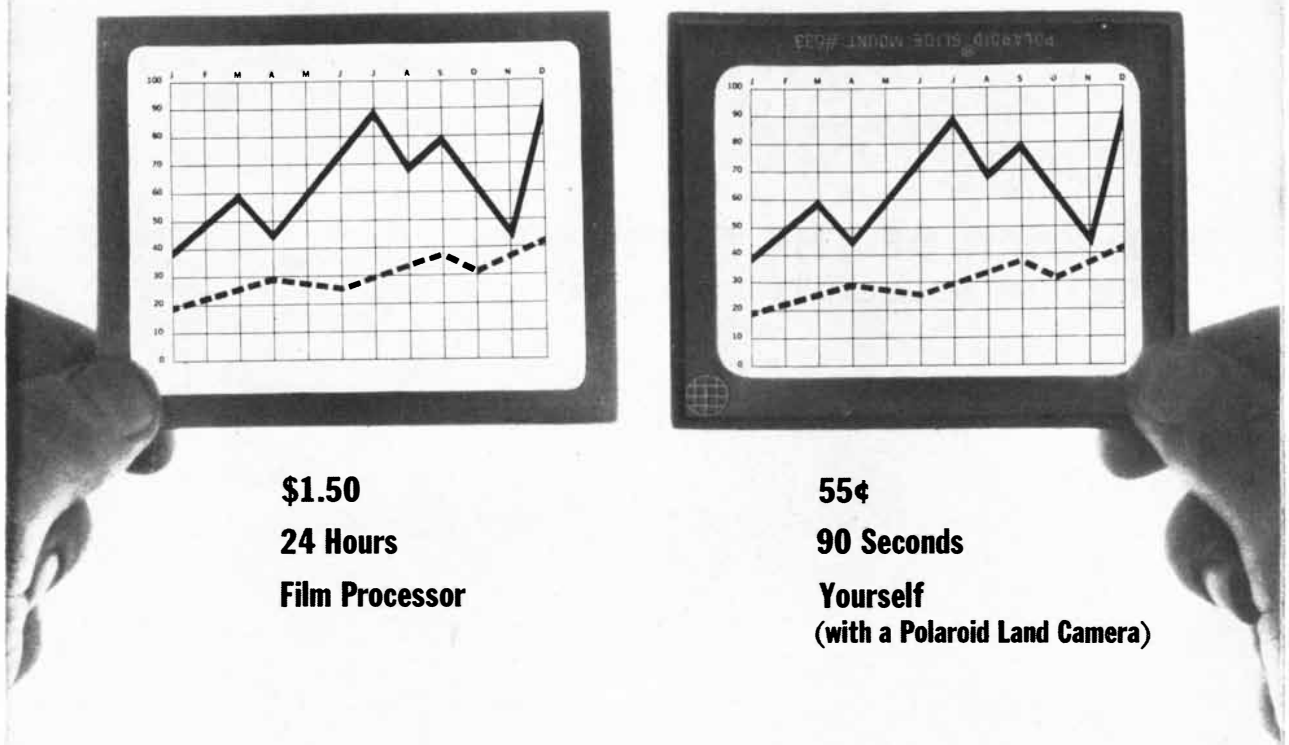
Scientific predictions indicate that solar activity will be at a minimum between July, 1964 and July, 1965. This has been designated as the International Year of the Quiet Sun, and during it a world-wide magnetic survey will take place. □ The Douglas Space Physics and Planetary Sciences Group is studying scientific experiments to be performed on satellite and space probe missions during this period. Instruments to be used will be among the following: magnetometers; ionization chambers; G-M detectors; scintillators; solid state detectors; and spectrometers. □ The present Douglas Antarctica Riometer Station program for the study of cosmic rays will continue through this "Quiet Sun" period and will provide important data relative to solar cosmic ray and auroral events and the geomagnetic K-index. Douglas was invited to participate with the National Science Foundation in this program.



Preparation for the Year of the Quiet Sun world scientific survey is one of more than 500 research projects that are under way at Douglas. Some of these relate to the solution of problems on programs of today and tomorrow. Others range through development and research programs whose effects may not be evident until ten or twenty years in the future.

DOUGLAS

"POLAROID" AND "POLALINE"®



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90 Seconds
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(with a Polaroid Land Camera)

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After a quick hardening and mounting in a snap-together frame, the slide is ready to be dropped into a projector. Total time: about 90 seconds. Total cost: about ⅓ the price of the average black-and-white slide.

A new type of transparency film, PolaLine film, is now available. It's been designed especially for line-copy slides and it produces crisp, black lines and clear, transparent backgrounds. These are 3¼ x 4 transparencies for standard lantern slide projectors.

There are also continuous tone films for both standard lantern slide projectors and for use in a complete Polaroid Land system that employs 2¼ x 2¼ slides in a Polaroid projector. (Development time for continuous-tone slides is two minutes.) All three projection film types can be used in any Polaroid Land Camera that uses 40-series films (except the J-66).

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Established 1845 SCIENTIFIC AMERICAN July 1962 Volume 207 Number 1

The Effects of Smoking

There is no longer any doubt that cigarette smokers have a higher death rate than nonsmokers. New biological studies help to explain how tobacco smoke damages the lungs, heart and other body tissues

by E. Cuyler Hammond

In 1560 Jean Nicot, the French ambassador to Portugal, wrote that an American Indian herb he had acquired had marvelous curative powers. For a time his view was widely accepted, and in his honor the herb was given the generic name *Nicotiana.* The species *Nicotiana rustica,* first introduced into Europe for smoking in pipes, was harsh and rather disagreeable. Later it was supplanted by *Nicotiana tabacum,* which produces a pleasanter smoke. *N. rustica* is still grown in the U.S.S.R. and other parts of Asia, but *N. tabacum* is now the chief source of smoking tobacco and is the only species cultivated in the U.S.

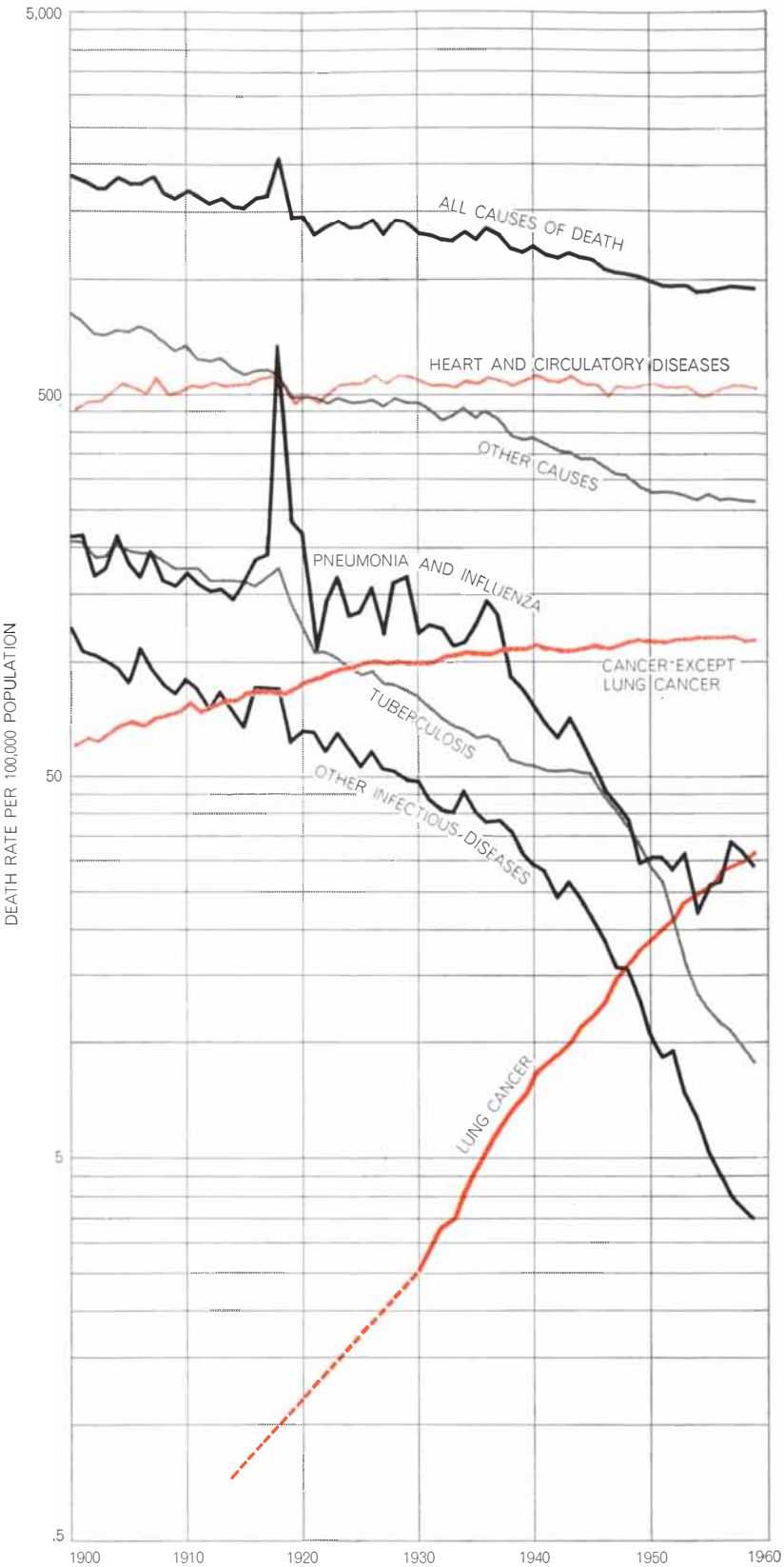
Skepticism about the medical value of tobacco developed near the end of the 16th century; not long thereafter smoking was condemned as a pernicious habit responsible for all manner of ills. This did not prevent smoking from becoming an almost universal habit among men in Europe and the American colonies. Actually there was no scientific evidence for any harmful effects of tobacco until the middle of the 19th century.

It appears that M. Bouisson, an obscure French physician, deserves credit for the first well-documented clinical study of the matter. In 1859, reporting on patients in the hospital at Montpellier, he observed that of 68 patients with cancer of the buccal cavity (45 of the lip, 11 of the mouth, seven of the tongue and five of the tonsil) 66 smoked pipes, one chewed tobacco and one apparently used tobacco in some form. He noted that cancer of the lower lip ordinarily developed at the point where the pipe was held in the mouth. He further noted that lip cancer occurred more frequently among individuals who smoked short-stemmed pipes (then called "mouth burners") than among those who smoked long-stemmed clay pipes or pipes with stems made of a substance that does not conduct heat. He suggested that the cancer resulted from irritation of the tissue by tobacco products and heat.

Bouisson's observations were confirmed repeatedly over the next half-century, but since mouth cancer did not loom as a major medical problem the effect on smoking habits was insignificant. Another statistically unimportant problem early recognized as being associated with smoking was Buerger's disease, a rare affliction of the peripheral arteries. It was found to occur exclusively among smokers and to subside when the patient stopped smoking. In 1936, however, two New Orleans surgeons, Alton Ochsner and Michael E. De Bakey, observed that nearly all their lung cancer patients were cigarette smokers. Noting that lung cancer seemed to be on the increase and that it was paralleled by a general rise in cigarette smoking, they suggested a causal connection between the two phenomena. In 1938 Raymond Pearl, the noted Johns Hopkins University medical statistician, reported that smokers had a far shorter life expectancy than those who did not use tobacco. The effect was so great as to indicate that smoking must be associated with diseases other than cancer. The first experimental evidence for an association between tobacco and cancer came in 1939, when A. H. Roffo of Argentina reported that he had produced cancer by painting tarlike tobacco extracts on the backs of rabbits. After World War II there was renewed interest in the subject of smoking and health, due partly to trends in tobacco consumption and partly to trends in death rates.

Before 1914 tobacco had been consumed mainly in pipes, cigars, chewing tobacco and snuff [*see illustration on page 41*]. Cigarettes began to be popular during World War I. In the period from the early 1920's to 1960 the consumption of manufactured cigarettes in the U.S. rose from about 750 per adult per year to 3,900 per adult per year. During the same period the consumption of tobacco in all other forms declined by about 70 per cent. The net result was that consumption of all tobacco products rose about 30 per cent.

The changes in smoking habits are more significant than the over-all rise in tobacco consumption. Smoke from cigars and pipes is heavy and as a rule slightly alkaline. Few people can inhale it without coughing or becoming dizzy or nauseated. Cigarette smoke, on the other hand, is relatively light, nearly neutral and can be inhaled readily. Most habit-



RISE IN LUNG CANCER DEATHS runs counter to the 60-year downtrend in total death rates among U.S. men. In 1959 lung cancer accounted for 29,335 deaths. Colon and rectal cancers, next in order of frequency, caused 19,129 male deaths. The nearly steady death rate for heart and circulatory diseases conceals a significant rise in coronary artery disease, which is offset by a long-term decline in infectious heart diseases. Curves are age-adjusted so that death rates are not spuriously shifted by the changing age composition of the population.

ual cigarette smokers inhale to some degree, and heavy cigarette smokers tend to inhale deeply. In a recent study conducted by the American Cancer Society detailed information has been obtained on the smoking habits of 43,068 men and women. Only 7 per cent of the cigarette smokers among the men said that they did not inhale, whereas noninhalation was reported by 53 per cent of the pipe smokers and 71 per cent of the cigar smokers. Deep inhalation was reported by 24 per cent of the cigarette smokers compared with only 3 per cent of the pipe smokers and 1.5 per cent of the cigar smokers. Women who smoke inhale to a lesser degree than men smokers do. Furthermore, women over the age of 40 smoke far fewer cigarettes than men of the same age do, and few women over 55 smoke as much as a pack a day. Among current cigarette smokers now over 50, the majority of the men started the habit before they were 20, whereas the majority of the women did not begin until they were over 35.

During the past half-century total death rates—including death rates from almost all infectious diseases and some noninfectious ones—have declined rapidly. Lung cancer is a striking exception. Deaths from lung cancer in the U.S. have climbed from 4,000 in 1935 to 11,000 in 1945 and to 36,000 in 1960. The toll in 1960 was approximately equal to the number of deaths caused by traffic accidents. In 1960, 86 per cent of those who died from lung cancer were men. Between 1935 and 1960 the age-standardized death rate from lung cancer among U.S. men (the death rate adjusted for age differences in the composition of the population) increased 600 per cent; among women it increased 125 per cent. And for the past several years lung cancer has been the principal form of fatal cancer among men.

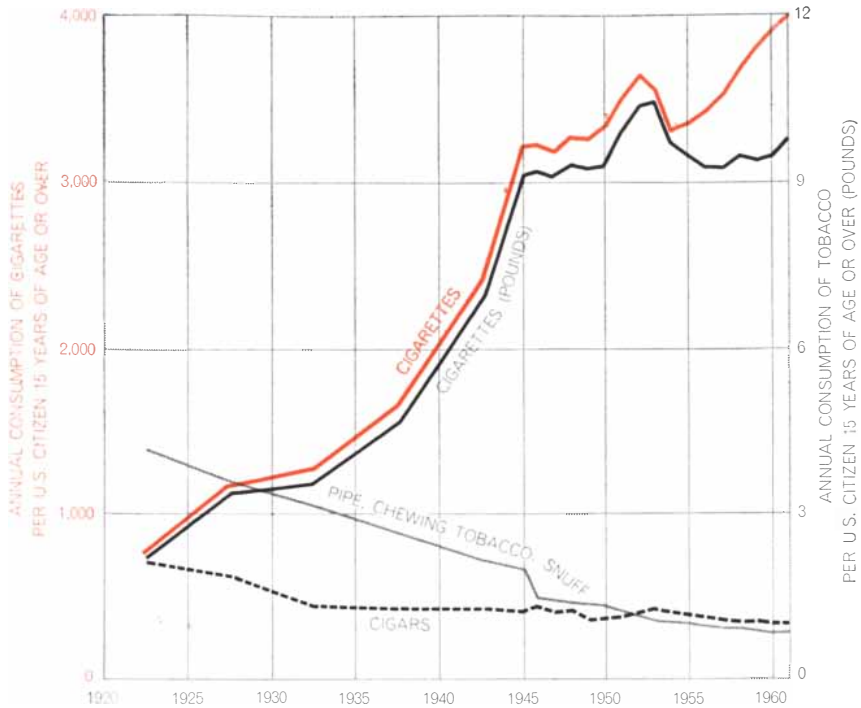
Painstaking studies have clearly demonstrated that the increase in lung cancer is real and not attributable merely to improvement in diagnosis. Lung cancer (that is, bronchogenic carcinoma) arises in the epithelium, or lining, of the bronchial tubes. The increase seems to be confined to two closely related forms of the disease: epidermoid carcinoma and undifferentiated carcinoma. There seems to be little, if any, increase in another form of the disease: adenocarcinoma. (In adenocarcinoma the diseased cells assume an arrangement resembling that of the cells in a gland.)

Lung cancer accounted for about 2 per cent of all U.S. deaths in 1960, and for about 6 per cent of deaths among men in their late 50's and 60's. The lead-

ing cause of death in the U.S. is coronary artery disease of the heart, which accounted in 1960 for nearly 29 per cent of all deaths, and for about 35 per cent of deaths among men still in their 40's and 50's. As in the case of lung cancer, coronary artery disease is less common among women, accounting for only about 16 per cent of the deaths occurring between the ages of 40 and 59.

In the late 1940's, when a number of investigators became concerned with lung cancer, cigarette smoking was only one of several factors suggested as possible causes for the increase in the disease. It was already well known that lung cancer could result from prolonged and heavy occupational exposure to certain industrial dusts and vapors. These include chromates, nickel carbonyl and dusts containing radioactive particles. Moreover, they result in epidermoid or undifferentiated carcinoma of the bronchial tubes and not in the less common adenocarcinoma.

This led to the hypothesis that the increase in lung cancer was due to increased exposure of the human population to air contamination of some sort. The factor involved had to be widespread and not confined to any particular occupational group. (In all countries with adequate mortality statistics lung cancer was found to have increased.) Three factors that met the requirements were: fumes from the combustion of solid and liquid fuels, dust from asphalt roads and the tires of motor vehicles, and cigarette smoking. The first two have not been ruled out as possibly contributing somewhat to the occurrence of lung cancer. It is the third that concerns us here.



CHANGES IN TOBACCO USE produced a fivefold rise in cigarette consumption between the early 1920's and 1961, and a drop of nearly 70 per cent in consumption of all other tobacco products. Cigarettes are plotted both in units (*color*) and in pounds of unstemmed-tobacco equivalent. Other tobacco products are shown only in pounds. Filter cigarettes, which use less tobacco than nonfilter types, have been growing in popularity since 1954.

As a first step a number of studies were made comparing the smoking habits of lung cancer patients with the smoking habits of individuals free of the disease. The results confirmed the 1936 observation of Ochsner and De Bakey. In every such study a far larger percentage of cigarette smokers was found in the lung cancer group than in the control group. Indeed, virtually all patients with epidermoid or undifferentiated carcinoma of the bronchial tubes admitted to smoking. There appeared to be less association, if there was any at all, between smoking habits and adenocarcinoma of the lung.

Cancer was not the only disease studied in relation to smoking habits. Knowing the acute effects of nicotine on the circulatory system, many physicians believed that smoking might be bad for patients with heart disease. In fact, a study made at the Mayo Clinic in 1940 by John P. English, Fredrick A. Willius and Joseph Berkson had indicated a considerable degree of association between smoking habits and coronary artery disease. Furthermore, many doctors were under the impression that smoking had a bad effect on patients with gastric and duodenal ulcers.

A number of investigators, myself among them, were uncertain as to the validity of these "clinical impressions" and "retrospective studies." A useful way to minimize bias and other difficulties in looking for an association between a disease and its possible causes is to employ the "prospective," or "follow up," method of investigation. The method consists of questioning a large number of presumably healthy individuals, keeping in touch with them for a number of years and finally ascertaining whether or not deaths in later years are associated with habits reported by the subjects before they became ill.

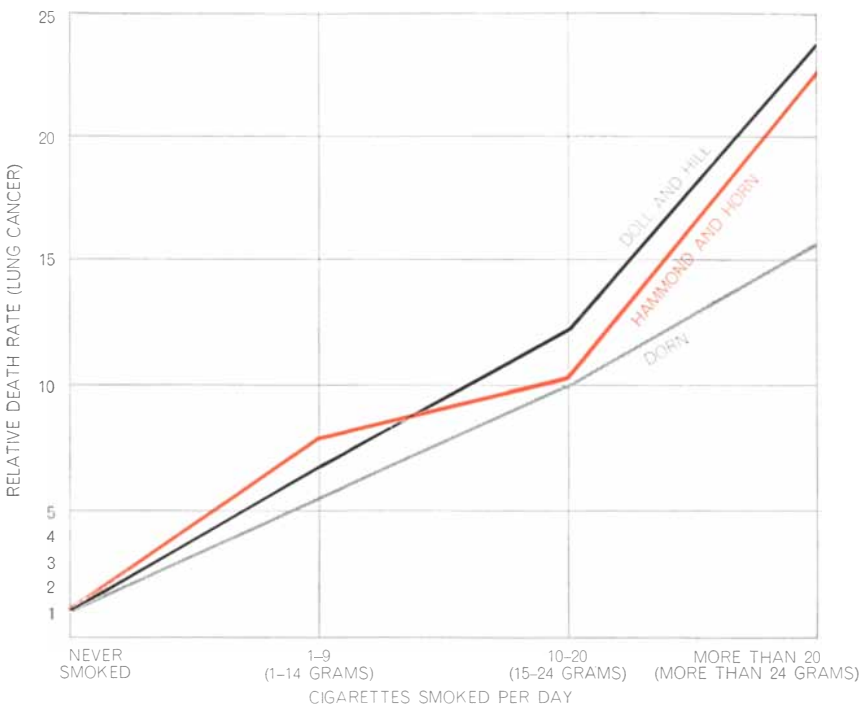
Two such prospective studies were undertaken in the fall of 1951, one in Britain by W. Richard Doll and A. Bradford Hill and the other in the U.S. by Daniel Horn and me. Under the auspices of the British Medical Research Council, Doll and Hill initiated their investigation by mailing questionnaires on smoking habits to all British physicians. They obtained information on all deaths among British physicians by checking death certificates. Their study is still in progress. Several years later similar investigations were undertaken by Harold F. Dorn, who studied U.S. veterans holding life insurance; by E. W. R. Best, G. H. Josie and C. B. Walker, who are studying Canadian veterans and pensioners; and by John Edward Dunn, Jr., George Linden and Lester Breslow, who are studying men employed in certain occupations in California. In 1959 I started a new and more extensive prospective study in which smoking is included as only one of many factors under investigation.

The findings in all these investigations are remarkably similar; indeed, they are as close as could possibly be expected considering that the subjects were drawn from different populations and were of different ages. In the interest of brevity, therefore, I shall present data only from two studies with which I am personally concerned. The first of these was carried out as follows.

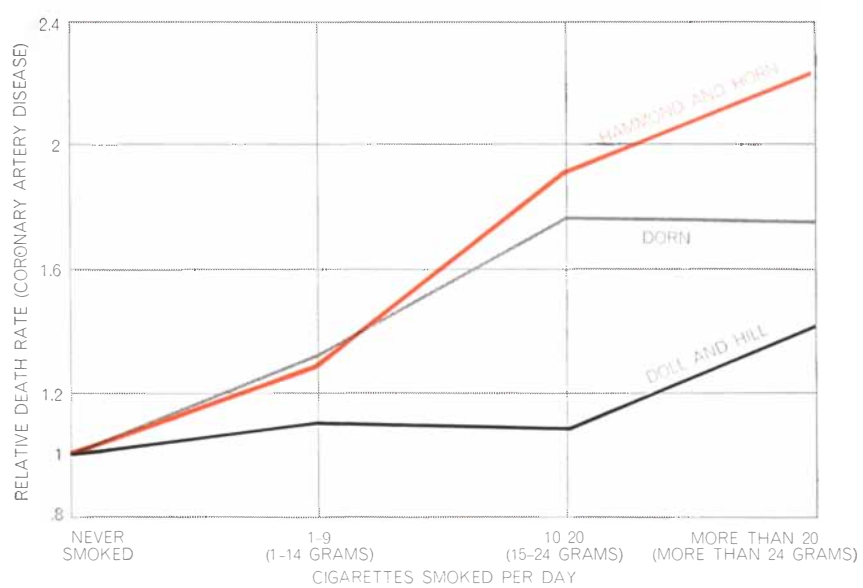
After designing and pretesting a questionnaire in the fall of 1951, we trained more than 22,000 American Cancer Society volunteers as researchers for the study. Between January 1 and May 31 of 1952 they enrolled subjects in 394 counties in nine states. The subjects,

all men between the ages of 50 and 69, answered a simple confidential questionnaire on their smoking habits, both past and present. A total of 187,783 men were enrolled, filled out usable questionnaires and were successfully kept track of for the next 44 months. Death certificates were obtained for all who died, and additional medical information was gathered for those who were reported to have died of cancer. All together 11,870 deaths were reported, of which 2,249 were attributed to cancer.

The most important finding was that the total death rate (from all causes of death combined) is far higher among men with a history of regular cigarette smoking than among men who never smoked, but only slightly higher among pipe and cigar smokers than among men who never smoked. This is illustrated in the first of the series of charts on pages 44, 45 and 46. The death rates have been adjusted for age, and for ease of comparison the death rate of men who never smoked has been set at one.



LUNG CANCER as a cause of death increases with the number of cigarettes (or gram equivalent) consumed per day, according to three major studies cited in the text. "Relative death rate" is the death rate among smokers divided by the death rate found among nonsmokers.



CORONARY ARTERY DISEASE as a cause of death also increases with the cigarettes smoked per day. The relative death rates are lower than for lung cancer because coronary artery disease is the leading cause of death among nonsmokers as well as among smokers.

Men who had smoked cigarettes regularly and exclusively were classified according to their cigarette consumption at the time they were enrolled in the study. It was found that death rates rose progressively with increasing number of cigarettes smoked per day, as shown in the second chart in the series. The death rate of those who smoked two or more packs of cigarettes a day was approximately two and a quarter times higher than the death rate of men who never smoked.

Being a heavy cigarette smoker myself at the time, I was curious to know the death rate of ex-cigarette smokers. This is shown in the third chart in the series. The death rate of men who had given up cigarette smoking a year or more prior to enrollment was considerably lower than that of men who were still smoking cigarettes when they were enrolled in the study.

Next we analyzed the data in relation to cause of death as reported on death certificates. Such information is subject to error, but on checking medical records we found that the diagnosis of cancer had been confirmed by microscopic examination of tissue in 79 per cent of the deaths ascribed to this disease. Even in some of these cases, however, the site of origin of the cancer was unknown or open to question. This is because cancer, unless successfully treated at an early stage, spreads through the body and its source is often difficult to determine. There is another difficulty that has to do with other causes of death. People in the older age groups not infrequently suffer from two or more diseases, one or another of which could be fatal. Since death can result from the combined effects of these diseases, it is difficult, and perhaps illogical, to ascribe death to one alone. These difficulties should be kept in mind in evaluating the following findings.

During the course of the study 7,316 deaths occurred among subjects with a history of regular cigarette smoking (some of whom smoked pipes and/or cigars as well as cigarettes). We divided these deaths according to primary cause as reported on death certificates. This is shown in the table on the opposite page under the heading "Observed deaths." Only 4,651 of these cigarette smokers would have died during the course of the study if their death rates had exactly matched those of men of the same age who had never smoked. This is shown in

the table under the heading "Expected deaths." The difference of 2,665 deaths (7,316 minus 4,651) can be considered the "Excess deaths" associated with a history of regular cigarette smoking. Of these excess deaths 52.1 per cent were attributed to coronary artery disease of the heart, 13.5 per cent to lung cancer and the remainder to other diseases. From this it is apparent that as a cause of death coronary artery disease is by far the most important disease associated with cigarette smoking.

From the standpoint of attempting to determine causal relations, it is best to study the figures in the table under the heading "Relative death rate." This is the observed number of deaths divided by the expected number of deaths, which in essence is the death rate of cigarette smokers divided by the death rate of subjects who never smoked.

Since coronary artery disease is the leading cause of death among men in the U.S. today, it is not surprising that we found it to be the leading cause of death among nonsmokers as well as among cigarette smokers. But the rate was 70 per cent higher among cigarette smokers. As shown in the fourth chart in the series on the next three pages, the death rate attributed to coronary artery disease increased progressively with the amount of cigarette smoking. We also found that ex-cigarette smokers had a lower death rate from this disease than did men who were still smoking cigarettes at the start of the study.

Lung cancer is an extremely rare cause of death among nonsmokers, except for those who have had prolonged and heavy occupational exposure to certain dusts and fumes. Taking death-certificate diagnosis at face value, the lung cancer death rate was more than 10 times higher among cigarette smokers than among nonsmokers. On obtaining medical records we found that, of 448 deaths attributed to this cause, the diagnosis of bronchogenic carcinoma was established by microscopic examination in addition to other evidence in 327 cases, of which 32 were adenocarcinoma. The fifth chart in the series shows age-standardized death rates by amount of cigarette smoking based on the 295 deaths from well-verified cases of bronchogenic carcinoma other than adenocarcinoma. The rate was very low for men who had never smoked, it increased with the amount of cigarette smoking, and it was very high for men who smoked two or more packs of cigarettes a day. When standardized both for age and for the amount of smoking, the rate for ex-cigarette smokers who had given up the habit for a year or more was considerably lower than the rate for men who were smoking cigarettes regularly at the start of the study. The lung cancer death rate of cigar and pipe smokers was very low compared with that of cigarette smokers, although higher than the rate for nonsmokers.

All together 127 deaths were attributed to cancer of other tissues (mouth, tongue, lip, larynx, pharynx and esophagus) that are directly exposed to tobacco smoke and material condensed from tobacco smoke. In 114 of these cases the diagnosis was confirmed by microscopic examination. Of these 114 men, 110 were smokers and only four had never smoked. The figures suggest that pipe and cigar smoking may be more important than cigarette smoking in relation to cancer of one or more sites included in this group, but the number of cases was not sufficient for a reliable evaluation of this point. Nevertheless, these cancers were the only causes of death for which the death rate of pipe and cigar smokers was found to be far higher than the death rate of nonsmokers.

Other reported causes of death showing a fairly high degree of association with cigarette smoking were gastric and duodenal ulcers, certain diseases of the arteries, pulmonary diseases (including pneumonia and influenza), cancer of the bladder and cirrhosis of the liver. Many other diseases appeared to be somewhat associated with cigarette smoking.

In 1959 I started a new study considerably larger than the first one. By securing the services of some 68,000 volunteer workers of the American Cancer Society in 1,121 counties in 25 states, we enrolled as subjects 1,079,000 men and women over the age of 30. Each of them filled out a lengthy confidential questionnaire including questions on family history, diseases and physical complaints, diet, smoking and other habits, residence history, occupational exposures and many other factors not included in previous studies. We plan to follow these subjects for six years. So far follow-up information is available only for the first 10½ months of observation.

The early findings on smoking are in close agreement with findings in all previous studies. In this study smokers were asked the degree to which they inhaled the smoke. It was found that, in relation to total death rates, the degree of inhalation is as important, and perhaps more important, than the amount of smoking [*see illustration on page 47*].

The new study has also revealed a high degree of association between cigarette smoking and a number of physical complaints, most particularly coughing, shortness of breath, loss of appetite and loss of weight [*see illustration on page 49*]. These complaints were related to the degree of inhalation as well as to the amount of smoking. They were reported less frequently by cigar and pipe smokers (most of whom do not inhale) than by cigarette smokers (most of whom

CAUSE OF DEATH	OBSERVED DEATHS	EXPECTED DEATHS	EXCESS DEATHS	PERCENTAGE OF EXCESS	RELATIVE DEATH RATE
TOTAL DEATHS (ALL CAUSES)	7,316	4,651	2,665	100.0	1.57
CORONARY ARTERY DISEASE	3,361	1,973	1,388	52.1	1.70
OTHER HEART DISEASES	503	425	78	2.9	1.18
CEREBRAL VASCULAR LESIONS	556	428	128	4.8	1.30
ANEURYSM AND BUERGER'S DISEASE	86	29	57	2.1	2.97
OTHER CIRCULATORY DISEASES	87	68	19	0.7	1.28
LUNG CANCER	397	37	360	13.5	10.73
CANCER OF THE BUCCAL CAVITY, LARYNX OR ESOPHAGUS	91	18	73	2.7	5.06
CANCER OF THE BLADDER	70	35	35	1.3	2.00
OTHER CANCERS	902	651	251	9.4	1.39
GASTRIC AND DUODENAL ULCER	100	25	75	2.8	4.00
CIRRHOSIS OF THE LIVER	83	43	40	1.5	1.93
PULMONARY DISEASE (EXCEPT CANCER)	231	81	150	5.6	2.85
ALL OTHER DISEASES	486	453	33	1.2	1.07
ACCIDENT, VIOLENCE, SUICIDE	363	385	−22	−0.8	0.94

DEATHS AMONG REGULAR CIGARETTE SMOKERS, labeled "Observed deaths," are compared with the number of deaths "expected" if the death rates for each age group among smokers had been the same as those found among nonsmokers. The table summarizes the results of the study conducted by the author and Daniel Horn. The column "Excess deaths" can be considered as the excess number of deaths associated with cigarette smoking. "Relative death rate" is the observed number of deaths divided by the expected number.

inhale either moderately or deeply).

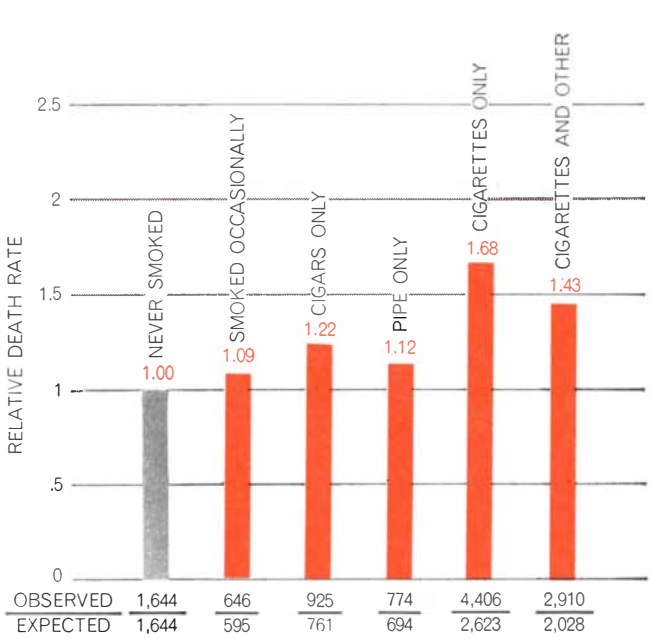
Two prospective studies of smoking in relation to the occurrence of coronary artery disease have been carried out in Framingham, Mass., and Albany, N.Y. The combined findings from these studies were published on April 19 in *The New England Journal of Medicine* by Joseph T. Doyle, Thomas R. Dawber, William B. Kannel, A. Sandra Heslin and Harold A. Kahn. On enrollment in these studies each subject was given a medical examination. No symptoms of coronary artery disease were initially found in 4,120 men. These men were reexamined from time to time for a number of years. Symptoms of coronary artery disease (as well as death from this disease) were found far more frequently among those who smoked cigarettes regularly than among those who did not smoke. The total death rate was more than twice as high among men who smoked more than 20 cigarettes a day as among men who had never smoked. Ex-smokers and cigar and pipe smokers had morbidity and mortality records similar to the records of those who had never smoked. Thus the findings in this study based on medical examination of subjects were in close agreement with findings in the other U.S. studies.

Although all the studies have shown essentially the same results, there are some interesting differences between the results in Britain and the U.S. Lung cancer death rates are about twice as high in Britain as they are in the U.S.; chronic bronchitis is reported to be a common cause of death by British physicians but is seldom mentioned as a cause of death in the U.S.; death rates from coronary artery disease (as reported on death certificates) are far lower in Britain than they are in the U.S. No one really knows the reasons for these differences. Speculations on the subject may be briefly summarized as follows.

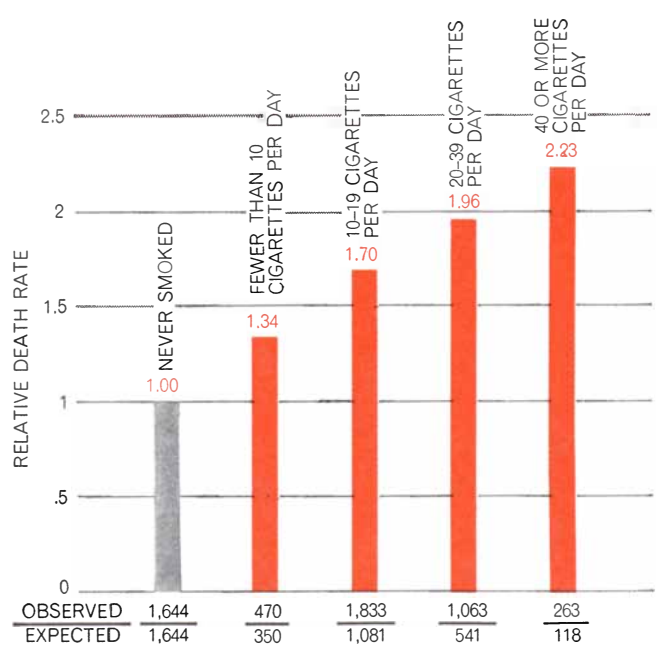
Climate, the method of heating houses, exposure to air pollutants and occupational exposure to dusts and fumes have all been suggested as possible reasons why both lung cancer and chronic bronchitis appear to occur more frequently in Britain than in this country. Differences in smoking habits have also been suggested as a possible factor. Doll and Hill have studied the length of discarded cigarette butts in England and Wales, and Ernest L. Wynder of the Sloan-Kettering Institute for Cancer Research and I have made similar studies on this side of the Atlantic. The average length of the butts was found to be 18.7 millimeters in England and Wales (where cigarettes are quite expensive), compared with 27.9 mm. in Canada and 30.9 mm. in the U.S. Therefore British smokers consume more of each cigarette and so receive a higher amount of nicotine and tobacco tar than Canadian and U.S. smokers do.

Diet has been suggested as a possible reason why death rates from coronary artery disease appear to be higher in the U.S. than they are in Britain. This apparent difference may be at least partly due to difference in diagnosis of the cause of death. Death can result from the combined effects of heart disease and lung ailments, particularly in older people. In the case of heart failure in a person suffering from a lung disease it is sometimes difficult to decide which to record as the principal cause of death. Thus the apparent high death rate reported as due to chronic bronchitis in Britain may be related to the comparatively low death rate reported as due to coronary artery disease in that country. Be that as it may, the Doll and Hill study showed less of a relation between smoking and coronary artery disease than did our U.S. study [*see lower illustration on page 42*]. On the other hand, Doll and Hill found a very high relation between smoking and death from chronic bronchitis.

In recent years considerable attention has been given to the chemical composition of tobacco smoke. A great many compounds have been identified, most of which are present in very small amounts. Some are distilled out of the tobacco and others are products of combustion. Included are numerous poisons (such as nicotine), various agents that are highly irritating to mammalian tissues, several carcinogenic (cancer-



DEATH RATE FROM ALL CAUSES in Hammond and Horn study was far higher among cigarette smokers than among men who never smoked, but only slightly higher among pipe and cigar smokers.



DAILY CIGARETTE CONSUMPTION showed a direct correlation with relative death rate from all causes. The study followed 187,783 men between the ages of 50 and 69 for 44 months.

producing) compounds and some co-carcinogenic compounds (materials that increase the potency of carcinogens). Most of this material is suspended in small particles, which together with carbon monoxide, air and other gases constitute tobacco smoke.

Ernest Wynder and his various collaborators have shown that tobacco-smoke condensate, or "tar," produces cancer in mice and rabbits if applied repeatedly to the skin over a long period of time. A number of investigators have confirmed these findings. The cancers so produced in rodents are of a type known as epidermoid carcinoma. (A synonym is squamous cell carcinoma, because the cells tend to be flattened, or squamous.) Different strains of animals vary in susceptibility, some being highly susceptible and others highly resistant.

Many investigators who have tried to produce lung cancer in rodents by exposing them to tobacco smoke have not succeeded in doing so. This may be because of two serious difficulties. Whereas a human smoker takes in smoke through his mouth, mice and other small rodents breathe through their noses, and in rodents this organ has developed into a remarkably efficient filter for preventing particulate matter from being drawn into the lung. Moreover, mice are sensitive to the acute toxic effects of tobacco smoke.

Several years ago I exposed mice to cigarette smoke under such conditions that they were forced to breathe smoke of approximately the same concentration as that of smoke taken in by human cigarette smokers. Unfortunately many of my animals went into convulsions and died within a few minutes. The remaining animals lived only a short time. By reducing the concentration of smoke the animals can be kept alive, but under such conditions it is doubtful whether or not their lungs are any more heavily exposed to the particulate matter of cigarette smoke than are the lungs of a nonsmoker sitting in a small room with several heavy smokers.

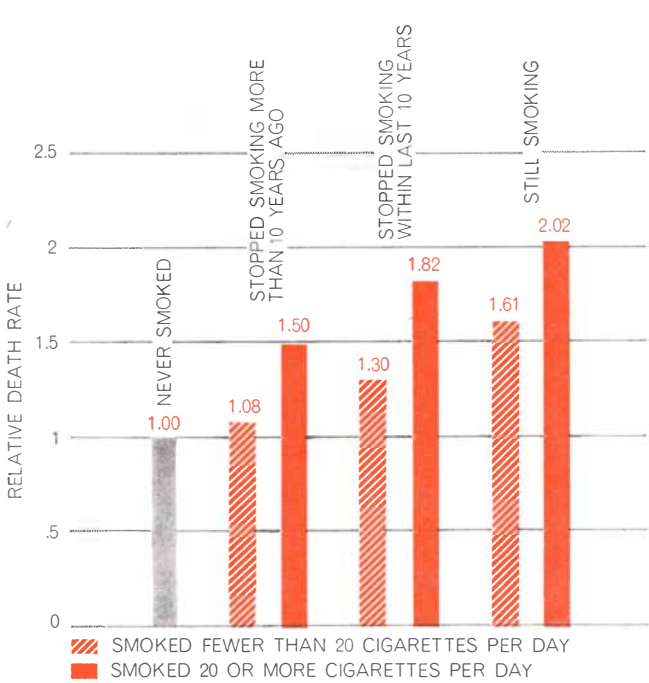
Nevertheless, by subjecting mice to tolerable concentrations of tobacco smoke Cecilie and Rudolph Leuchtenberger and Paul F. Doolon of the Children's Cancer Research Foundation in Boston have succeeded in producing various changes in the lining of the bronchial tubes of mice. These changes are similar to changes found in the bronchial tubes of human cigarette smokers. So far no cancers have been produced in mice thereby. This is consistent with the finding that lung cancer rarely occurs in human beings who are only slightly exposed to tobacco smoke.

During smoking the tissues first exposed to tobacco smoke are the lips, the tongue and the mucous membrane of the mouth. Some of the components of tobacco smoke (including known carcinogens) fluoresce under ultraviolet light. Robert C. Mellors of the Cornell University Medical College has shown that this material penetrates the cells of the lining of the mouth. The type of cancer that arises in this tissue is epidermoid carcinoma—the same type of cancer that is produced when tobacco tar is applied to the skin of experimental animals. Furthermore, the amount of tar required to produce epidermoid carcinoma of the skin in mice is roughly comparable to the exposure of a heavy smoker who develops epidermoid carcinoma of the lip or mouth.

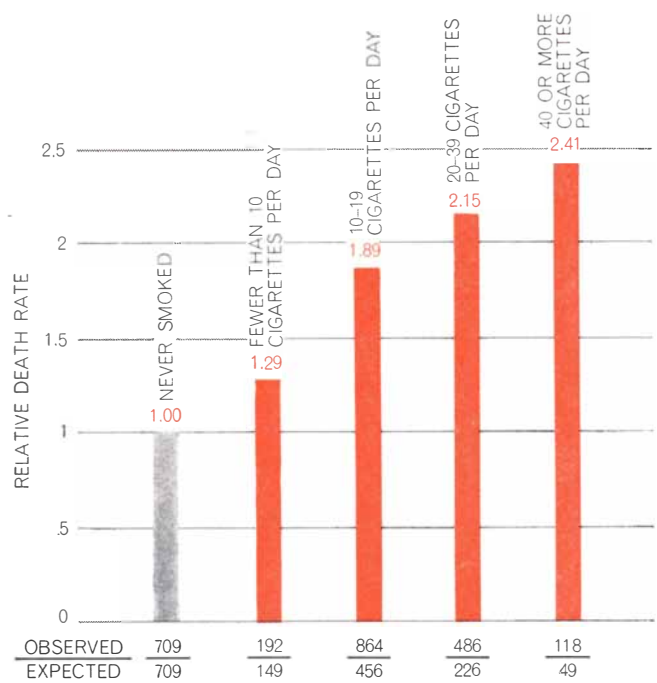
In study after study a high degree of association has been found between smoking of all types (as well as the chewing of tobacco) and the occurrence of cancer of these tissues. It is hard to escape the conclusion that this association reflects a direct causal relation. This does not preclude the possibility that other factors (such as host susceptibility or exposure to other carcinogenic materials) are involved in at least some cases.

What has just been said of smoking in relation to cancer of the lips, mouth and tongue also applies to cancer of the pharynx and cancer of the larynx. The situation is slightly different in cancer of the esophagus; this passageway is exposed to ingested tobacco-smoke condensate but not directly to the smoke. The strong association between smoking and epidermoid carcinoma of the esophagus, however, would seem to point to the same conclusion.

When inhaled, tobacco smoke travels



FORMER SMOKERS had a lower relative death rate than those still smoking, particularly if they had smoked fewer than 20 cigarettes a day and had stopped smoking for at least 10 years.



CORONARY ARTERY DISEASE, which accounted for 52.1 per cent of excess deaths among regular smokers of cigarettes, was also correlated very closely with the smoker's daily cigarette consumption.

down the trachea to the bronchial tubes of the lungs. All but a few cases of lung cancer originate in the lining, or epithelium, of these tubes. This is remarkable tissue, well worth describing here. Normally it consists of just two layers of cells that rest on a thin mat of tiny fibers called the basement membrane. This membrane separates the epithelium from the underlying tissue. Directly on top of the basement membrane is a layer of small, round cells with relatively small nuclei. They are called basal cells. On top of the basal cells is a single layer of cells known as columnar cells (because from the side they look like columns) interspersed with a few goblet cells (which look like little wine goblets). The goblet cells secrete a sticky fluid onto the surface. This is augmented by fluid secreted by glands located below the basement membrane. Protruding from the top of the columnar cells are short, hairlike cilia, which constantly move in a whiplike manner. This causes fluid on the epithelium to move up through the bronchial tubes and the trachea into the mouth, where it is either swallowed or expectorated.

The cilia and the fluid perform an extremely important function in cleansing the lungs. Small particles of dust or smoke that settle on the surface of the bronchial tubes are trapped in the fluid and, together with the fluid, are moved up and out of the lungs.

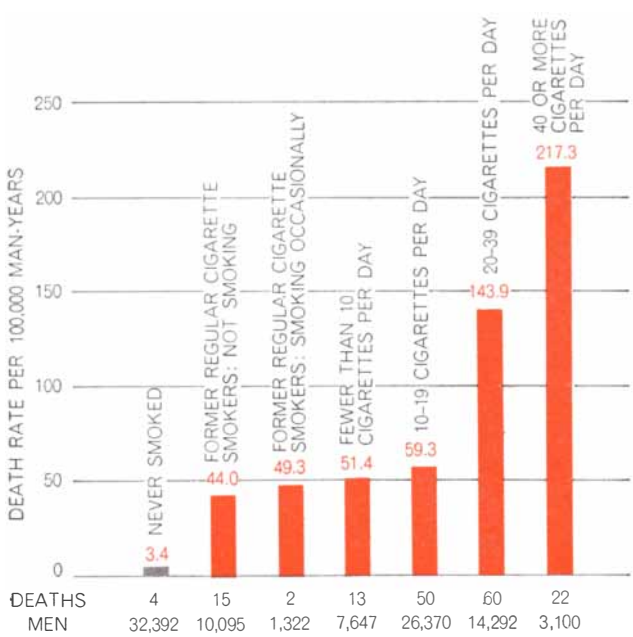
It has been shown by Anderson C. Hilding of St. Luke's Hospital in Duluth, Minn., by Paul Kotin of the University of Southern California School of Medicine and by others that tobacco smoke inhibits the movement of the cilia to such a degree that the flow of fluid is slowed down, if not stopped altogether. This allows an accumulation of tobacco-smoke products and whatever other material happens to fall on the lining of the bronchial tubes. Smokers and nonsmokers alike—particularly those living in cities with polluted air and those engaged in certain occupations—inhale dust of various types, and some of the dusts contain carcinogenic substances.

For a number of years I have been cooperating in an extensive study of human lung tissue with Oscar Auerbach, a pathologist at the Veterans Administration Hospital in East Orange, N.J., and with Arthur Purdy Stout of the Columbia University College of Physicians and Surgeons. Some of our findings can be summarized as follows.

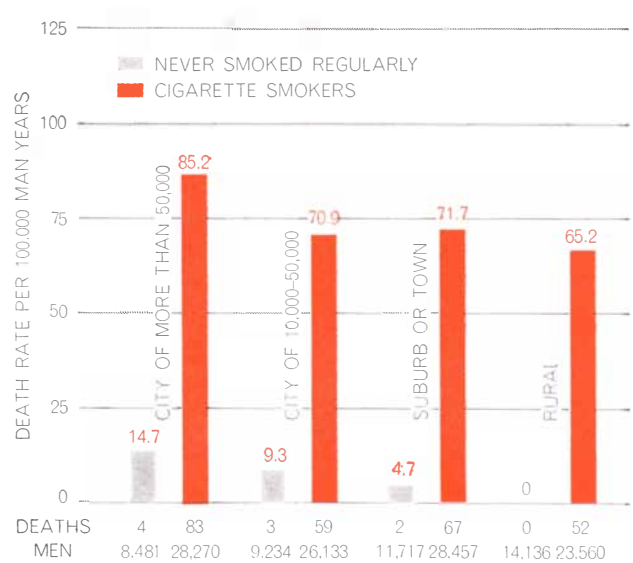
At the East Orange Veterans Hospital and at a number of hospitals in upstate New York the lungs are routinely removed at autopsy. The trachea and bronchial tubes are dissected out of the lungs and systematically divided into 208 portions, each of which is embedded in paraffin. A thin section of tissue is cut from each of these portions, mounted on a glass slide and stained with a suitable dye for microscopic examination. Independently, under the supervision of Lawrence Garfinkel of my staff, an interviewer is sent to the home of each patient to obtain information on his or her occupational history, residence history and smoking habits. We do not include a case unless this information can be obtained. All told we have studied tissue from the bronchial tubes of more than 1,000 individuals.

In each of our studies microscope slides from a number of different patients have been put in completely random order by the use of a table of random numbers. They are then labeled with a serial number that gives no clue to their identity. All the slides are studied microscopically by Auerbach and samples of them are checked by Stout. After the slides are examined, the serial numbers are decoded so that the microscopic findings can be analyzed in relation to other information about the subjects.

Three major types of change occur in bronchial epithelium: hyperplasia (an increase in the number of layers of cells), loss of ciliated columnar cells and changes in the nuclei of cells [*see illustration on page 50*]. Hyperplasia is the usual reaction of surface tissues to almost any type of irritation, either chemical or mechanical. A familiar example is the formation of calluses on the hands. We found some degree of hyperplasia in 10 to 18 per cent of slides from nonsmokers, in more than 80 per cent of slides from light cigarette smokers and in more than 95 per cent of slides from heavy cigarette smokers. Extensive hyperplasia (defined as five or more layers of cells between the basement mem-



LUNG CANCER DEATH RATES, age-standardized and based on well-established cases exclusive of adenocarcinoma, rose sharply for men smoking more than a pack a day in the Hammond and Horn study. But the death rate among former smokers was much lower.



NONSMOKERS IN THE CITY sometimes die of lung cancer, but the death rate was only a fraction of that found among cigarette smokers who lived in the country. The death rates are based on well-established cases of lung cancer, exclusive of adenocarcinoma.

brane and the columnar cells) was frequently found in heavy cigarette smokers but rarely in other subjects.

Loss of ciliated columnar cells was observed in nonsmokers but far more frequently in cigarette smokers, and the frequency of this observation increased with the amount of cigarette smoking. The implication is that foreign material tends not to be removed, and thus can accumulate where the cilia have been destroyed.

An important finding was the occurrence of cells with atypical nuclei. The nuclei of cancer cells are usually large, irregular in shape and characteristically have many more than the normal number of chromosomes. A few cells with nuclei that have such an appearance are occasionally found in the bronchial epithelium of men and women who have never smoked. Presumably they result from somatic mutation or some similar process. In nonsmokers the frequency of such cells does not increase with age.

Large numbers of cells with atypical nuclei of this kind were found in slides from cigarette smokers, and the number increased greatly with the amount of smoking. In heavy cigarette smokers we found many lesions composed entirely of cells with atypical nuclei and lacking cilia. Fewer such lesions were found in light cigarette smokers and none were found in nonsmokers. Among heavy cigarette smokers the number of cells with atypical nuclei increased markedly with advancing age.

In our latest study of bronchial epithelium we matched 72 ex-cigarette smokers, 72 men who had smoked cigarettes regularly up to the time of their terminal illness and 72 men who had never smoked. None of the men had died of lung cancer. Within each of the 72 triads, the three men were the same age, had similar employment histories and similar residence histories. Somewhat more changes were found in slides from ex-cigarette smokers than in slides from men who had never smoked. The important finding, however, was that the cellular changes, particularly the occurrence of cells with atypical nuclei, were fairly rare in ex-cigarette smokers compared with men who had smoked up to the time of their terminal illness. The study indicated that the number of cells with atypical nuclei declines when a cigarette smoker gives up the habit. This probably occurs slowly over a period of years.

The location of lesions is also significant and correlates with an observation one can make by passing cigarette smoke through glass tubing. Some years ago I found that when smoke was passed through a tube with a Y-shaped bifurcation, more tar precipitated where the tube branched than elsewhere. Acting on this lead, we have studied changes in bronchial epithelium in relation to bifurcations. There are numerous such points in the bronchial tree, because the tubes divide and redivide into smaller and smaller tubes. We found that lesions composed entirely of cells with atypical nuclei occur far more frequently at bifurcations than elsewhere.

In order to determine the significance of these changes we studied the bronchial epithelium of men who had died of bronchogenic carcinoma. Carcinoma is defined as a tumor, composed of cells with atypical nuclei, that originated in the epithelium and has penetrated the basement membrane and "invaded" the underlying tissue. Once such an invasion has occurred, the tumor grows—often to considerable size—and spreads to many parts of the body. In men who had died of lung cancer we found large numbers of cells with atypical nuclei, as well as many lesions composed entirely of such cells, scattered throughout the epithelium of the bronchial tubes of both lungs. In a few instances we found tiny independent carcinomas in which the tumor cells had broken through the basement membrane at just one small spot. These carcinomas looked exactly like many of the other lesions composed entirely of cells with atypical nuclei, except that in the other lesions we did not find any cells that had broken through the basement membrane. We are of the opinion that many, if not all, of the lesions composed entirely of atypical cells represent an early, preinvasive stage of carcinoma. This is a well-known occurrence in the cervix of the uteri of women and is called carcinoma *in situ*.

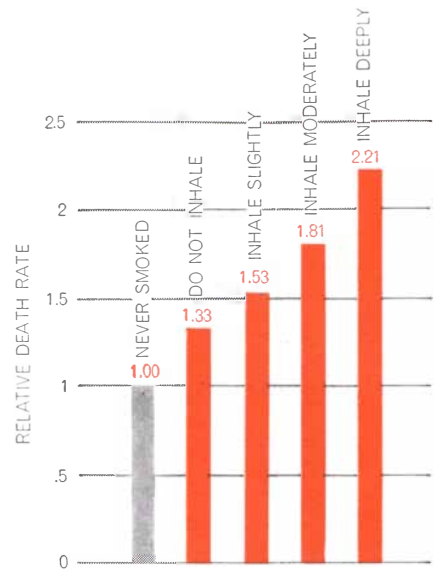
Judging from experimental evidence as well as from our findings in human beings, we are of the opinion that carcinoma of bronchial epithelium originates with a change in the nuclei of a few cells; that by cell division the number of such cells gradually increases; that finally lesions composed entirely of atypical cells are formed; and that occasionally cells in such a lesion penetrate the basement membrane, producing the disease known as carcinoma. Apparently the process is reversible up to the time the cells with atypical nuclei break through the basement membrane.

Where does the inhalation of tobacco smoke fit into this picture? There appear to be three possibilities:

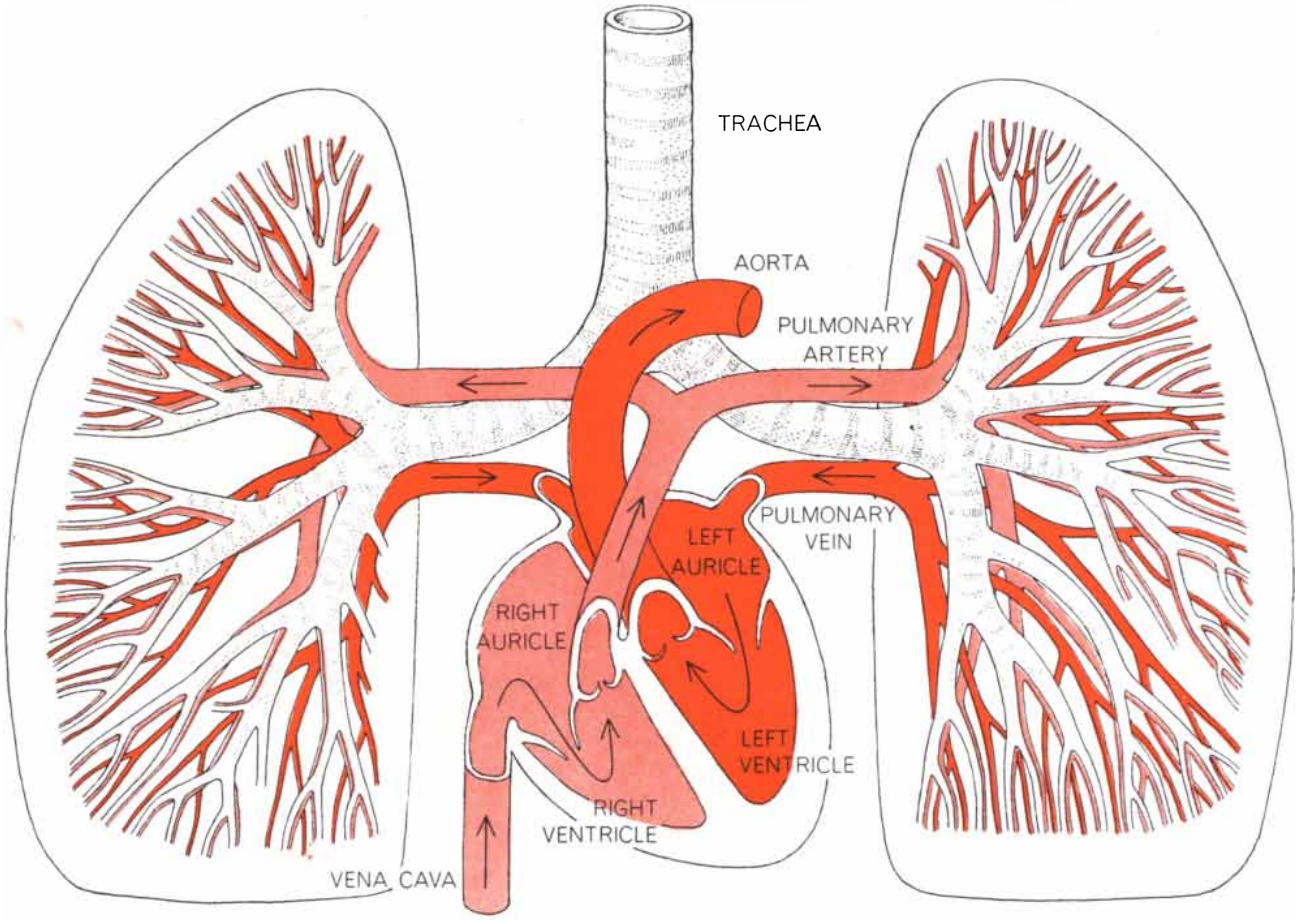
1. It may be that exposure to tobacco smoke induces changes in the nuclei of cells. This would account for the increase of such cells both with the amount of smoking and with the number of years of smoking. It would not, however, in itself account for the finding of a decrease in the number of such cells when a cigarette smoker gives up the habit.

2. It may be that exposure to tobacco smoke simply increases the probability of changes taking place in the nuclei of cells as a result of exposure to inhaled carcinogenic agents other than those in tobacco smoke. The inhibition of ciliary movement by tobacco smoke may be the major factor involved in such a relation. Again this would not in itself account for the decrease in cells with atypical nuclei following cessation of cigarette smoking.

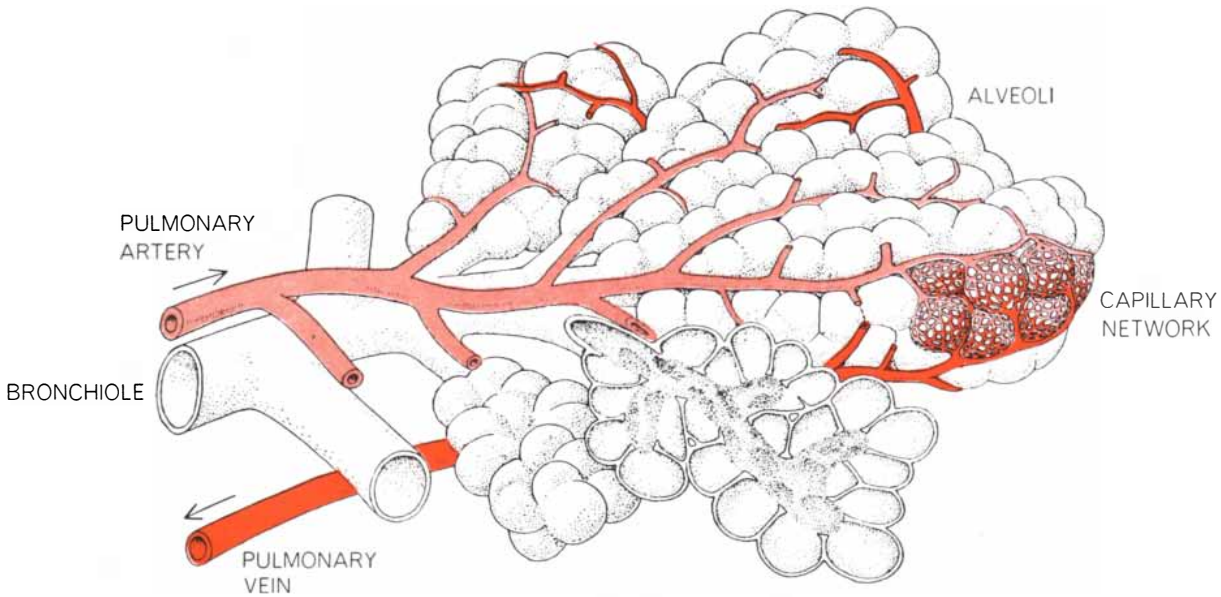
3. It may be that exposure to tobacco smoke produces a change in the local environment of bronchial epithelium so as to favor the survival and reproduction of certain mutant cells that have atypical nuclei of the type observed, as opposed to the survival and reproduction of normal cells. On this hypothesis the development of cancer results from natural selection under conditions of greatly altered environment. It is unnecessary to assume that tobacco smoke causes mutations, since a few cells with atypical nuclei are sometimes found in the bronchial epithelium of nonsmokers. This hypothesis suggests that normal cells are best adapted to an environment free of tobacco smoke, whereas cells with atypical nuclei are best adapted to an environment that includes smoke. The hypothesis thus accounts for the decline in the number of cells with atypical nu-



DEGREE OF INHALATION among cigarette smokers is charted against relative death rates from all causes. Rates are based on the author's new study of 1,079,000 men and women, which was begun in 1959.



HEART AND LUNGS are both affected by inhaled tobacco smoke, which travels down the trachea, through the bronchial tubes to the alveoli. "Tars" deposit on the epithelium and lead to clogging of alveoli. These and the capillaries are often ruptured by coughing. The heart must then pump blood through a smaller number of capillaries, against increased pressure, on a reduced oxygen supply.



ALVEOLI of the lungs are air sacs formed by terminal expansion of the bronchioles. Oxygen is supplied to the blood through the capillaries embedded in the alveolar walls. Destruction of this tissue thus reduces the rate at which the lungs can take up oxygen.

clei on the cessation of cigarette smoking.

I favor the last of these three hypotheses. It appears to account for all the findings, whereas the other two hypotheses account for only some of them. The three hypotheses are not, however, mutually exclusive.

To account for the association between cigarette smoking and certain other diseases, such as lung infections and coronary artery disease, other plausible mechanisms exist. On inhalation, air and any smoke it may contain passes through bronchial tubes of decreasing diameter, which finally deliver it to the tiny sacs called alveoli. The alveoli have thin walls supported by fibers of connective tissue. These walls contain capillary tubes through which blood flows from the pulmonary arteries to the pulmonary veins. During its passage through these capillaries the blood releases carbon dioxide and absorbs oxygen. At the same time carbon monoxide, nicotine and other impurities that may be present in the air or smoke are absorbed into the blood.

The small bronchial tubes are subject to being plugged with mucus. This frequently occurs in infectious diseases of the lung, with the result that secretions and bacteria are trapped in the alveolar spaces, thereby producing pneumonia. In cigarette smokers the interior diameter of the small bronchial tubes is considerably reduced by hyperplasia, so that the opening is very small indeed. In addition we find that smoking results in increased activity of the glands that secrete mucus into the bronchial tubes. This combination almost certainly increases the likelihood of the tubes being plugged by mucus. In my opinion this is enough to explain the finding that death rates from infectious diseases of the lung are considerably higher among cigarette smokers than among nonsmokers.

The occlusion of a bronchial tube by mucus (or by a spasm) often traps air in the alveoli to which that tube leads. If the person then happens to cough, the pressure of the trapped air can be increased to such a degree that the thin walls of the alveoli rupture. Coughing, excess mucus and reduction in the diameter of the small bronchial tubes increase the likelihood of such rupture.

Recently we have studied the alveoli in relation to cigarette smoking. We found extensive rupturing of the walls of a great many alveoli in the lungs of heavy cigarette smokers, a considerable amount in lighter cigarette smokers and very little in nonsmokers. The rupturing of the walls is usually accompanied by a fibrous thickening of the remaining alveolar walls, together with a fibrous thickening of the walls of the small blood vessels in the vicinity. This probably results from the mechanism outlined above, since cigarette smoking produces coughing as well as hyperplasia of the bronchial tubes and increased secretion of mucus.

Ruptures in the walls of the alveoli destroy the capillary tubes located in the walls. If many are destroyed, far greater pressure is required to force the same quantity of blood through the remaining capillaries. All the blood must pass through them each time it circulates through the body, and the right ventricle of the heart has to supply the pressure. As a result the work load of the heart is increased in proportion to the degree of destruction of the alveoli.

Since oxygen is supplied to the blood through the capillaries in the alveoli, destruction of this tissue reduces the oxygen supply on which all the tissues of the body depend. In smokers this is compounded by the inhalation of carbon monoxide, which combines with hemoglobin more readily than oxygen does. This combination is enough to account for the shortness of breath often reported by cigarette smokers.

Because of its great activity heart muscle requires an abundant supply of oxygen. The inhalation of tobacco smoke increases the work load of this muscle and at the same time reduces the quantity of oxygen available to the muscle. In addition the action of nicotine on the nervous system produces a temporary increase in the heart rate and a constriction of the peripheral blood vessels, which in turn produces a temporary increase in blood pressure. This also puts an added strain on the heart. Since a normal heart has extraordinary reserve powers, it can probably withstand these effects of smoking. A diseased heart may not be able to do so.

Autopsy studies (including a study of young men killed in the Korean war) have shown that the great majority of American men have at least some degree of atherosclerosis of the coronary arteries that supply blood to the muscle of the heart. Atherosclerosis consists of the progressive development of plaques (composed largely of cholesterol) within the walls of these relatively small blood vessels, which thereby reduces their interior diameter. This in turn reduces the supply of blood to the heart muscle. Eventually it may completely cut off the supply of blood to a portion of the heart muscle, and this portion dies. Moreover, blood clots often form in diseased coronary arteries. This can also shut off the blood and cause the death of heart tissues. The common symptom of a stoppage in coronary blood flow is a heart attack.

As described above, cigarette smoking decreases the quantity of oxygen per unit volume of blood. Atherosclerosis of the coronary arteries tends to reduce the volume of blood delivered to the heart muscle per minute. Therefore if a person with atherosclerosis of the coronary

COMPLAINT	CIGARETTE SMOKERS (PER CENT)	NONSMOKERS (PER CENT)	RATIO (SMOKERS TO NONSMOKERS)
COUGH	33.2	5.6	5.9
LOSS OF APPETITE	3.3	0.9	3.7
SHORTNESS OF BREATH	16.3	4.7	3.5
CHEST PAINS	7.0	3.7	1.9
DIARRHEA	3.3	1.7	1.9
EASILY FATIGUED	26.1	14.9	1.8
ABDOMINAL PAINS	6.7	3.8	1.8
HOARSENESS	4.8	2.6	1.8
LOSS OF WEIGHT	7.3	4.5	1.6
STOMACH PAINS	6.0	3.8	1.6
INSOMNIA	10.2	6.8	1.5
DIFFICULTY IN SWALLOWING	1.4	1.0	1.4

PHYSICAL COMPLAINTS are more frequent among people who smoke a pack of cigarettes or more a day than among nonsmokers. The figures are from the author's large new study.

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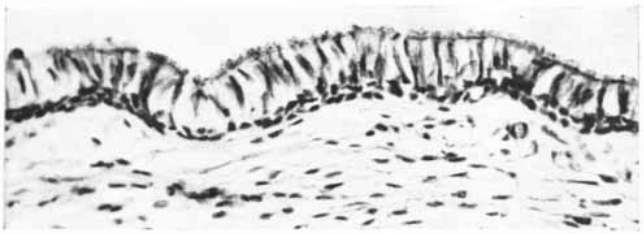

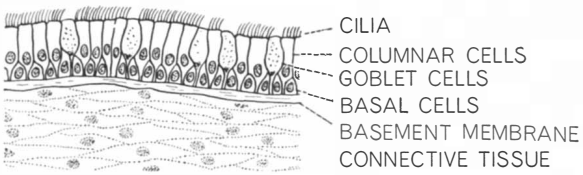

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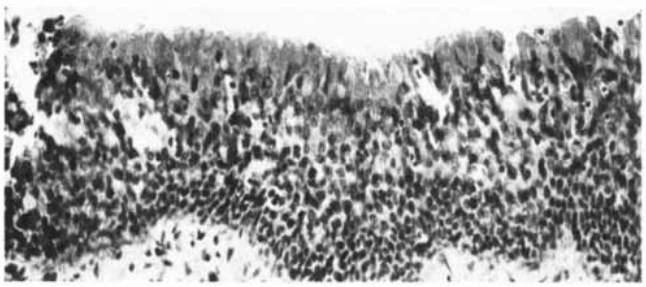

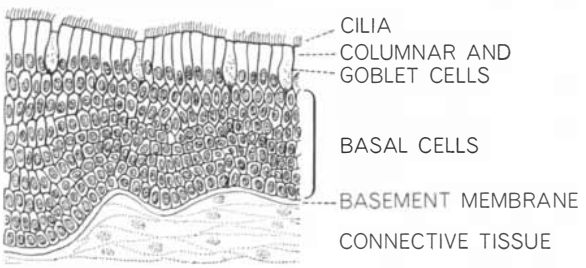

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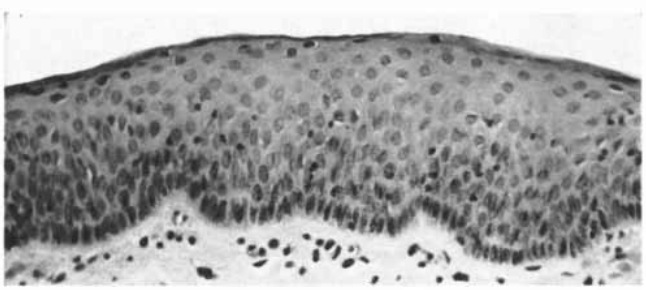

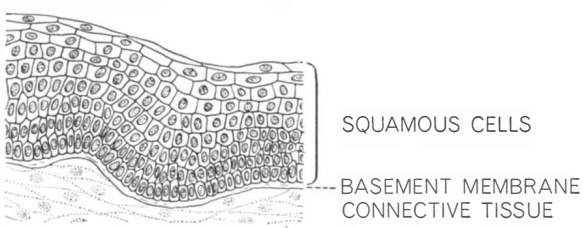

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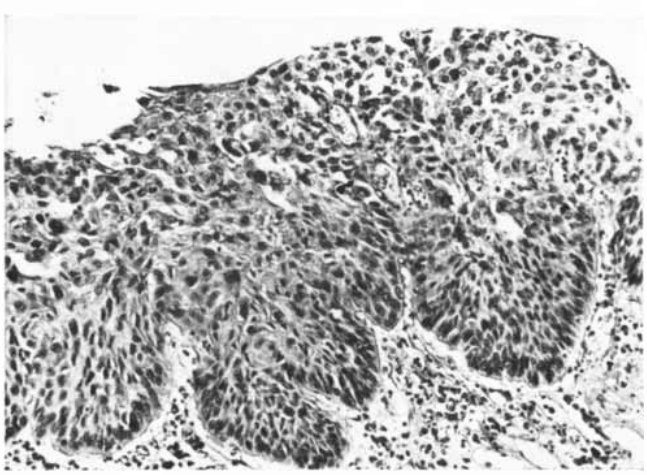

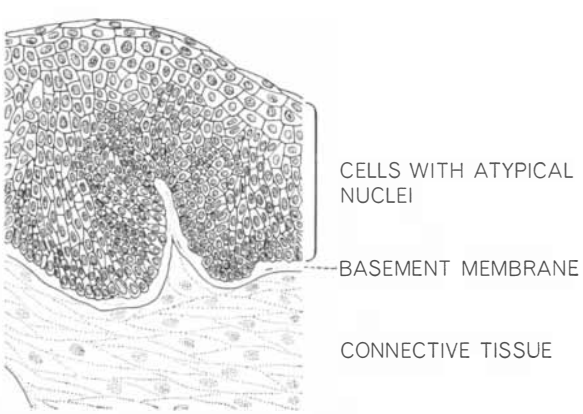

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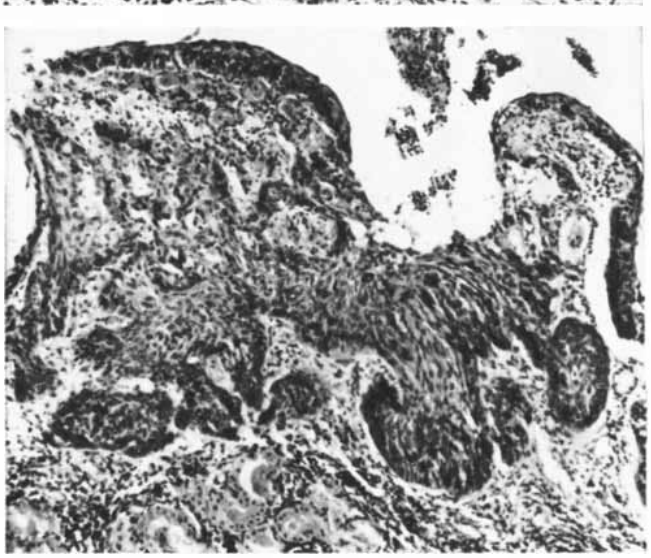
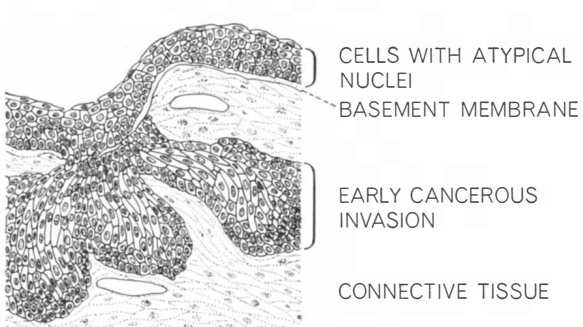




arteries is also a cigarette smoker, his heart muscle receives far less than the normal supply of oxygen per minute. At the same time, because of the effects of smoking, a heavy work load is placed on his heart muscle. In my opinion this combination of conditions is sufficient to account for the finding that the death rate from coronary artery disease is higher in cigarette smokers than it is in men who never smoked, that the rate increases with the amount of cigarette smoking, and that it is lower in ex-cigarette smokers than it is in men who continue to smoke cigarettes.

Not only the heart but also all other organs of the body require oxygen obtained through the alveoli of the lungs and distributed by the blood. Thus a reduction in oxygen supply resulting from smoking may have a serious effect on any diseased organ, and in some instances it can make the difference between life and death. Perhaps this accounts for the finding that death rates from a multiplicity of chronic diseases are slightly higher among cigarette smokers than among nonsmokers.

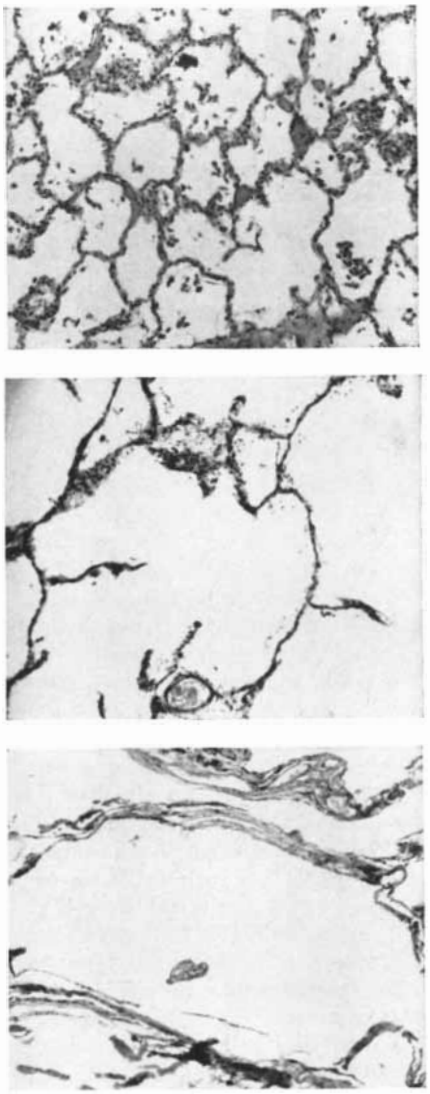
I shall touch only briefly on two other diseases that appear to be significantly associated with cigarette smoking: gastric and duodenal ulcers and cancer of the bladder. In our first study cigarette smokers, compared with nonsmokers, had four times the relative death rate from the two kinds of ulcer and twice the death rate from cancer of the bladder. Doll and his associates in England recently performed a controlled clinical experiment demonstrating that smoking is indeed harmful to patients with gastric ulcer. Eighty patients who were regular smokers were divided at random into two groups, one allowed to continue smoking, the other advised to stop. Among the 40 patients who continued to smoke, the ulcers healed at a significantly slower rate than they did among the 40 patients who cut down on their smoking or stopped altogether. The mechanism by which smoking evidently retards recovery is unknown. It may be due to indirect effects, such as the effect of nicotine in the bloodstream, or to direct action of ingested tobacco smoke on the lining of the stomach.

As for cancer of the bladder, it is well known that exposure to carcinogenic agents can produce cancer in parts of the body remote from the tissue to which the agent is applied. For example, prolonged exposure to beta-naphthylamine often produced cancer of the bladder in workers in aniline dye plants. Conceivably some agent in tobacco smoke works in the same way, but until the problem is thoroughly investigated judgment should be deferred.

After reviewing the evidence, the mildest statement I can make is that, in my opinion, the inhalation of tobacco smoke produces a number of very harmful effects and shortens the life span of human beings. The simplest way to avoid these possible consequences is not to smoke at all. But one can avoid the most serious of them by smoking cigars or a pipe instead of cigarettes, provided that one does not inhale the smoke. An individual who chooses to smoke cigarettes can minimize the risks by restricting his consumption and by not inhaling.

The individual solution to the problem apparently requires more will power than many cigarette smokers have or are inclined to exert. I am confident, however, that more generally acceptable solutions can be found. There is good reason to suppose that the composition of tobacco smoke, both qualitative and quantitative, is a matter of considerable importance. Until several years ago the mainstream smoke of most U.S. cigarettes contained about 35 milligrams of "tar" per cigarette, of which about 2.5 milligrams was nicotine. The smoke from filter-tip cigarettes now on the market ranges in tar content from as low as 5.7 milligrams per cigarette to nearly 30 milligrams and the nicotine content from .4 to 2.5 milligrams. It is apparent that by selection of tobacco and by means of an effective filter, the nicotine and tar content of cigarette smoke can be markedly reduced. Some filters are selective in their action. For example, Wynder and Dietrich Hoffmann have recently found that a certain type of filter, which passes a reasonable amount of smoke, removes almost all the phenols. This may be important, since the same investigators have reported that the phenols in cigarette smoke strongly inhibit the action of cilia in the bronchial tubes, and that some phenols increase the action of known carcinogenic agents. Furthermore, by various processes it is possible to alter the chemical composition of the smoke before it reaches the filter.

Considering this, I believe that extensive research should be undertaken to determine the effects of various constituents of cigarette smoke and to find means of removing those that are most harmful. Until this has been accomplished it seems advisable to reduce the total tar and nicotine content of cigarette smoke by the means now available.



RUPTURE OF ALVEOLAR WALLS is a progressive process, from the normal state (*top*) to the rupture of some walls (*middle*) to the disappearance in certain areas of all the alveolar tissue (*bottom*). These photomicrographs, made by Auerbach, magnify the tissue approximately 120 diameters.

BRONCHIAL EPITHELIUM is the original site of almost all lung cancer, which often develops as shown on the opposite page. The photomicrographs (*1* through *5*), made by Oscar Auerbach of the East Orange, N.J., Veterans Administration Hospital, magnify human epithelial tissue 325, 250, 250, 75 and 110 diameters respectively. One of the first effects of smoking on normal epithelium (*1*) is hyperplasia (*2*), an increase in the number of basal cells. The epithelium is lost and the cells become squamous, or flattened (*3*). When the cells develop atypical nuclei and become disordered (*4*), the result is called carcinoma *in situ*. When these cells break through the basement membrane (*5*), the cancer may spread through lungs and to the rest of the body.

The Plastic Layer of the Earth's Mantle

Earthquake waves indicate that at a depth between 37 and 155 miles the stuff of the earth is less rigid than that above and below it. Such a layer would have an important bearing on tectonic processes

by Don L. Anderson

Earth scientists have often pointed out that physical conditions inside our own planet are less well understood than those in stars light-years away. Even more paradoxical is the fact that the region within a few hundred miles of the surface presents more problems and gives rise to more technical controversy than the region below. One long-standing item of debate is the zone called the low-velocity layer.

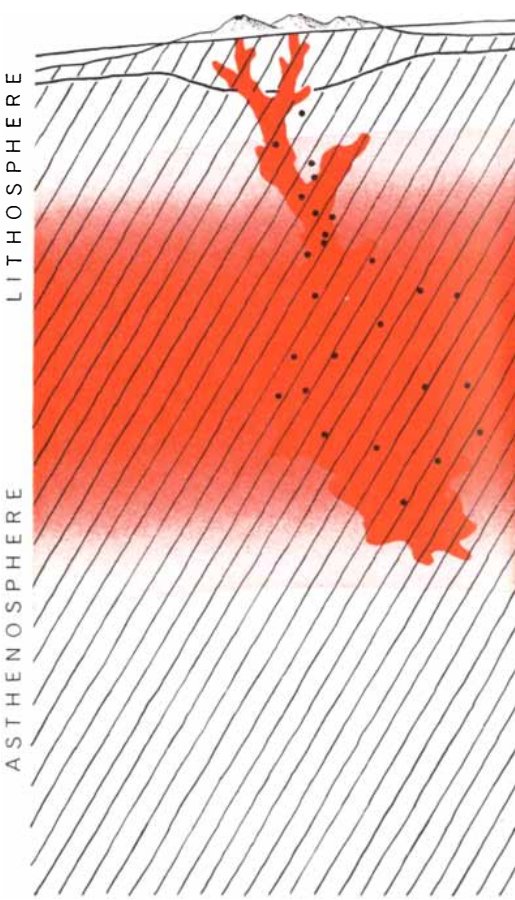
In 1926 the seismologist Beno Gutenberg suggested that earthquake waves slow down when they travel through a zone roughly 100 to 200 kilometers (60 to 120 miles) below the surface. He attributed the effect to a decrease in the rigidity of the material in the zone compared with that above and below it. Most authorities considered his evidence to be dubious at best, and for 30 years they largely ignored his proposal. Recently a mass of data has accumulated that strongly supports the concept of a low-velocity, low-rigidity layer. Its existence has important implications for all theories concerned with structural changes in and near the earth's surface.

The idea that the earth becomes plastic—if not, indeed, liquid—at moderate depths goes back to the earliest days of geology. Volcanic lava flows pointed to a molten interior not too far below the surface. Observations on the rate of increase of temperature in deep mines indicated that if the temperature continues to increase at the same rate, rocks should be molten at depths of less than 100 kilometers. The enormous cracks and folds found in the earth's crust suggested upheavals in a mobile substratum. All this agreed with prevailing views of the origin of the solar system, which held that the earth and other planets had been torn loose from the sun and had had time to solidify only at the surface.

One of the most compelling arguments for some degree of fluidity in the interior came from the principle of isostatic equilibrium. As long ago as 1854 gravity measurements led geologists to suspect that the earth's crust floats on a denser material. Like other floating bodies, the crust seeks an equilibrium, riding deeper where it is heavier and rising higher where it is lighter. Subsequent studies, of both the strength of gravity and the propagation of earthquake waves, confirmed the notion, indicating that mountains have deep roots that support them just as the submerged portion of an iceberg supports the part above water, whereas plains resemble ice floes, having smooth upper and lower surfaces. Moreover, when the load on a part of the crust changes suddenly (on the geological time scale), the surface can be observed to respond by rising or sinking to restore equilibrium. For example, land covered by ice during the last glaciation is still rising at the rate of about a meter per century. Obviously this behavior implies that the material under the crust can flow, if only slowly.

On the other hand, several facts appeared to rule out the idea of widespread fluid material anywhere near the surface. From the tidal distortions of the solid earth in response to the pulls of the sun and moon, Lord Kelvin calculated that the earth is more rigid than steel. Studies of earthquake waves indicated that at depths down to thousands of kilometers the earth transmits not only compression waves (P waves) but also transverse, or shear, waves (S waves). Shear waves, which oscillate at right angles to their direction of motion, cannot propagate through liquids because liquids have no shear strength. When liquids are subjected to shearing forces, they simply flow. Finally, seismologists discovered that earthquakes originate as deep as 700 kilometers below the surface. Since an earthquake represents the abrupt yielding of rock to accumulated stress, it characterizes brittle, not plastic, material.

The answer to this apparent contradiction is suggested by the properties of noncrystalline materials such as glass and pitch, which behave like solids in



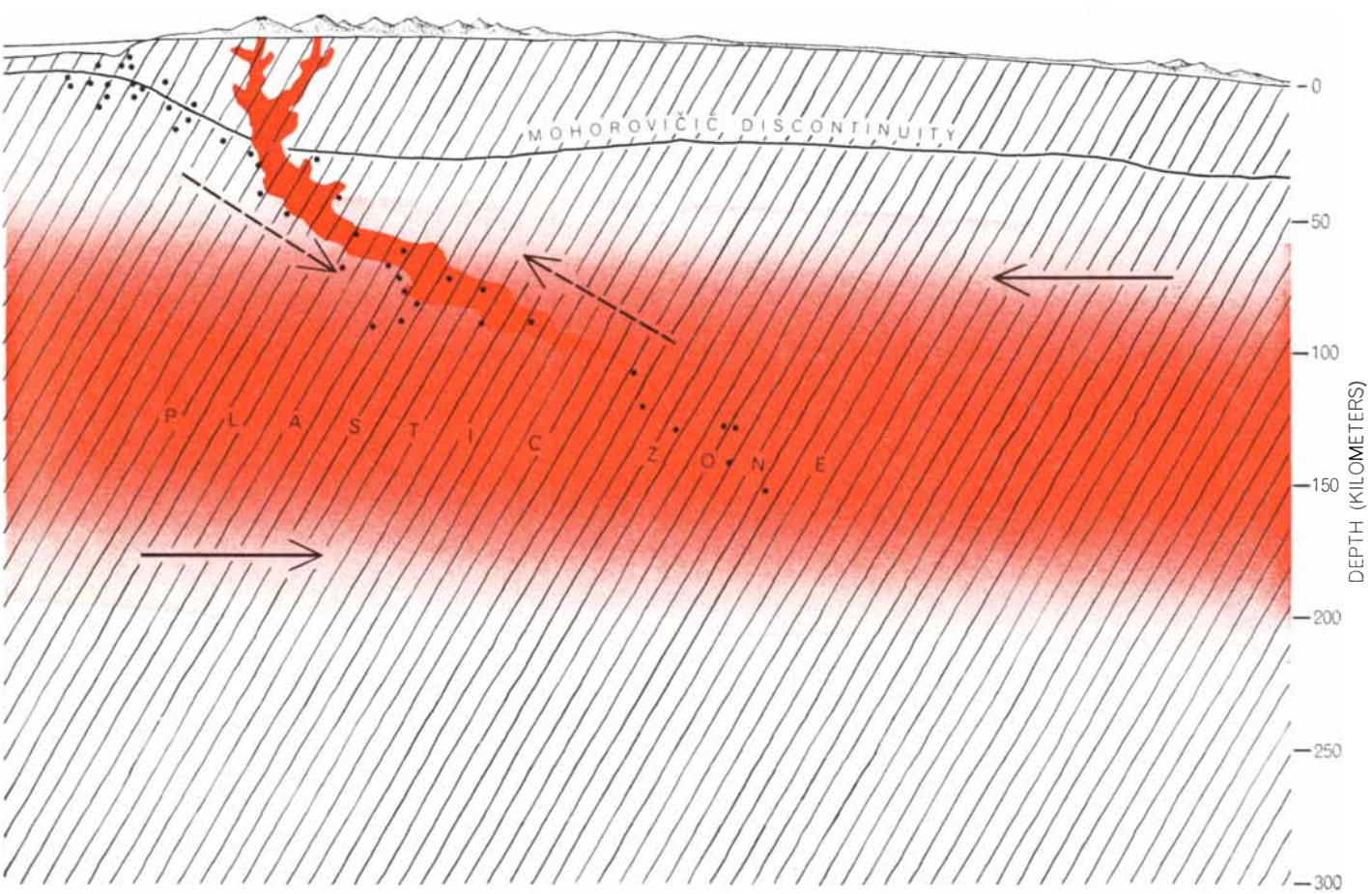
PLASTIC ZONE of earth's mantle (*color*) occupies an ill-defined region some 60 to perhaps 250 kilometers below the surface. In the plastic or low-velocity zone the tem-

the short run and like fluids over longer periods. They transmit shear waves and can support loads for a short time, but under a steady, long-lasting force they are plastic; that is, they flow and change their shape permanently. Under conditions of high temperature and high pressure the rock under the crust could also behave plastically. It would respond like a rigid solid to the relatively short-lived stresses that build up to cause earthquakes and the even briefer stresses involved in earthquake waves, while flowing slowly to adjust to the long-term stresses caused by changes in the weight of overlying material. Some geologists believe that the plastic substance under the crust is a glassy basalt. Recent evidence suggests, however, that it is crystalline. At high temperature even a crystalline material can flow easily, because melting at the boundaries of individual crystal grains allows them to slide over one another.

In 1909 the Yugoslav seismologist Andrija Mohorovičić proposed that at some distance below the surface there is a discontinuity where the velocity of earthquake waves jumps from about seven kilometers per second to eight. Subsequent measurements placed the Mohorovičić discontinuity, or Moho, at an average depth of 35 kilometers below the surface of the continents and only about five kilometers below the ocean floor. Under high mountains the Moho is as deep as 65 kilometers. Geologists saw in the Moho the lower boundary of the rigid, floating crust. The material between the Moho and the presumably liquid core of the earth they named the mantle. Yet the fact that seismic waves travel faster below the Moho than they do above it implies a greater rigidity at the top of the mantle than in the crust. It now seems clear that the Moho marks a change in chemical composition or crystal structure rather than an abrupt transition from strong to weak material.

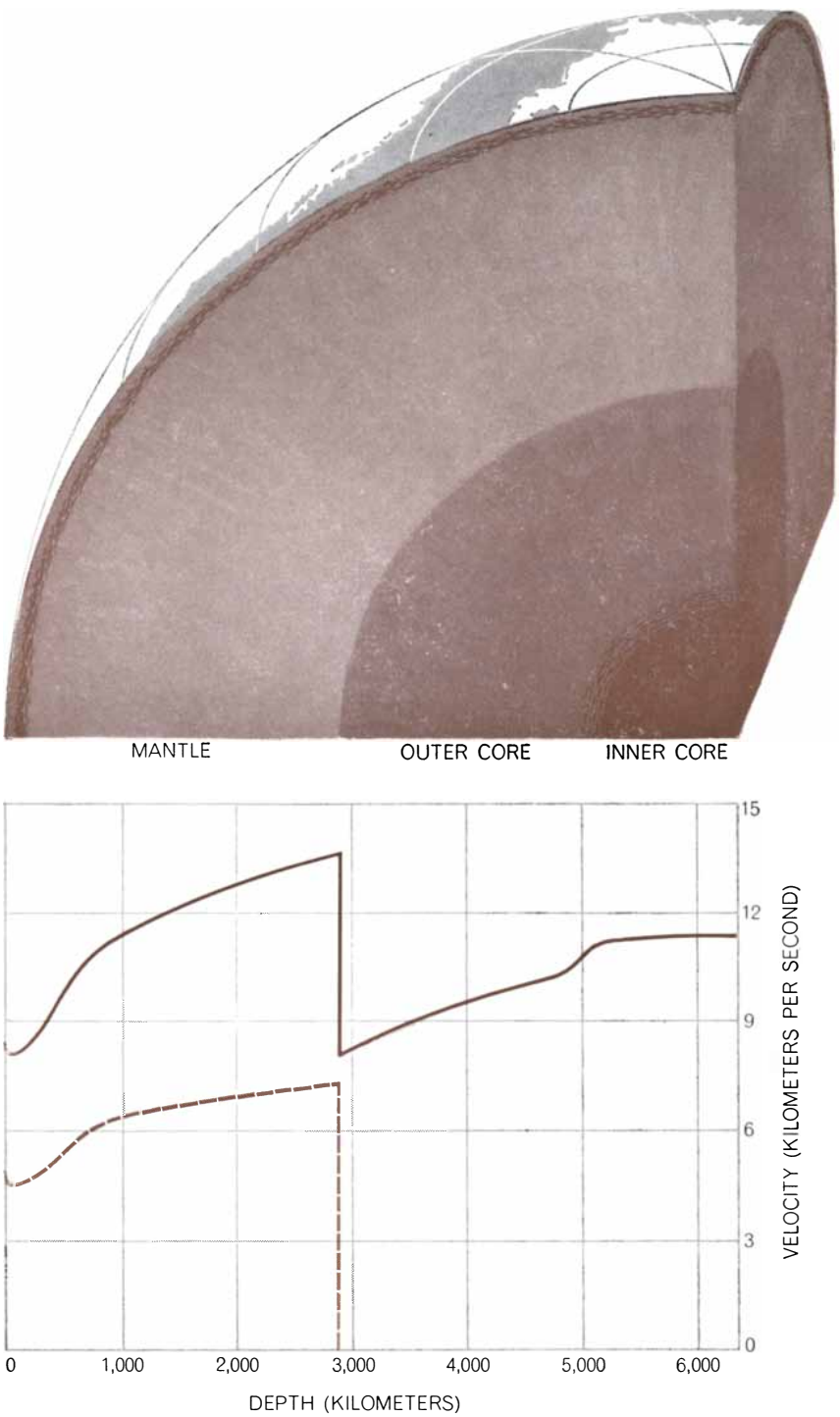
The first seismic evidence for this transition was not forthcoming until Gutenberg announced the low-velocity zone. Actually what he had found was a decrease in the amplitude of compressional waves reaching the surface at a distance between 100 and 1,000 kilometers from an earthquake. At 1,000 kilometers the amplitudes were only a hundredth as great as they were at 100 kilometers. Beyond 1,000 kilometers the amplitudes increased sharply.

Gutenberg explained the effect by assuming a subsurface layer in which the earthquake waves travel slower than they do in the regions above or below. A wave entering this layer obliquely from above would be refracted downward, away from the surface, as light is bent downward when it passes from air to water. On leaving the bottom of the layer the wave would be refracted upward again [*see illustration on page 55*]. The result is that the wave would arrive at the surface farther away from its source than it would if there had been no decrease in velocity. Hence a gap would appear between the last "ray" that had missed the low-velocity layer and the first one to enter it. As the illustration shows, the gap, or shadow zone, is great-



perature approaches the melting point of the rock. The lithosphere is very elastic or brittle rock; the asthenosphere, extending down to earth's core, can flow and relieve stress. In this highly schematic cross section of upper portion of earth, ocean and islands are at left. Dots denote earthquake foci. Broken arrows indicate possible movement of continents over ocean basin. Solid arrows mark hypothetical slippage of whole lithosphere over asthenosphere. The two solid-color regions represent magma, or molten rock.

est for an earthquake originating just above the top of the layer. Those coming from deeper levels evince no gap. From the extent of the shadow zone for different earthquakes, Gutenberg calculated that the layer is centered at a depth of about 150 kilometers, and that between 100 and 200 kilometers the velocity is some 6 per cent less than it is just under the Moho. Such a decrease in velocity means that the rock within the layer must be substantially less rigid than the material above and below it. The velocity does not reach the value it had at the base of the crust until some 250 or 300 kilometers below the surface.



INTERNAL STRUCTURE OF THE EARTH is deduced from travel times of seismic waves. Solid line represents compressional, or P, waves; broken line represents shear, or S, waves. The latter disappear entirely at the outer core, indicating that this region is liquid. Low-velocity zone causes dip in curves at far left. Hatching on block diagram near surface marks low-velocity zone. It also marks transition zone above inner core at depth of 5,000 kilometers.

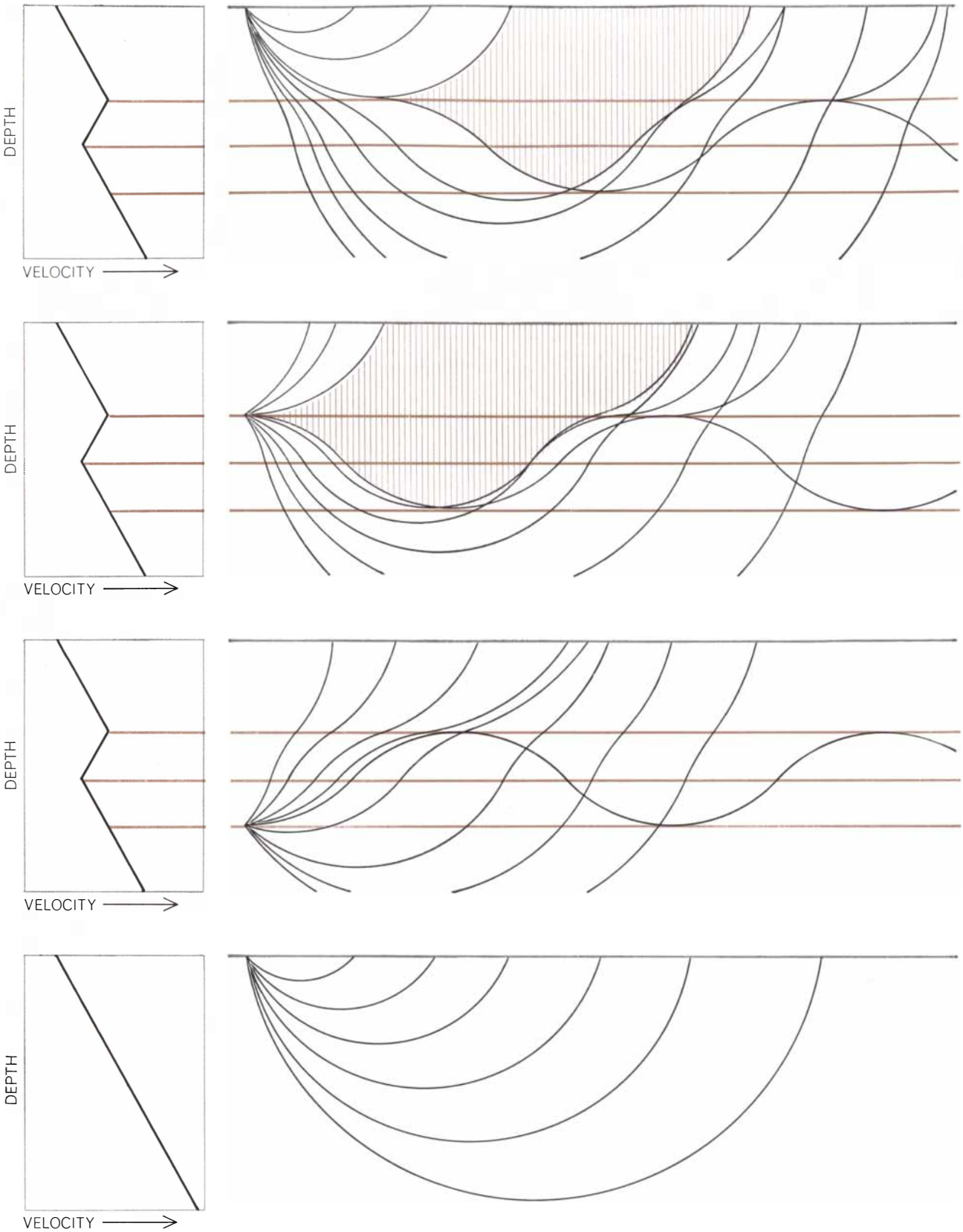
If the low-velocity layer were perfectly uniform, and if the waves really traveled as rays, the shadow zone at the surface would be completely "black." No waves at all would emerge within its limits. Actually the layer is full of inhomogeneities, and seismic waves do not travel strictly along classical ray paths. Like all waves, they bend around corners by diffraction, thereby leaking into shadowed regions. Both effects contribute to the energy that is found in the shadow zone.

It was partly this energy leak that made other workers reluctant to accept Gutenberg's conclusion. In those days seismologists paid little attention to the comparative amplitudes of earthquake waves. They were primarily interested in travel times, and they tended to accept any signal, weak or strong, if it appeared in their records at a time when readings at other seismographic stations led them to expect it.

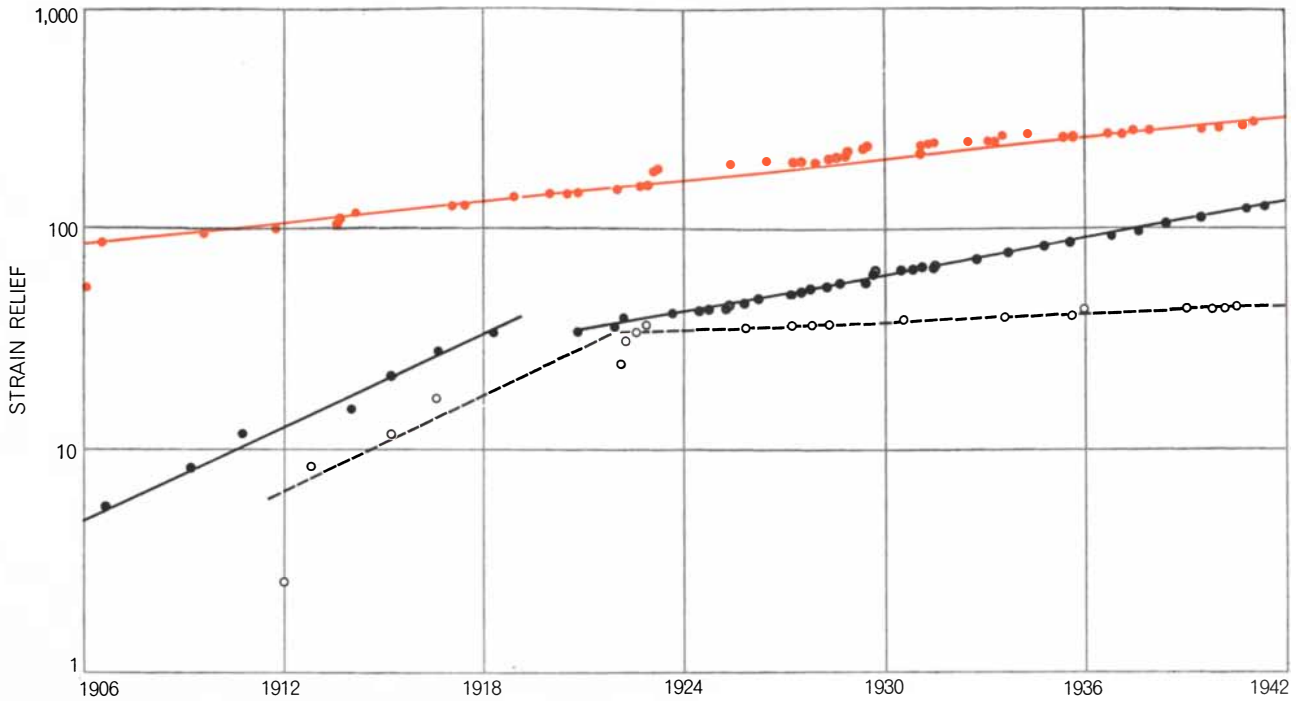
Moreover, the evidence for the low-velocity layer was by no means clear-cut. The statistics were assembled from many earthquakes, large and small, shallow and deep. The data came from seismographs of different designs. In his calculations Gutenberg could make only approximate corrections for these variations as well as for the local irregularities, mostly unmapped, in the rock through which different waves traveled.

Underground nuclear explosions finally made possible a controlled experimental test of Gutenberg's analysis. The time, strength and location of these events is known so precisely that a single blast provides excellent data. Furthermore, seismographs today are more numerous, more sensitive and more standardized than they were in 1926. Studies of several explosions have confirmed the conclusions Gutenberg extracted so tediously from earthquake records [*see illustration on page 57*]. Seen in sharper detail, the low-velocity layer extends from about 60 kilometers to about 250 kilometers. (It is interesting to note that the layer damps blast waves so effectively that many seismologists think it poses a major difficulty for the detection of underground nuclear tests.)

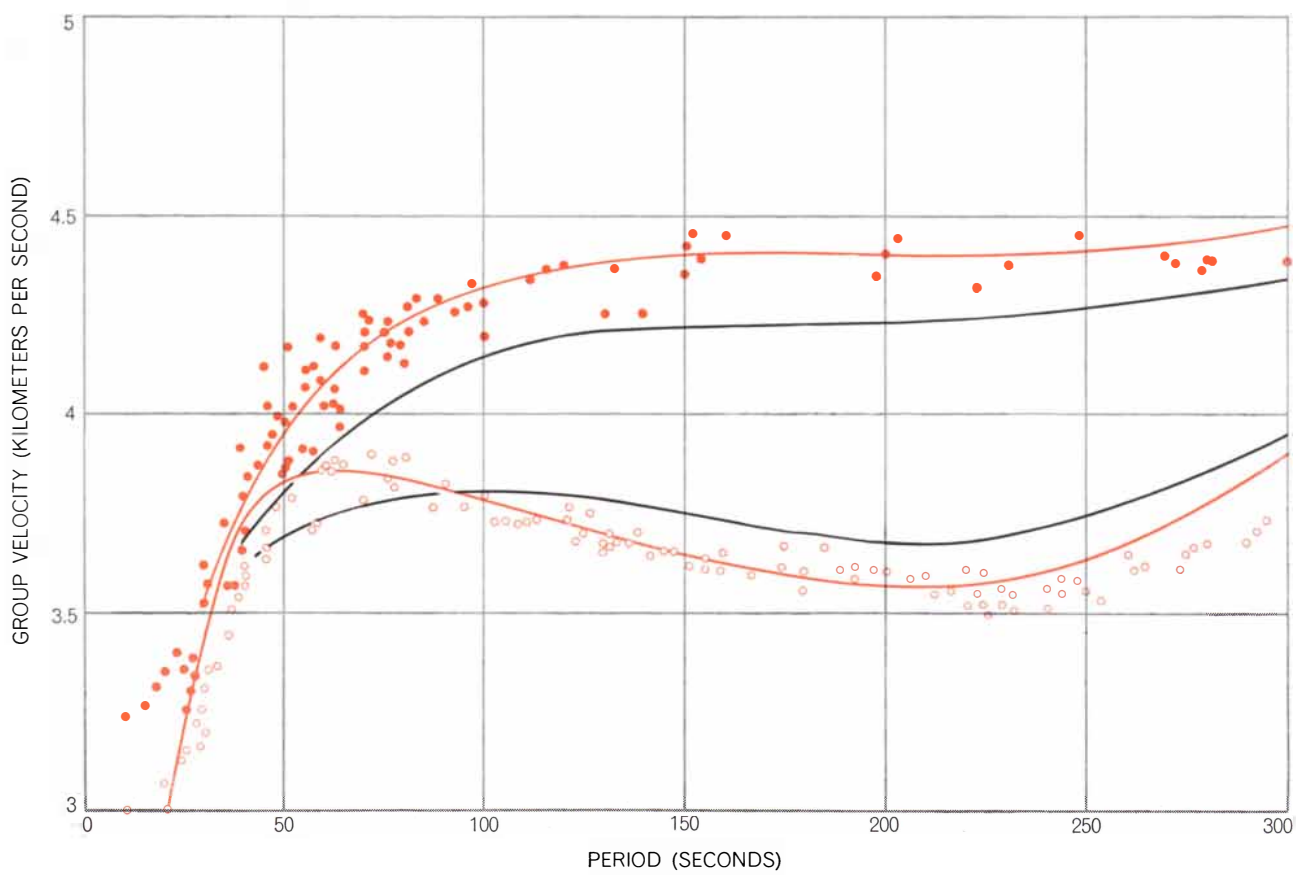
Several independent pieces of evidence now support the idea of a low-velocity plastic layer. One is furnished by surface waves. These are seismic disturbances that follow the curved surface of the earth [*see bottom illustration on page 56*] instead of passing through its body. Although the waves travel along the surface, they "feel" the elastic properties of the underlying material to a



PATHS OF EARTHQUAKE WAVES bend in various ways in response to the low-velocity zone, depending on whether the earthquake occurs at the surface of the earth (*top*), at the top of the low-velocity zone (*second from top*) or below the zone (*third from top*). In the first two cases, refraction of waves by the zone creates a "shadow zone" (*hatching*), where direct waves from the earthquake do not appear. The bottom diagram shows how waves from an earthquake at the surface would travel if there were no low-velocity zone to bend them down. The graphs at left show changes in the velocity of earthquake waves with increasing depth.



SEQUENCE OF EARTHQUAKES between 1906 and 1942 along west coast of South America falls into three groups: those occurring down to a depth of 70 kilometers (*colored dots, colored line*), those from 70 to 250 or 300 kilometers (*black dots, black line*) and those from 300 to 600 kilometers (*open dots, broken line*). The vertical scale shows relative amount of strain relieved by the quakes. Break in two lower groups around 1921 shows that they are mechanically coupled and are quite separate from the upper group.



SURFACE-WAVE DATA reflect existence of low-velocity zone. The two types of dot represent actual observations of velocity of two kinds of surface waves plotted against wave period or length. Theoretical curves for an earth with a low-velocity zone (*colored lines*) fit observational data far more closely than do theoretical curves for an earth without a low-velocity zone (*black lines*).

depth that depends on their wavelength; the longer the wave, the deeper it feels [see "Long Earthquake Waves," by Jack Oliver; SCIENTIFIC AMERICAN, March, 1959]. Since in general elasticity increases with depth, longer waves travel faster than shorter ones, and waves that start out together are dispersed, or spread out. Detailed analyses of the dispersion patterns show that elasticity does not increase continuously with depth but falls off in the region of the low-velocity layer.

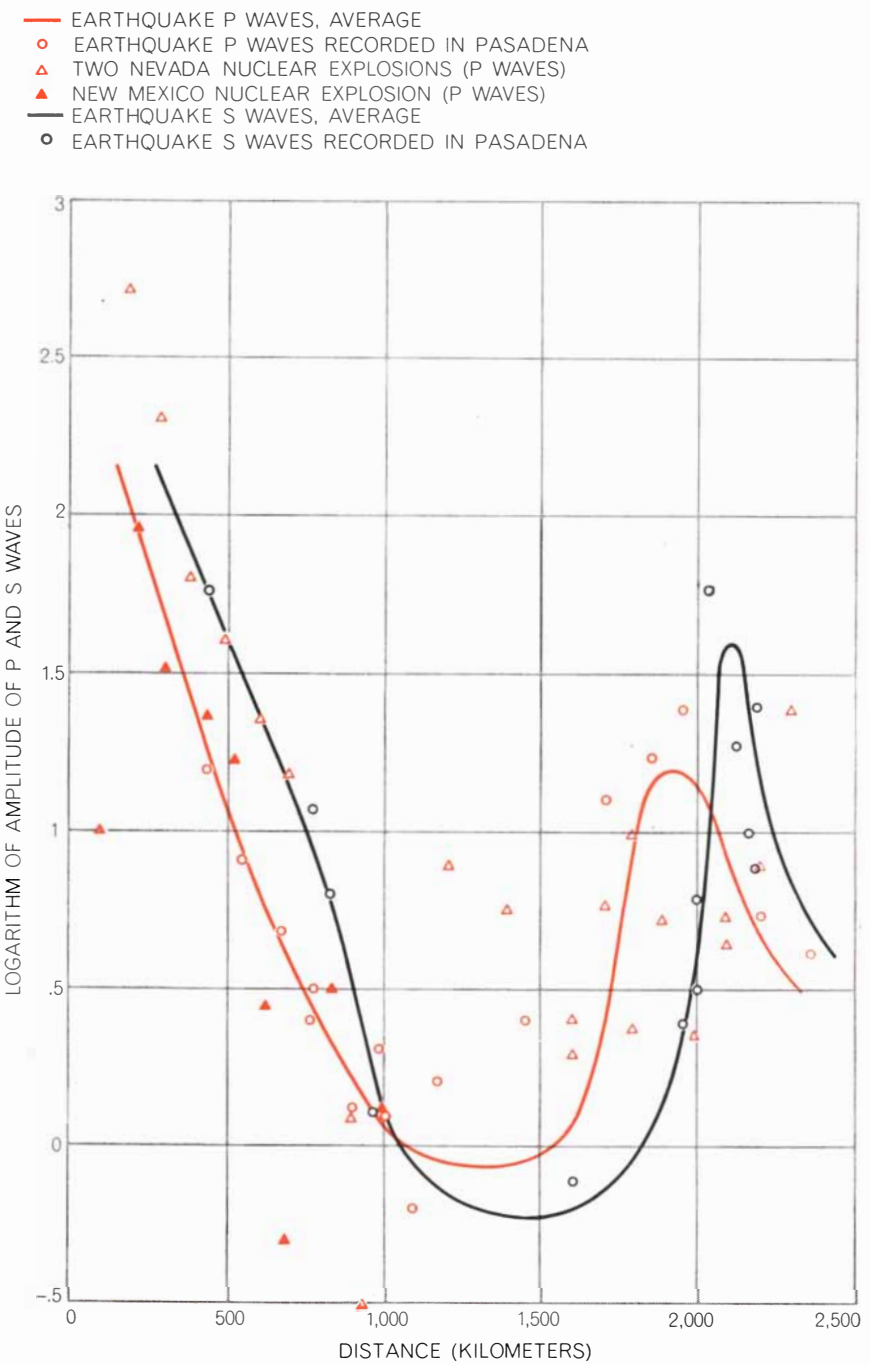
Body waves, which pass through the deep interior, provide only a point-by-point sampling of the outer regions of the earth. Surface waves, on the other hand, contain information about these regions over their entire path. Recent studies of surface waves in our laboratory at the California Institute of Technology and at Columbia University have demonstrated for the first time that the low-velocity layer is present below the oceans as well as below the continents. Some of the waves used in the analysis had traveled around the earth as many as seven times. They indicate that the layer is in fact a world-wide phenomenon. Comparison of oceanic and continental paths shows that the waves are slowed more under the oceans. Evidently the geological differences between ocean basins and land masses are not limited to the crust but extend several hundred kilometers into the mantle.

Conclusive proof of the world-wide extent of the low-velocity layer came from the great Chilean earthquake of May 22, 1960. It was so violent that it set the earth as a whole into vibration, making it "ring" like a bell. The tone of a bell—that is, the frequencies at which it vibrates—depends on its elastic properties; a steel and a bronze bell emit different sounds. From records of the free vibrations following a big earthquake it is possible, with enormous mathematical labor, to deduce the elastic structure of the earth. The labor has been performed. It shows that the low-velocity zone is necessary to account for the observed frequencies.

In an attempt to construct a model of the earth that fits the current seismic data, I have been obliged to conclude that the low-velocity zone transmits the horizontal and vertical vibrations in shear waves at different speeds. A crystalline material in which the crystal grains were aligned in one direction would behave this way. One mechanism that could bring about such an alignment is a flow of the material. Others are directional heat flow and differential stress.

In addition to the purely seismic data, several other phenomena attest to a lowered rigidity in the material near the top of the mantle. Variations in atmospheric pressure cause measurable deflections of the earth's surface. The amount of deflection is much greater than it would be if the crust and mantle had the same strength. By assuming a weak layer in the upper mantle the observations can be explained quite well. Moreover, most earthquakes originate in the first 60 kilometers below the surface, at an average depth of 25 kilometers. At a depth of more than 60 kilometers the number falls abruptly, indicating a sudden drop in the strength of the rock.

From 60 kilometers down the frequency of earthquakes decreases steadily, dying away to zero at about 700 kilometers. This distribution implies that the rock becomes less brittle all the way from 60 to 700 kilometers and that it does not regain its strength at any deeper



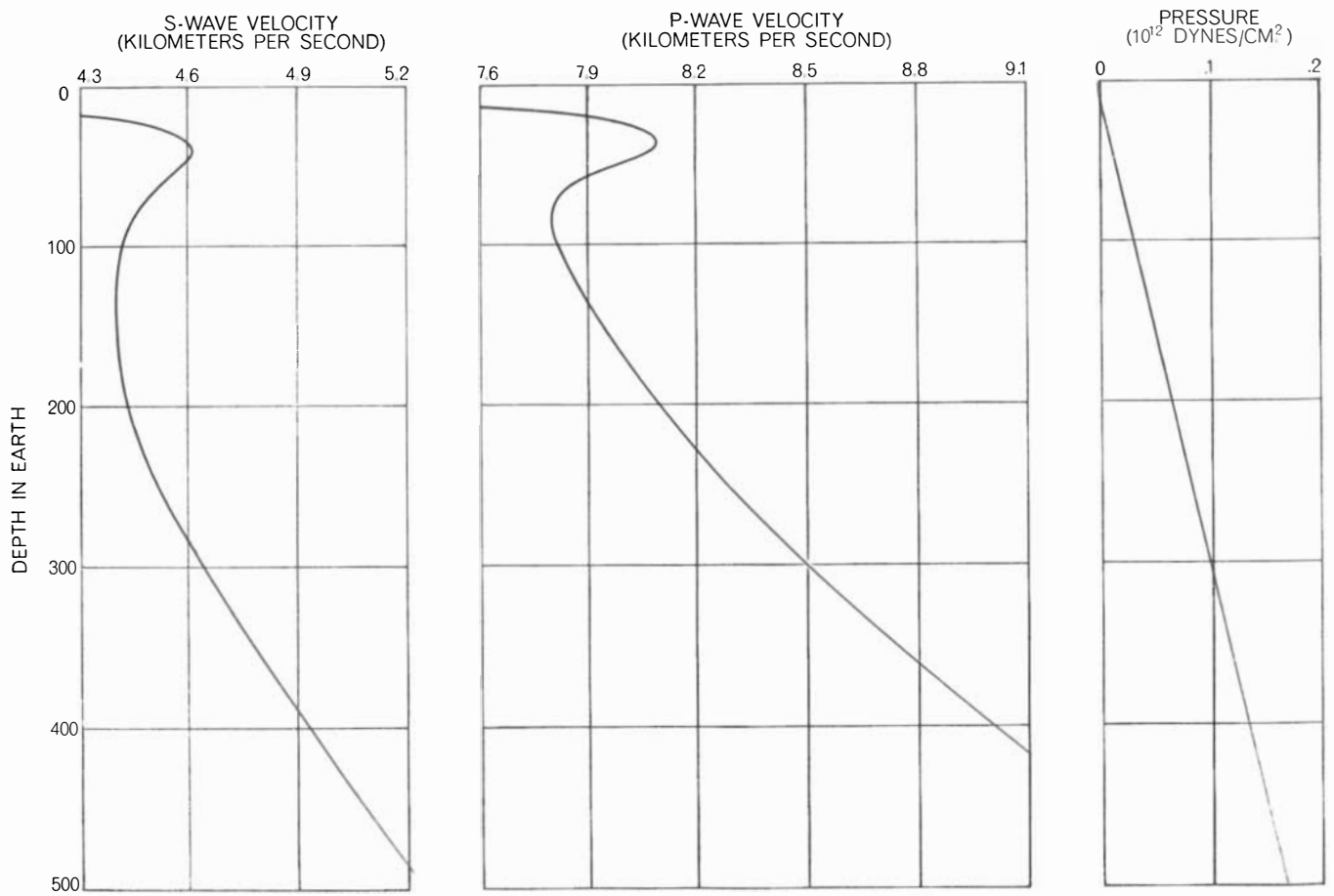
SHARP DROP IN AMPLITUDE of earthquake and nuclear-explosion waves between about 100 kilometers and 1,000 kilometers from the event is caused by low-velocity zone. The two curves of averages for earthquake P and S waves were drawn by Beno Gutenberg on basis of data from many earthquakes and observatories and represent world-wide averages.

level. The picture agrees with a nomenclature first proposed in 1914 by the U.S. geologist Joseph Barrell. He spoke of an upper, rigid "lithosphere" (from the Greek word *lithos,* meaning stone) and a lower, more plastic "asthenosphere" (from the Greek word *asthenes,* meaning weak). Barrell placed the boundary between the two at a depth of 100 kilometers. Now it appears to be not a sharp boundary but a transition zone starting at some 60 kilometers.

The concept of strength and weakness in the foregoing discussion applies to the time in which stresses build up to cause earthquakes. Viewed on this temporal scale the mantle undergoes a transition from a brittle to a plastic state at about 60 kilometers and thereafter increases in plasticity. On the much shorter time scale of earthquake-wave vibrations, however, the material reverts to a stronger, or more elastic, condition at a depth of more than 250 kilometers. The decrease in velocity at the top of the mantle is gradual; it is not yet clear whether the base of the low-velocity zone is characterized by a gradual or an abrupt increase in velocity.

Almost certainly the short-term properties that set apart the low-velocity layer are determined by the temperature and pressure of the mantle in relation to its melting point at different depths. In general the elasticity of any material decreases as its temperature approaches the melting point. But an increase in pressure raises the melting point and elasticity. Below the surface of the earth both temperature and pressure increase with depth, and so the two have opposing effects on the proximity to the melting point as well as on the elastic strength of rock. Presumably at a depth of about 60 kilometers temperature takes the upper hand and the rock begins to approach its melting point, growing weaker as the depth increases. This trend continues down to some 200 kilometers, where it reverses. Then pressure raises the melting point faster than the temperature increases and the material becomes more elastic (until the liquid outer core is reached). A few laboratory experiments on rock under high temperature and pressure seem to confirm this picture. Extrapolating the rather scanty data indicates a very low strength at a depth of somewhat more than 100 kilometers.

Hugo Benioff of the California Institute of Technology has discovered a remarkable indication of discontinuity at the level of the top of the low-velocity zone. In studying a large number of earthquakes in the Pacific Ocean earthquake belt he was able to connect certain sequences of earthquakes to single fault structures. One sequence that occurred in South America between 1906 and 1942 delineates a great fault off the west coast of the continent. The fault is some 4,500 kilometers long and goes down 600 kilometers—a tenth of the distance to the center of the earth. The earthquakes related to the fault fall naturally into three groups: (1) those shallower than 70 kilometers, (2) those from 70 to 250 or 300 kilometers and (3) those from 300 to 600 kilometers [*see top illustration on page 56*]. Analysis of the earth motions in the quakes showed a marked similarity between the intermediate and deep groups but no resemblance of these to the shallower group. In particular the motions of the two deeper groups changed suddenly, and in the



DATA FOR UPPER MANTLE reflect existence of plastic or low-velocity zone. The seismic-wave velocities and the number of earthquakes are the only curves made from direct measurements in the earth. Pressure is derived directly from depth. Temperature curve

same way, in 1921. There was no corresponding change in the shallower earthquakes. Evidently there is some mechanical coupling between the lower layers, but these are sharply decoupled from the region above 70 kilometers. Other areas of the circum-Pacific tectonic belt show similar phenomena.

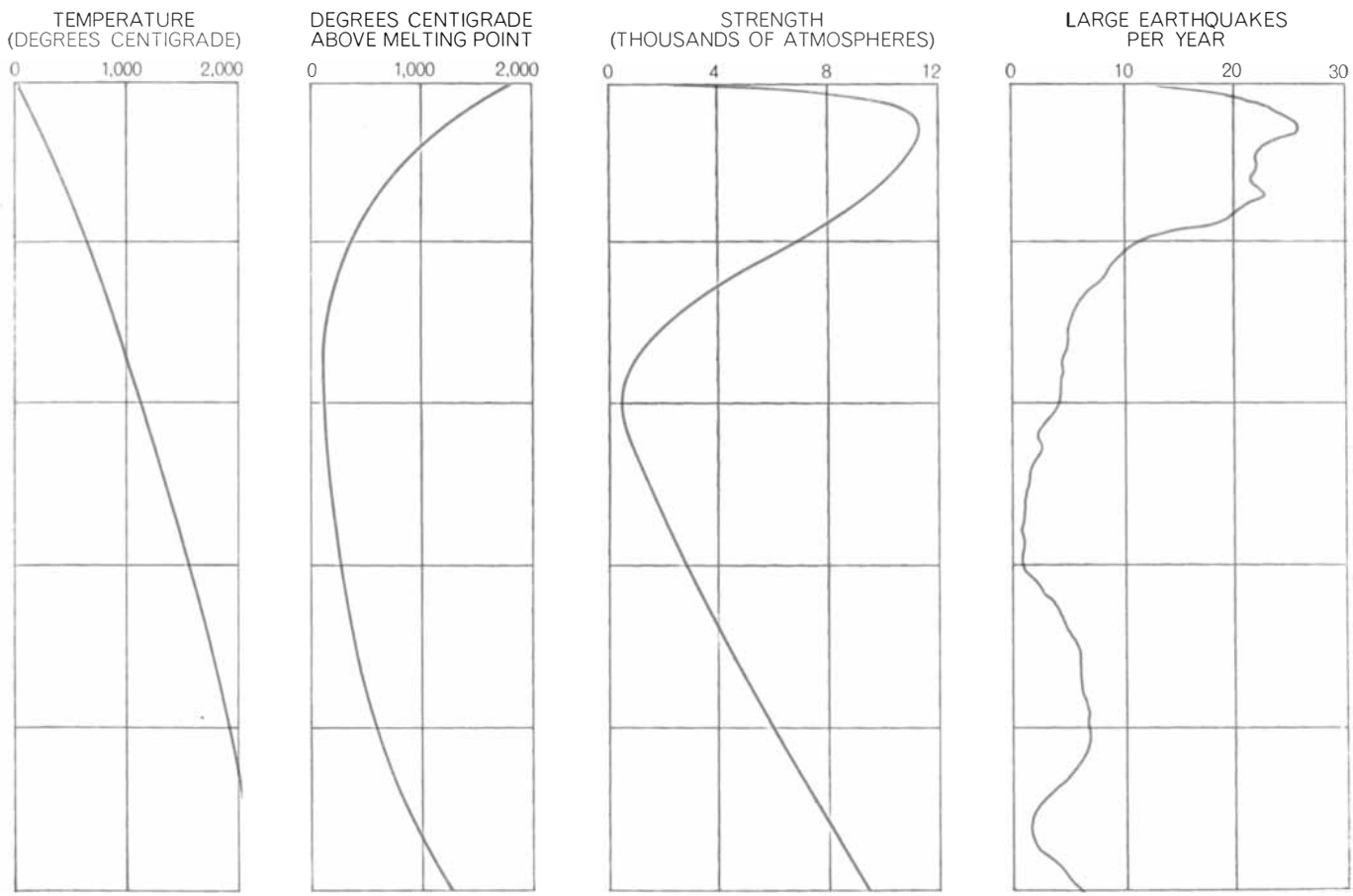
When the earthquake foci are plotted in three dimensions, those down to 250 kilometers fall in a plane about 900 kilometers wide, dipping about 33 degrees under the continents with respect to the surface of the earth. The deep earthquakes, on the other hand, are on a plane tilted at 60 degrees. Thus, although they are mechanically connected, the intermediate and deep layers are spatially discontinuous. The dimensions and location of the intermediate layer correspond closely to those of the low-velocity zone.

An interesting clue to the state of the material in the upper mantle was furnished by the Soviet volcanologist G. S. Gorshkov in 1957. He found that shear waves from Japanese earthquakes do not reach the Kamchatka Peninsula when their paths cross the volcanic belt between Japan and the peninsula. Gorshkov concluded that there must be pockets of liquid magma at a depth of 55 kilometers that absorb the waves. Apparently in certain regions the temperature not only approaches the melting point but even exceeds it. Many seismologists have remarked on the fact that the average wavelength of shear waves is many times longer than that of compressional waves. The observation could be accounted for by a weak, perhaps partially molten, layer that absorbs the shorter S waves more than the longer S waves.

Volcanoes are concentrated in parts of the world where earthquakes are most common, and the earthquakes actually associated with volcanism mostly originate at depths between 60 and 200 kilometers. This suggests that volcanoes are connected with disturbances in the region of the low-velocity zone. Therefore the distribution of volcanoes constitutes direct evidence for the temperature–melting point relation inferred from laboratory measurements and suggests that the low-velocity layer may be the source of primary basaltic magma.

Volcanism and the postglacial uplift of the crust constitute the only dynamic, as opposed to static, geological "experiments." Both indicate fluidity, and some degree of actual flow, in the material below the crust. Moreover, they are consistent with the idea of a layer of maximum plasticity in the upper mantle.

Almost all present theories of isostasy and tectonics, including those concerned with mountain building, faulting and the possible drifting of the continents, focus attention on the Mohorovičić discontinuity, which divides the crust of the earth from the mantle. If the picture I have tried to outline in this article is correct, the important discontinuity is farther down, at the ill-defined boundary of the rigid lithosphere and the weaker asthenosphere. Most of the activity responsible for the broad-scale features of the earth's surface probably takes place in a low-velocity or plastic layer at the top of the asthenosphere, extending roughly from 60 to 250 kilometers in depth. In particular the existence of such a plastic layer makes the idea of continental drift much more plausible than it has seemed heretofore.



is based largely on theoretical considerations. Temperature above melting point is calculated from pressure and temperature curves. Strength, down to 50-kilometer depth, is derived indirectly from laboratory measurements; below that it is an extrapolation.

THE BEHAVIOR OF SHARKS

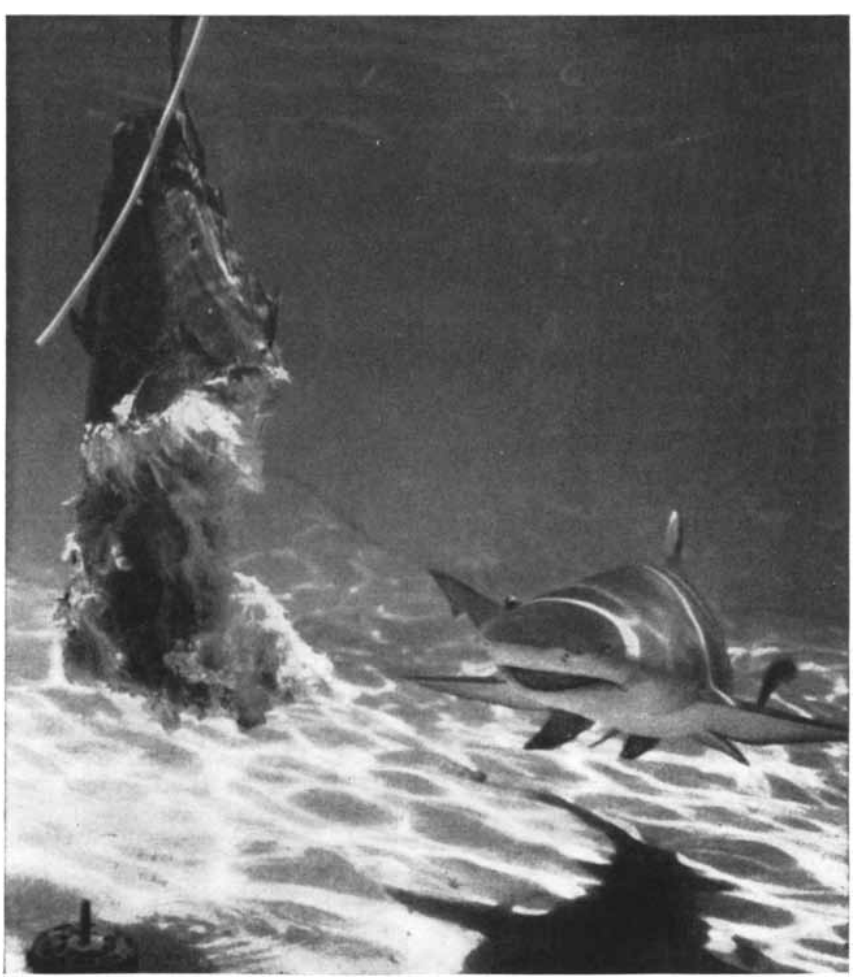
In which large sharks are studied at close range to assess the role of their various senses in their feeding behavior. The results give promise that the problem of preventing shark attacks can be solved

by Perry W. Gilbert

Among the many "crash" programs of applied research sponsored by the U.S. armed forces during World War II was the effort to develop a shark repellent. The aim, of course, was to protect military personnel who might be cast away at sea from one of the more unpleasant hazards of that experience. Investigators soon had encouraging results to report. They were able to show that decomposed shark flesh or, alternatively, copper acetate would inhibit the feeding activities of smooth dogfish, a harmless species, and certain other sharks. Whether or not the repellents that incorporated these findings have ever protected anyone from a shark attack is uncertain. During the past five years, however, it has been demonstrated that the odor of decomposed shark flesh or of copper acetate has no inhibitory effect whatever on the behavior of the species native to the Caribbean Sea, nor on the behavior of those Pacific Ocean sharks on which they have been tested.

A year or two ago people responsible for the safety of bathers at beaches found reason to hope that the device called the bubble curtain might keep sharks away. The curtain, set up offshore by leaking compressed air from perforations in a pipe or hose, was supposed to present some sort of sensory or psychological barrier to approach by sharks. Unfortunately, when it was tried out on sharks in a laboratory pen, it proved to be no barrier at all [*see top illustration on page 67*].

These two stories may serve to remind bathers, skin divers, small-boat sailors and others who venture into the ocean that there is as yet no sure protection from sharks in open water. They serve also to emphasize the practical motivation of a field of investigation that has been attracting increasing interest in this country and abroad in recent years. It has long been suspected that sharks possess a remarkable ability to locate their prey, often at a considerable distance. Study has accordingly been focused on the sensory organs that direct their predatory behavior. Although all sensory systems undoubtedly come into play, it appears that three are particularly involved. They are the familiar senses of smell and vision and the "vibration sense," peculiar to fishes and aquatic amphibians, that is embodied in the



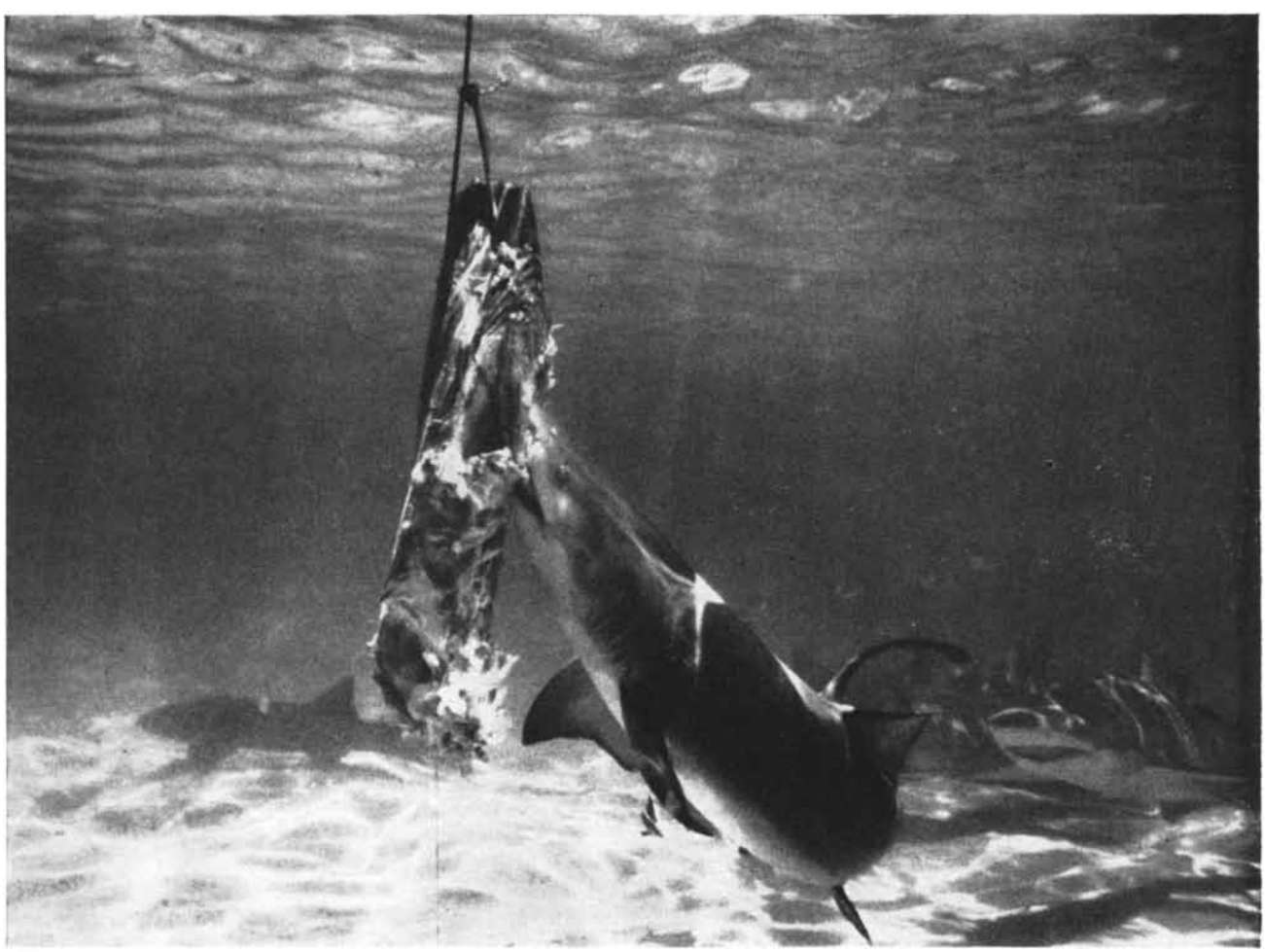
LEMON SHARK PREPARES TO ATTACK a 150-pound chunk of blue marlin by circling it. The shark, which is about nine feet long, was photographed by the author from an underwater cage at the Lerner Marine Laboratory on the island of Bimini in the Bahamas.

lateralis system, located on the head and along each side of the body. These organs in the shark show a high degree of elaboration and specialization. Investigation of the feeding behavior of sharks, progressing in parallel with study of their anatomy, has now begun to yield the understanding that must come before control.

Although the anatomical work can be done in the laboratory, observation of a large shark requires facilities in scale with the formidable dimensions of the animal. At the Lerner Marine Laboratory of the American Museum of Natural History on the island of Bimini in the Bahamas the Office of Naval Research has provided two spacious pens, each measuring 40 by 80 feet; these make it possible to confine sharks up to 15 feet in length under conditions that reasonably approximate those of the open sea. In a small central pen a shark selected for study can be trapped and brought alongside the dock with the help of a net and an electric hoist. After the shark has been anesthetized by having its gills sprayed with an anesthetic known as M.S. 222, it can be lifted out of the water for whatever preparation the experiment requires. For about 20 minutes, without danger to either the investigator or the shark, the animal can be laid out on the dock for such a purpose as fixing plastic shields over its eyes to deprive it temporarily of sight.

In our work at the Lerner Laboratory my colleagues and I have found that it is unsafe to generalize from observation of a single shark or even a single species of shark. When we tested the effectiveness of the bubble curtain, for example, we found that it did stop one of a group of 12 large tiger sharks, whereas the other 11 swam heedlessly through it. We have repeatedly noted that six or seven lemon sharks in a group exhibit greater interest in the bait presented and attack it more vigorously than does a solitary animal. Our experience shows that it is important to learn as much as possible about the normal feeding behavior of a species before attempting to manipulate it experimentally. The knowledge that lemon sharks feed more actively during the evening and at night, and that they may cease feeding altogether for days at a time when the temperature of the water drops below 65 degrees Fahrenheit, can be crucial to the evaluation of a whole series of experiments. For these reasons we work not only with solitary sharks but also with groups of sharks of the same species and at different times of the day and year before we attempt to draw conclusions about their behavior.

Of the shark's three principal sensory systems, the sense of smell has long been regarded as the most acute; indeed, the shark has been described as a "swimming nose." For this characterization there is considerable anatomical support. The nostrils, located on the underside of the flat snout just ahead of the mouth, open into capacious cups, or sacs, lined with folds of tissue. Since the tissue con-



SHARK ATTACKS its prey by braking its rapid forward motion with its large pectoral fins, tilting its head and body upward and opening its jaws wide. Next it drops both upper and lower jaws to secure a firm grip on its prey and shakes its head and body violently from side to side until it has torn off a 10-to-15-pound chunk of tissue. Then, still shaking its head violently, it swims away quickly.

tains the olfactory cells, the folds greatly enlarge the sensory surface. When a shark takes water into its mouth to aerate its gills, suction causes some water to flow in and out of each olfactory sac. In addition the forward motion of the shark brings water through the funnel-shaped nostrils into the sacs. A fleshy flap extending across the portal of each sac separates the inflowing stream from the outflowing. Thus the olfactory system of a shark is constantly bathed by a current of water whether the shark is at rest or in motion. In one of the oddest of all sharks, the hammerhead, the nostrils (as well as the eyes) are located far apart at the ends of the "hammer." This anatomical fact, coupled with the hammerhead's habit of swinging its head from side to side through a considerable arc as it swims, may lend enhanced directionality to the species' sense of smell.

Ralph E. Sheldon, working at the Marine Biological Laboratory in Woods Hole, Mass., was the first to demonstrate scientifically that the sense of smell is important in guiding sharks to a meal. He observed that smooth dogfish had no difficulty distinguishing a cheesecloth packet that contained crushed crabmeat from identical packets containing stones. When Sheldon plugged the sharks' nostrils with cotton so that a current of water no longer washed the olfactory sacs, they no longer "homed in" on the food packets, although they swam quite close to them. To obviate the possibility that the cotton plugs merely rendered the sharks uncomfortable and so discouraged them from eating, Sheldon plugged the nostril on one side only of several dogfish; after a brief period of adjustment all but one of the animals readily located the food packet.

We have performed similar experiments at Bimini. To healthy adult and subadult lemon sharks, five to nine feet in length, we presented four identical perforated cans, only one of which contained chunks of fresh bonito or tuna. The sharks approached and circled the baited container five or six times oftener than they did all three unbaited ones together. When we plugged their nostrils with cotton dipped in a dilute anesthetic, they no longer showed any such preference.

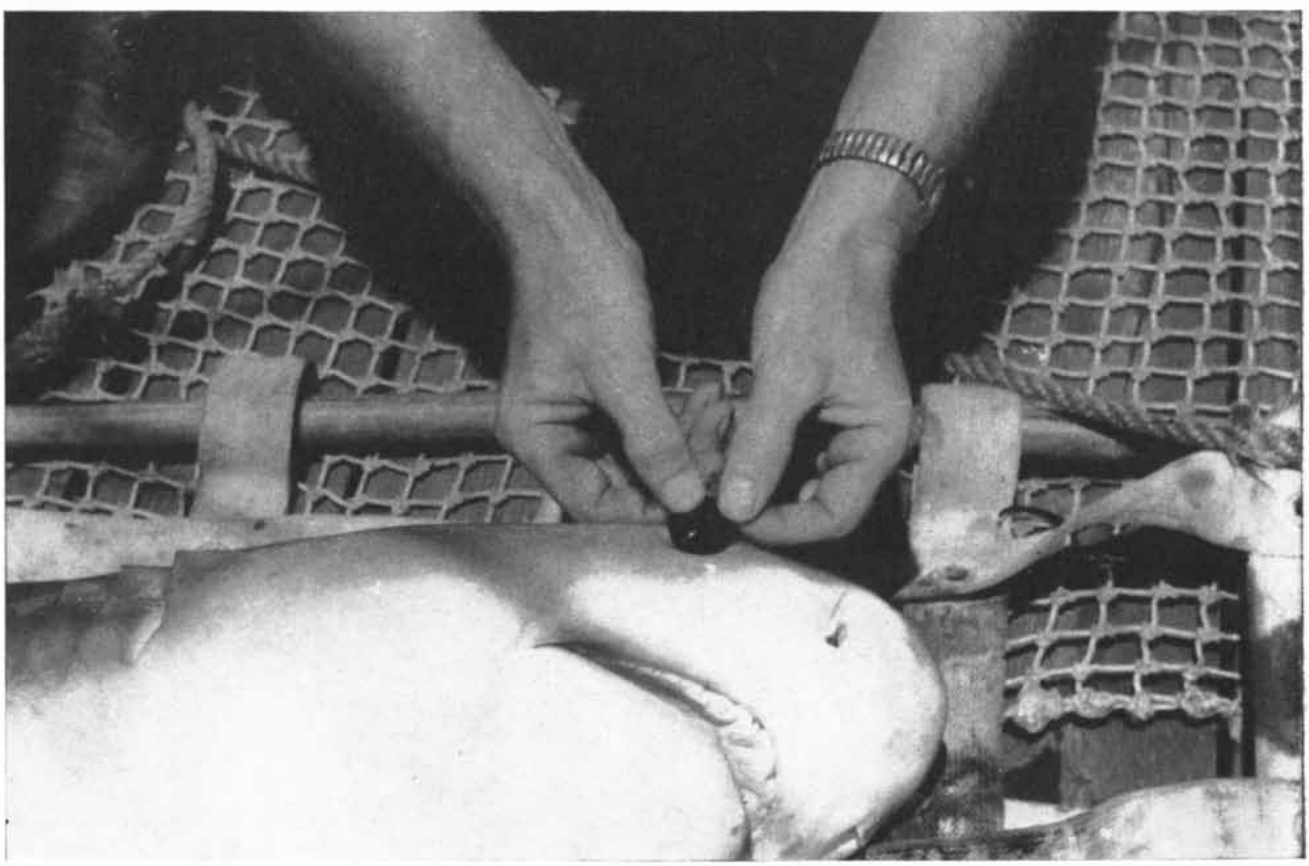
Obviously the distance at which a shark can smell an odorous substance depends on conditions in the water as well as on the shark's acuity of smell. If a strong current prevails, there is evidence that a shark may detect an odor a quarter of a mile from its source. It is a question of the degree to which the odorous substance is diluted in the water. In the case of salmon, it has been shown that they can detect a substance in dilutions down to one part in several million. We have seen lemon sharks detect small fluid samples of freshly caught tuna (one of the strongest shark attractants we have found) placed upcurrent at a distance of 75 feet. Given the speed of the current and the probable dimensions of the "olfactory corridor," as indicated by dyes released in the water, we estimated that the tuna juice must have been diluted to one part in 1.5 million.

Recently Albert L. Tester of the University of Hawaii reported that blacktip sharks and gray sharks, two Pacific species, showed a mild response to water siphoned into their tank from another in which fish were swimming. When these fish were agitated, the sharks showed a marked attraction to the siphoned water. This suggests that a frightened or distressed fish gives off some substance in sufficient quantity to attract sharks to it. As in Ernest Hemingway's *The Old Man and the Sea,* big-game fishermen frequently experience the frustration of losing a prize fish to attacking sharks. In these cases, however, sight and the vibration sense may play an equal role.

AUTHOR SPRAYS mouth and gills of a lemon shark to prepare it for experiment. It takes about a minute to anesthetize a 500-pound shark. This photograph and the one at top of opposite page were made by Peter Stackpole and are reproduced through the courtesy of *Life*.

It has been postulated, in fact, that it is the lateralis system that enables sharks to locate such disturbances as the torpedoing of a ship from a long way off. The mass attacks by sharks that have occurred in connection with sea disasters suggest that the sharks in a wide area of the surrounding sea may somehow be attracted to the site. In sharks the lateralis system is large and well developed. It consists of fine canals, filled with watery solution, that are just beneath the skin of the head and along both sides of the body. (In the primitive frilled shark the lateral lines appear as open grooves.) The canals are connected at intervals to the surface through tiny

AUTHOR EXAMINES the eye of an anesthetized mako shark with an ophthalmoscope. The fish can safely be kept under anesthetic for as long as 20 minutes. It has been lifted horizontally from the water by an electric hoist and placed on the dock for examination.



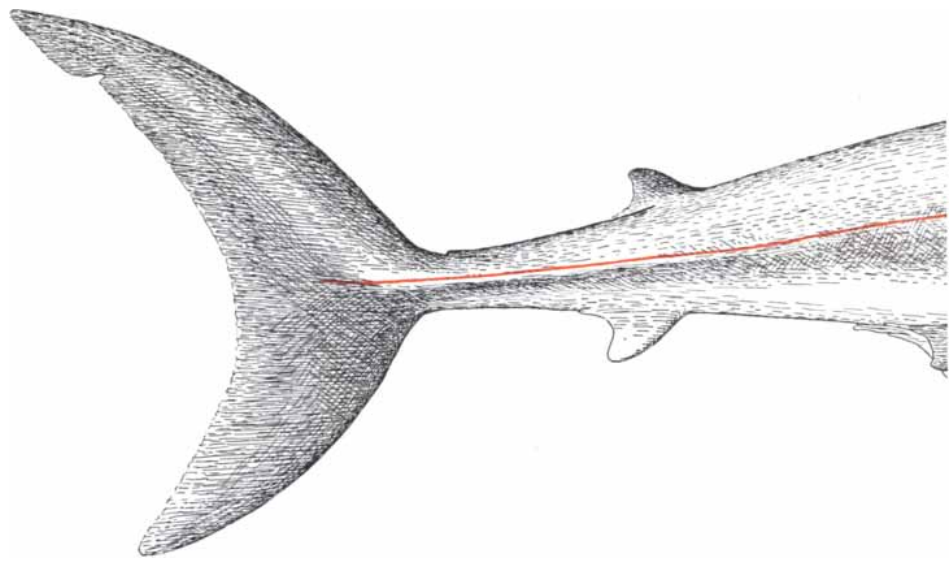
BLACK PLASTIC EYE SHIELD is inserted into a lemon shark's eye by the author. After the other eye had also been occluded, the fish was returned to the water for observation of the effects of blindness on its ability to locate chunks of bait placed in its pen.

tubules and pores. Clusters of sensory cells called neuromasts are arrayed along the inner surface of the canals. From the neuromasts bunches of tiny hairlike processes reach into the fluid that fills the canal. This structure plainly suggests that any movement of the fluid must cause the neuromast processes to move ever so slightly and thereby trigger the firing of a nerve impulse. Movement of the fluid could well be induced by a mechanical disturbance in the water such as the erratic movements of a wounded fish or the splashing of a human swimmer.

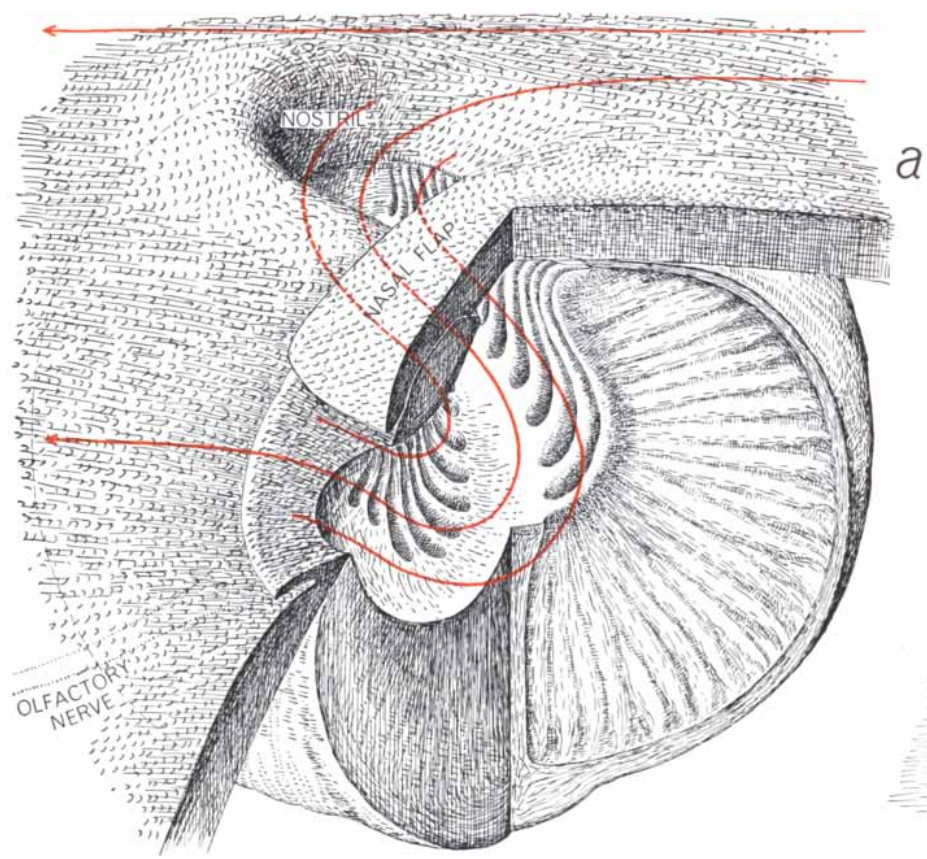
Nearly half a century ago George H. Parker of Harvard University found that a shark deprived of the senses of sight and of hearing would continue to respond to a source of disturbance in the water as long as its lateralis system remained intact. When Parker severed the nerve-trunk connections of the lateralis system, however, the shark ceased to respond.

Recently Otto E. Lowenstein of the University of Birmingham suggested that the system may serve to "echo-locate" objects by measuring the time relations of reflected vibrations set up by the swimming movements of the fish itself. This would be a particularly useful faculty in water that is too turbid or dark for the fish to see in. Just how sensitive the lateralis organs are and at what distances they can detect disturbances are unanswered questions that confront the ingenuity of the investigator.

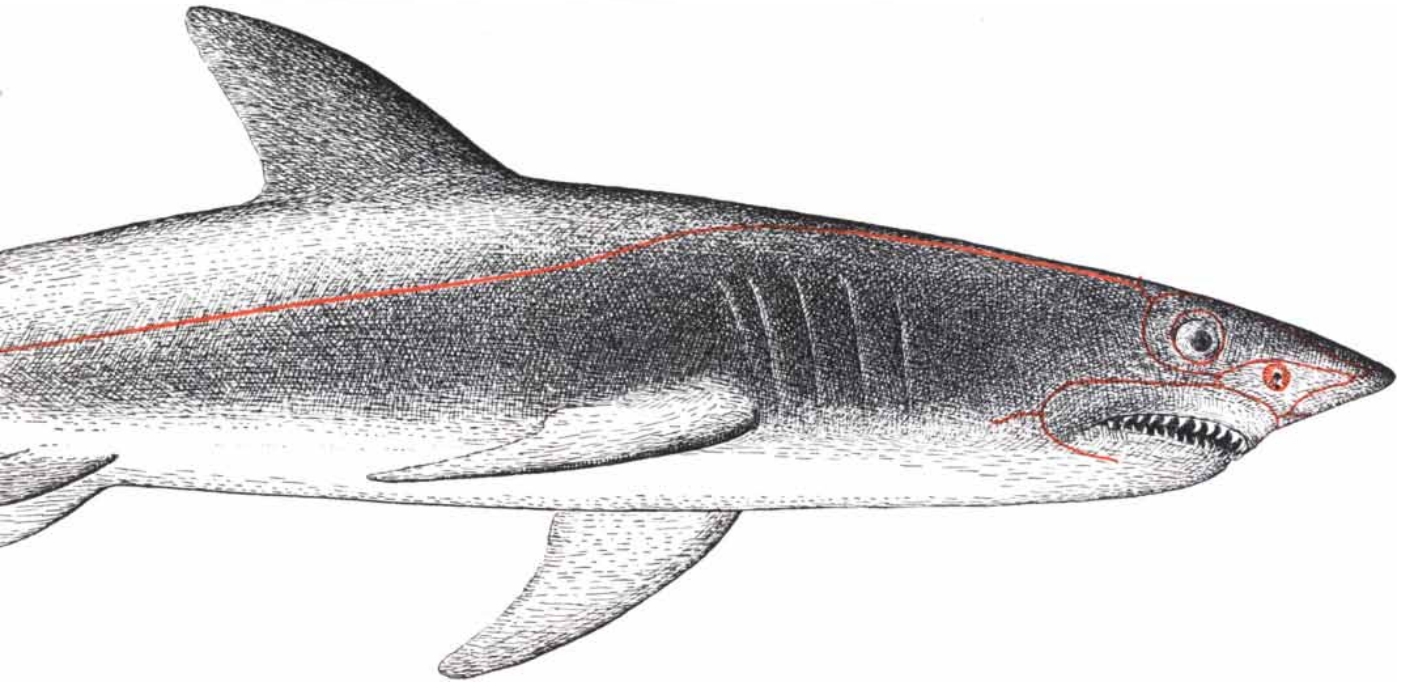
Against the argument still heard from some quarters that vision plays a minor role in the feeding behavior of sharks, the anatomy of the shark's eye presents conclusive evidence. In its basic design this eye is a somewhat flattened version of the standard vertebrate eye, with iris, lens and retina and three fluid-filled chambers contained within the tough cartilaginous envelope of the sclera. Since the retina of the shark has no cone cells (except in one species), it can be concluded that the shark sees no color and has a vision of low acuity. On the other hand, the shark's retina is abundantly supplied with rods, which give it high sensitivity to contrasts of light and shadow and to motion. This sensitivity is greatly amplified by an extraordinary structure, the *tapetum lucidum:* a mirror-like reflecting layer that underlies the retina. Made up of tiny plates silvered with guanine crystals, the tapetum reflects incoming light back through the retina, thereby restimulating the light-sensitive rods. The tapetum thus helps



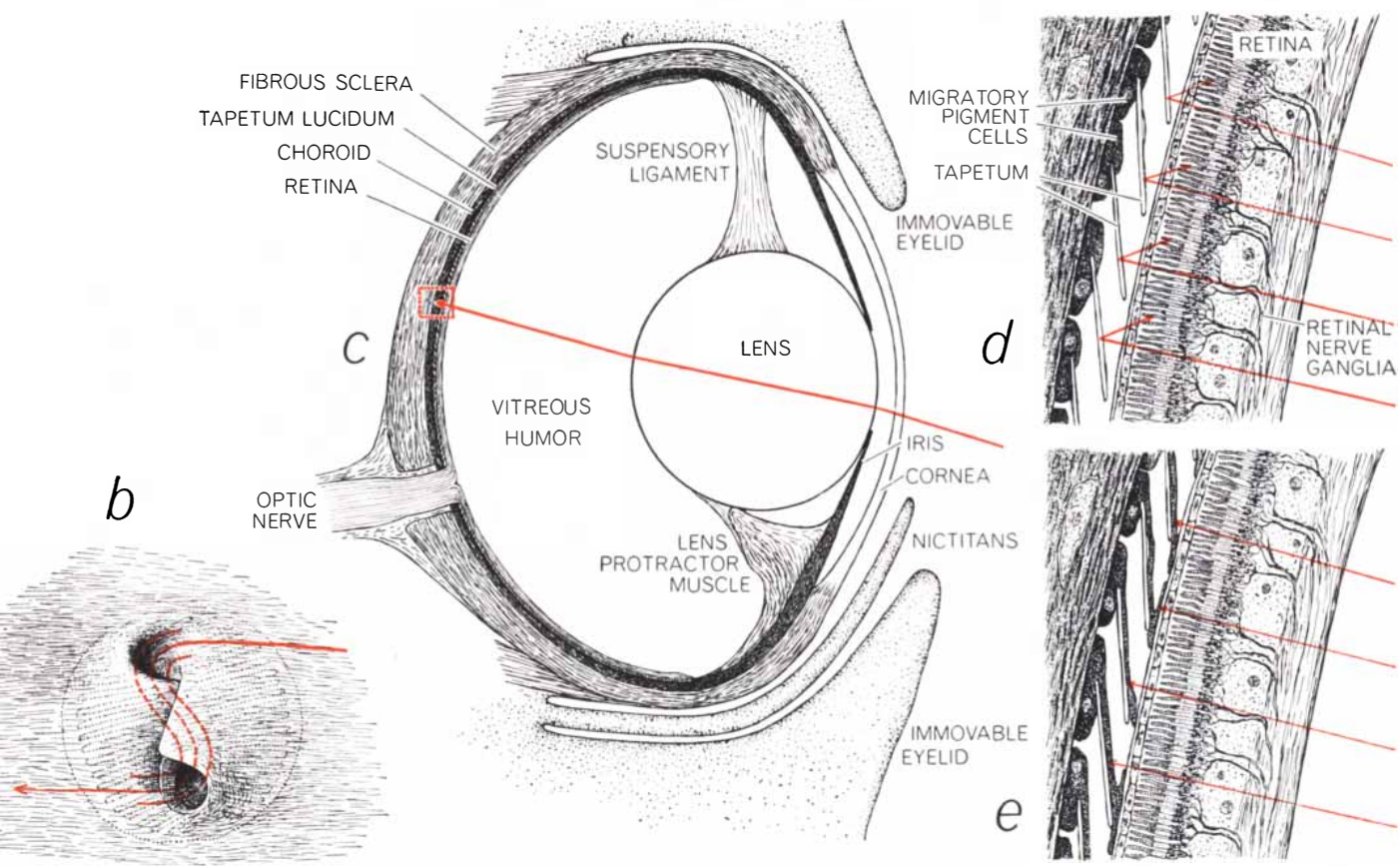
MAJOR SENSORY SYSTEMS guiding the predatory activities of the shark are the visual, the olfactory and the lateralis system, or vibration sense. These three are indicated in color



OLFACTORY AND VISUAL SYSTEMS of the shark are outlined. Each nostril opens into an olfactory sac (*a*), which is connected with the olfactory nerve. The sac is lined with folds of tissue containing the olfactory cells. These folds increase the olfactory surface and thus enhance the shark's sensitivity to the odors carried on the currents of water that bathe the sac. A fleshy flap (*b*) across the entrance to the sac divides the nostril, separating the



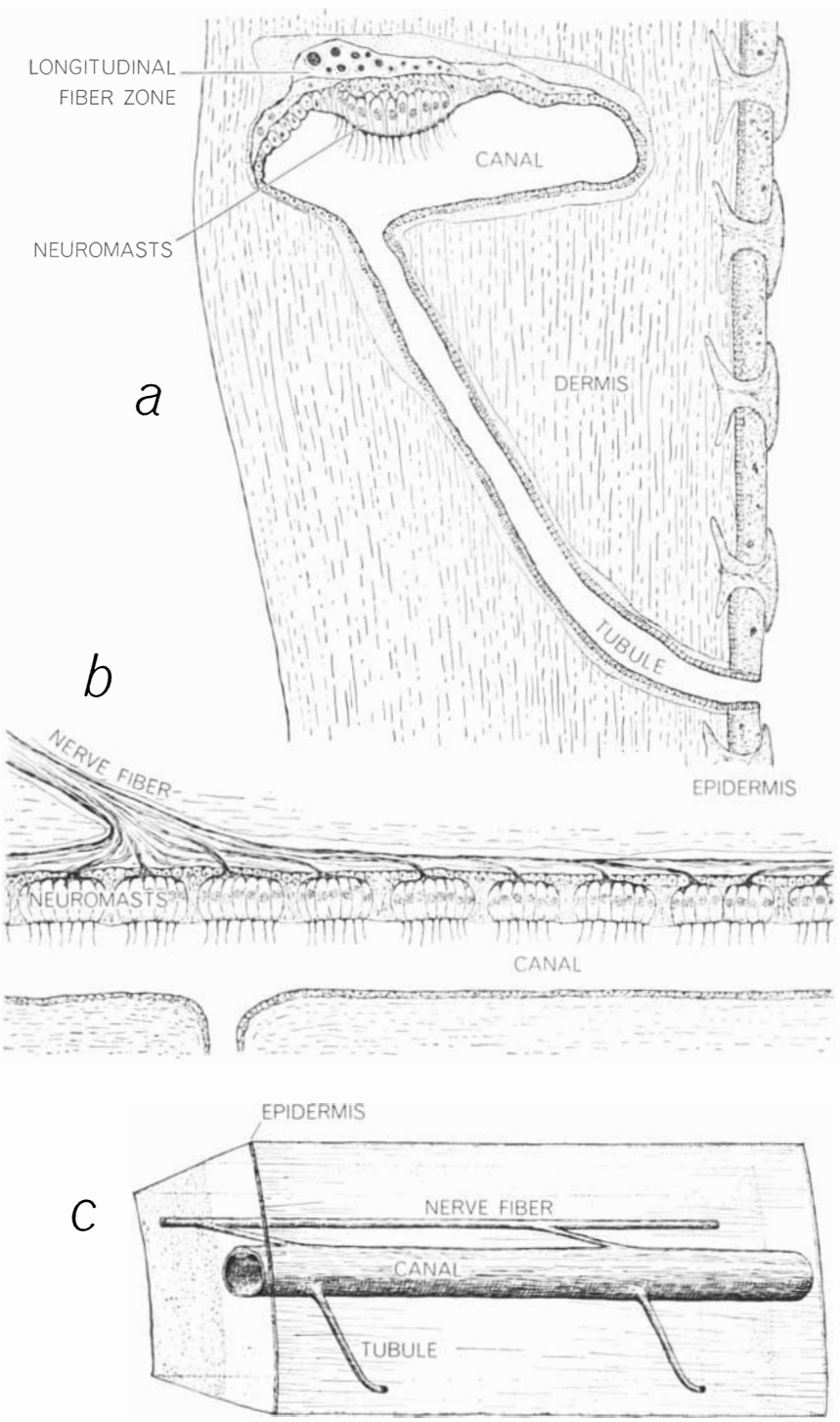
in this drawing of a mako shark. The visual and olfactory systems are localized in the head. The lateralis system has branches both in the head and along each side of the body. All of the shark's sensory systems are connected with appropriate centers in the brain.



inflowing and outflowing water. The colored lines show this current flow. In design the shark's eye (*c*) is similar to the standard vertebrate eye. Most species have a movable eyelid, the *nictitans*, which protects the eyeball. The retina of only one species has cones, but all have many rods. Sharks therefore have high visual sensitivity. Behind the retina is the *tapetum lucidum* (*d*), a series of plates silvered with guanine crystals, which reflects light back through the retina. Many species of sharks have pigment cells in front of the tapetum that expand to cover the plates when it is light (*e*) and contract when the shark becomes dark-adapted.

shark species that feed at night or in very deep water make the most of the scant amount of light entering the eye.

In the species that feed during daylight hours this remarkable anatomical adaptation is compensated by another one: a curtain that temporarily occludes the tapetum. Pigment-containing cells expand by reflex over each tapetal plate as the shark moves into bright light. Conversely, as the shark becomes dark-adapted, the pigment cells contract, thereby uncovering the reflecting surface. The movement of the pigment curtain can be seen by looking into the dark-adapted eye of an anesthetized shark with an ophthalmoscope. In some shallow-water species the lower half of the tapetum, which faces upward toward the light, is permanently occluded. Only the upper portion of the tapetum, aimed toward the bottom over which the shark is swimming, reflects light back to the visual cells of the retina.

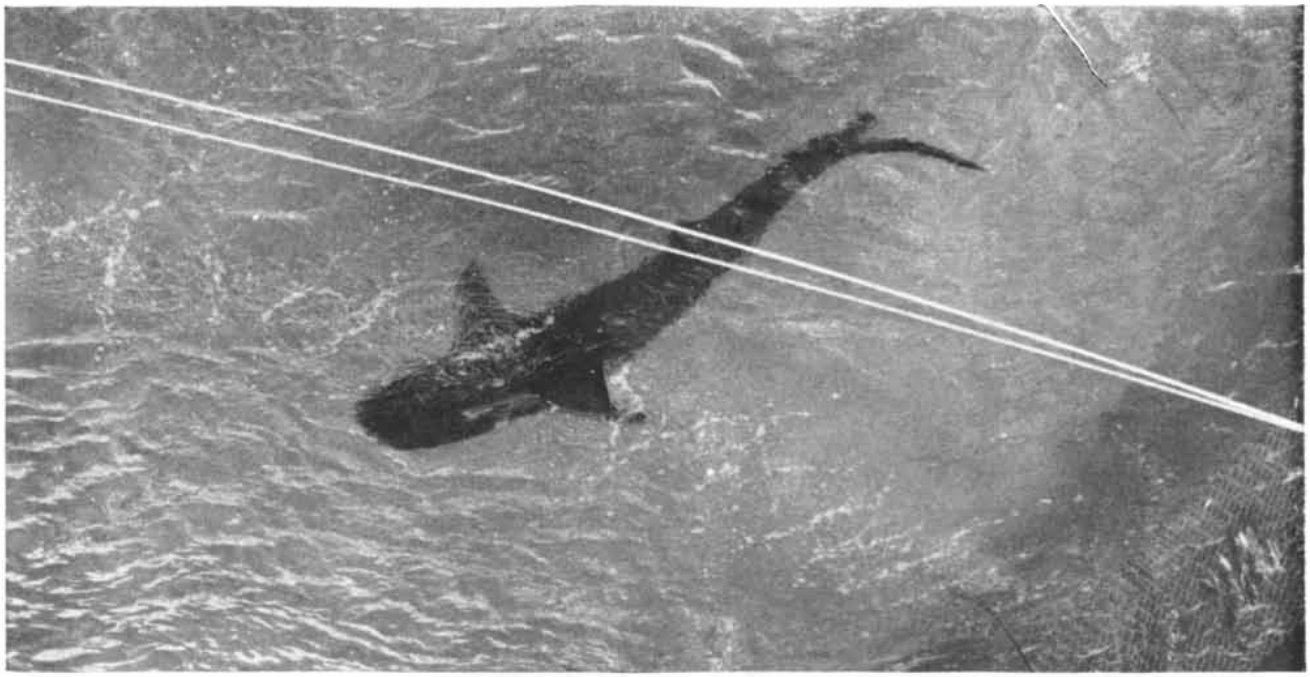


LATERALIS SYSTEM enables the shark to sense movements of the surrounding water. The system comprises a series of fluid-filled canals in the head and along each side of the trunk. The canals, seen here in three views, lie beneath the skin and open to it through small tubes. Neuromasts, hairlike processes connected to the nervous system, extend into the canals from their inner walls. Movement of the fluid in the canals, produced by disturbances in the water outside, causes the neuromasts to move and thereby triggers release of a nerve impulse.

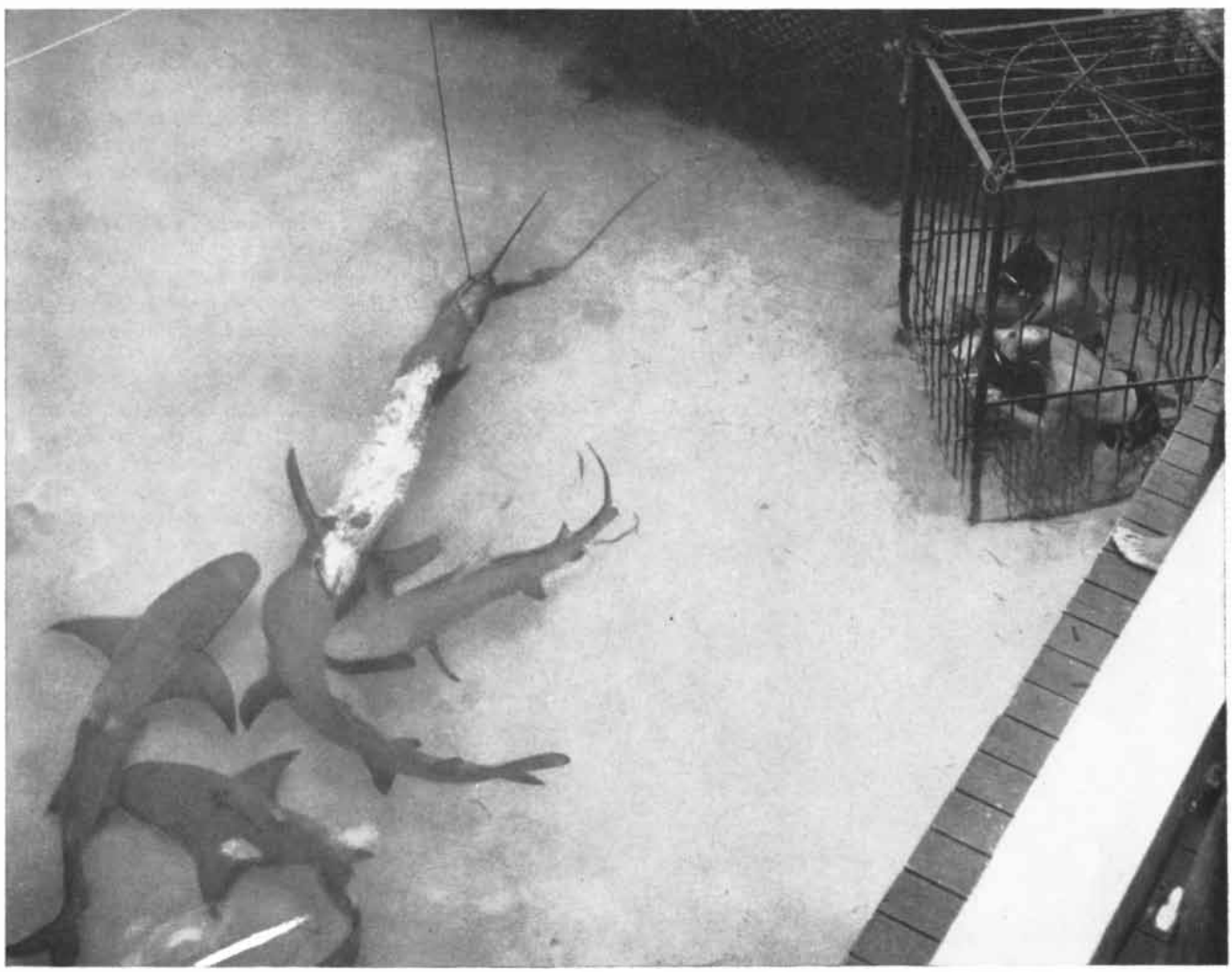
Eugenie Clark of the Cape Haze Marine Laboratory has recently tested the ability of an adult lemon shark to distinguish visually between targets of various shapes. She presented the fish with a diamond and a square, rewarding it with food when it pressed its snout against one and punishing it by bumping its snout when it pressed the other. Although both targets were white, the shark had little difficulty in learning to discriminate between them. It did have difficulty, however, when presented with a circular and a square target, both white; apparently it could not clearly distinguish these differences in shape. On the other hand, responding to difference in brightness, the shark learned to distinguish between red and white targets of the same shape fairly easily.

Our experiments at Bimini have clearly demonstrated the importance of vision in the feeding behavior of the sharks. A shark that can see has no trouble locating bait. On the other hand, sharks temporarily blinded by opaque plastic eye shields have great difficulty finding their food. Vision may not be a major factor in guiding sharks that swim in turbid waters. In very clear water such as prevails at Bimini, however, vision becomes important as soon as the shark is within 50 feet of a stationary or slowly moving lure. Thereafter, as the distance from the lure diminishes, the importance of vision increases. By the time a shark is 10 feet from its prey its sense of sight is probably its principal guide.

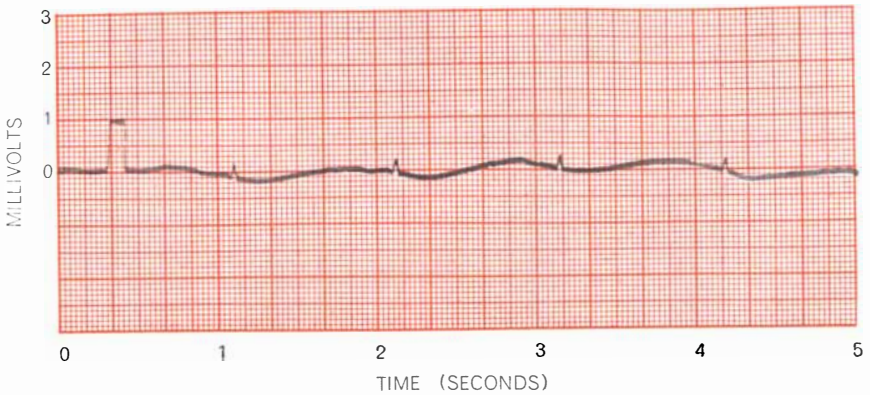
The sense of sight, in fact, is the target of what appears to be the only effective, although not universally practicable, shark repellent, the discovery of which was an inadvertent by-product of the wartime experiments with decomposed shark flesh and copper acetate. In some of these experiments nigrosine dye was added to the other ingredients. The repellent incorporating the dye was found to be effective against many species of shark. Indeed, the dye is effective entirely by itself. If an open bottle of nigrosine dye is placed in a circular tank with a free-swimming shark, the dye will gradually diffuse through the water, coloring it black. As the dye spreads from the center, the shark alters its pattern of



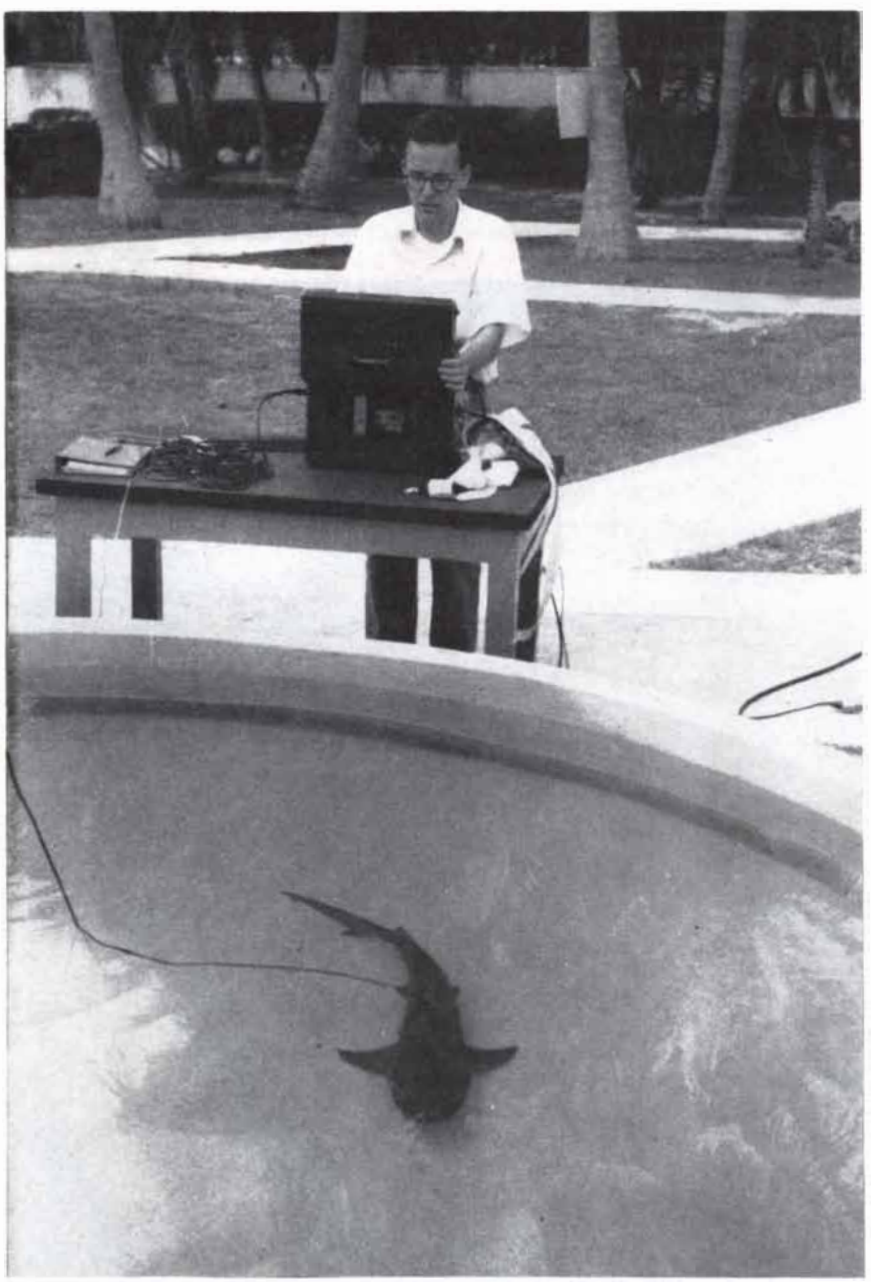
BUBBLE CURTAIN, proposed as a means of protecting swimmers against shark attacks, is produced by pumping compressed air through a perforated hose. Experiments with tiger sharks at the Lerner Laboratory showed the bubble curtain to be ineffective.



GROUP OF LEMON SHARKS preparing to attack a 450-pound chunk of marlin was observed from an underwater cage. One fish moves in for the first bite. Then the others follow, each becoming more agitated until what is known as a "feeding frenzy" develops.



ELECTROCARDIOGRAM of a young lemon shark shows that its heart beats 50 times a minute. The first upward deflection standardizes the machine's response to one millivolt of current. Each subsequent deflection represents a ventricular excitation of the shark's heart.



SHARK swims freely in a circular pool while its electrocardiogram is made. These experiments represent the first time such measurements have been made of free-swimming sharks.

swimming to avoid the dark area, restricting its movement to the spots that remain clear. By the time the dye bottle is completely empty, the shark has been penned in a small, crescent-shaped segment of the tank, near one side. This effect is not produced by the smell of the dye; a shark with plugged nostrils will also avoid the dyed areas of the tank. If, however, a shark is fitted with opaque eye shields, it will swim straight through the dyed water.

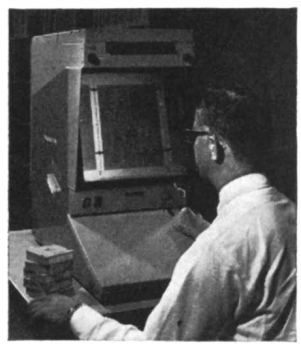
In the large pens at Bimini we are now studying, with the help of underwater motion-picture photography, the behavior of sharks at the moment they attack and consume their prey. When a large dead fish such as a 400-pound blue marlin is offered, lemon sharks first slowly circle it at a distance of six to 10 feet. Then, as they swim faster, the circle tightens and presently one shark moves in for the first bite. Contrary to popular belief, the shark seldom rolls on its side. Braking its forward motion with its large pectoral fins, the shark points upward slightly as its mouth makes contact with the bait. It opens its jaws wide, the lower jaw dropping downward and the upper jaw protruding markedly from beneath the thin upper lip. If the first bite does not give the shark an adequate hold, it bites a second and third time until it anchors its teeth deeply. Then it closes its jaws and shakes the entire forward part of its body violently from side to side until it has torn 10 to 15 pounds of tissue from the marlin. Still shaking its head vigorously from side to side, the shark swims quickly away.

As the blood and body juices of the marlin flow from the wound, the other sharks in the pack become more and more agitated and move in rapidly for their share of the meal. Frequently three or four sharks will attack the marlin simultaneously. A wild scene, sometimes called a "feeding frenzy," now ensues. The behavior of the animals appears to be determined entirely by the visual sense. An observer can substitute tin cans and wooden boxes for the marlin, and the sharks will indiscriminately attack and consume them. It is clear that any effective shark repellent will have to take effect long before the animals go into a feeding frenzy. Research on living sharks is, however, still relatively young. Although there is much to be learned about these remarkable fish, the work now under way in many parts of the world holds out hope that new and better methods can be found to protect man from attack by sharks.

Kodak reports on:

microfilm to paper in 30 seconds . . . how to tie up a transamidinase . . . modulation transfer curves for film

Retriever for sale



So you think information-retrieval schemes have been over-automated to the point of silliness, do you? You may be right.

Let us assume no army of wise (but personally unambitious) scholars has been raised to encode all knowledge that has been accumulated through all past time in a given field. Let us merely assume that you have a collection of microfilm and a rough idea of how its content is organized. Let us assume that you have a new machine known as a RECORDAK LODESTAR Reader-Printer, Model PES. You want to retrieve.

Select a likely cartridge of your microfilm and insert it into the reader. This action illuminates the screen and starts the motors. A flick of a lever threads the film into the machine and regulates the speed of film advance or rewind up to 600 feet per minute. Such high searching speed is made possible by a miraculous sensing device, the human eye, assisted by a scale on the side of the screen and a touch of foresight in having done the microfilming with a camera that exposes index marks alongside the document images.

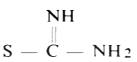
With the desired image centered on the screen, press the "PRINT" button. Thirty seconds later there emerges before you a neatly cut 8½″ x 11½″ positive copy of the retrieved microfilm document, truly photographic in quality, dry in seconds. Each additional print of the same image takes 17 seconds to deliver. Search can be resumed 17 seconds after the "PRINT" button is pressed. Only one processing solution is used, and it's good for one week or 150 prints (whichever comes first). No darkroom facilities are required.

The machine stands 31″ high, 16″ wide, and 28½″ deep; weighs 143 lbs.; is sold for $2650 by Recordak Corp., 770 Broadway, New York 3, N. Y. (Subsidiary of Eastman Kodak Company).

—SH

Some obscure organic compound is first synthesized in 1937 or 1927 or 1887. Investigators of a later generation who base a technique on the compound get scant credit for gall suffered and gold spent on the dreary old synthesis, however grimy the bottoms of any pitfalls discovered.

Consider *1,1′-Dithiodiformamidine Dihydrochloride*. It has been found to split and provide



that seems to seek out active sulfhydryl sites on transamidinases with which it forms disulfide links, with the result that the transamidinase cannot transfer metabolic amidine until something like cysteine comes along that is more attractive to the thioformamidine and breaks the blockage (*Archives of Biochemistry and Biophysics, 86*, 80). By offering it as EASTMAN 8479 we hasten fuller knowledge of enzyme action.

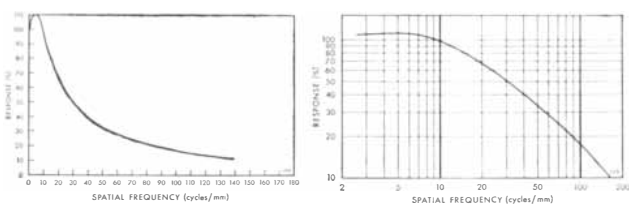
We are not vain men but merely ambitious men who are just as eager to sell this as any of the 3900 other Eastman Organic Chemicals available from Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).

No snow job

Flip through one of those magazines that point high on the taste-making hierarchy. Look at those ads. Notice that nearly all depend on photographs to generate emotion. Very potent. Here dangles the carrot that powers the economic machine. Here, in an extremely important function of photography in today's world, a subjective attitude by the viewer is intended and achieved with ever more resounding success.

At the same time and with no less skill, success, or importance for today's world, photography (a word becoming quite difficult to define) is being wrung as dry as possible of subjectivity.

Hopped up on information theory, habituated to the tube-handbook way of life, harried by urgent need to watch some vane flutter fifty miles high in the sky, heavy-footed engineers are trampling on the nuances where the grapes of art are stored. Curves they want, not adjectives. Curves they shall have. Like these for KODAK ROYAL-X PAN RECORDING FILM:



53 sets of them. They have just been published in "Modulation Transfer Data for KODAK Films," a pamphlet obtainable free from Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.

This is not a snow job. We have thought it worthwhile to go to a great deal of trouble to obtain these data from actual measurements on actual film.

To spend great gobs of engineering time on a system and then shop for film to run it on with the question, "What's the resolving power?" is naive.

"Then what would you suggest, bud?" counters the engineer.

Now, for the first time, we can do better than mumble something scientific in answer. The resolving power, which was never very objective, is now merely a point on the curve. Unfortunately, a single number like that isn't quite enough.

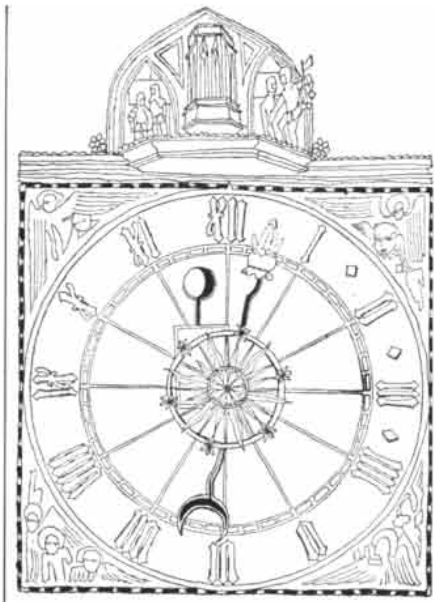
Much work still lies ahead. Publication of these modulation transfer curves for KODAK films may hasten the advent of modulation transfer curves for lenses. In the meantime, it is possible to work backward by measuring the over-all modulation transfer function and "dividing" it by the function the pamphlet gives for the film. As a simpler expedient to aid in distinguishing the feasible from the unfeasible, one can use the modulation transfer function for a perfect (i.e. diffraction-limited) lens. It's included with the pamphlet.

A review paper on all this entitled "Methods of Appraising Photographic Systems" has been much in demand not only by instrumentation and communication engineers but by scientists as well. Perhaps they are troubled as to the validity of their experimental assumptions. If you ask for the curves but not for the review paper, we shall assume that you already have it or are too well informed to need it.

Price subject to change without notice.

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

SCIENCE AND



The Effects of Nuclear Weapons

The Department of Defense and the Atomic Energy Commission have published a third, revised edition of *The Effects of Nuclear Weapons.* As in the 1957 edition (the first edition was published in 1950), 20 megatons is the upper limit of explosive power for which effects are detailed, but with the help of scaling laws the reader can compute "the effects to be expected from a nuclear explosion of any prescribed TNT equivalent." In the present edition the estimate of the intensity of the initial radiation from early fallout has been doubled, and it is pointed out that chance concentration of fallout particles can vastly multiply the hazard of residual radiation at large distances downwind.

New material includes effects on radio communications and radar, more extensive treatment of civil defense measures and appendixes on nuclear-weapons safety and on the detection of distant nuclear explosions in the atmosphere and underground. A "corrected page" inserted after the book was bound reflects the experience of Project Gnome, undertaken last December to show that an underground test could be "decoupled" and so concealed by firing it in a salt bed. The original page 689, still in the book, reads: "In other words, salt has a decoupling factor of about 2.5 compared to tuff for a tamped explosion." The corrected page reads: "Salt has a coupling (rather than a decoupling) factor of 2.5 compared to tuff for tamped nuclear explosions."

Some effects of nuclear weapons not covered in the handbook are treated in a symposium on the medical consequences of thermonuclear war in the May 31 issue of *The New England Journal of Medicine.* The authors are physicians and physicists associated with the medical schools and universities of the Boston area and organized as Physicians for Social Responsibility. Adopting the model 1,446-megaton attack on the continental U.S. featured in the civil defense hearings of the Joint Congressional Committee on Atomic Energy held in 1959, they consider in detail the consequences of the 20 megatons scheduled for Boston in that attack.

Since the explosion is assumed to have taken place at the ground, the effects of blast and fire have been minimized, but local fallout is severe. Somewhere between 739,000 and 2.24 million people have been killed outright. Among the dead are 4,850 physicians. The 640 physicians who have escaped without injury, assisted by the 260 physicians not incapacitated by their injuries, now face the task of caring for between 900,000 and 1.53 million injured. With 1,000 to 1,700 injured persons per doctor, "most of the fatally injured persons will never see a physician, even for the simple administration of narcotics.... Many of those injured who might survive with adequate care will also die. Burn injury is likely to cause the greatest number of casualties.... But thousands of patients will also present fractures, ruptures of internal organs, penetrating wounds of the skull or thorax and infections; many, in fact, will suffer all these and burns as well." The sorting out of the more "salvageable" injured will be "made even more difficult by the presence of radiation injury.... The necessity of making quick judgments involving life-and-death decisions for individual patients after only cursory examination... would represent a profound and difficult reversal in the attitudes and performance of the physician."

In the aftermath of the catastrophe the authors foresee unprecedented public health problems: "It is likely that the vectors of epidemic disease would survive radiation injury better than the human population. Eastern equine encephalitis, hepatitis, poliomyelitis and other endemic disease could easily reach epidemic proportions under these circumstances." Prompt disposal of the

THE CITIZEN

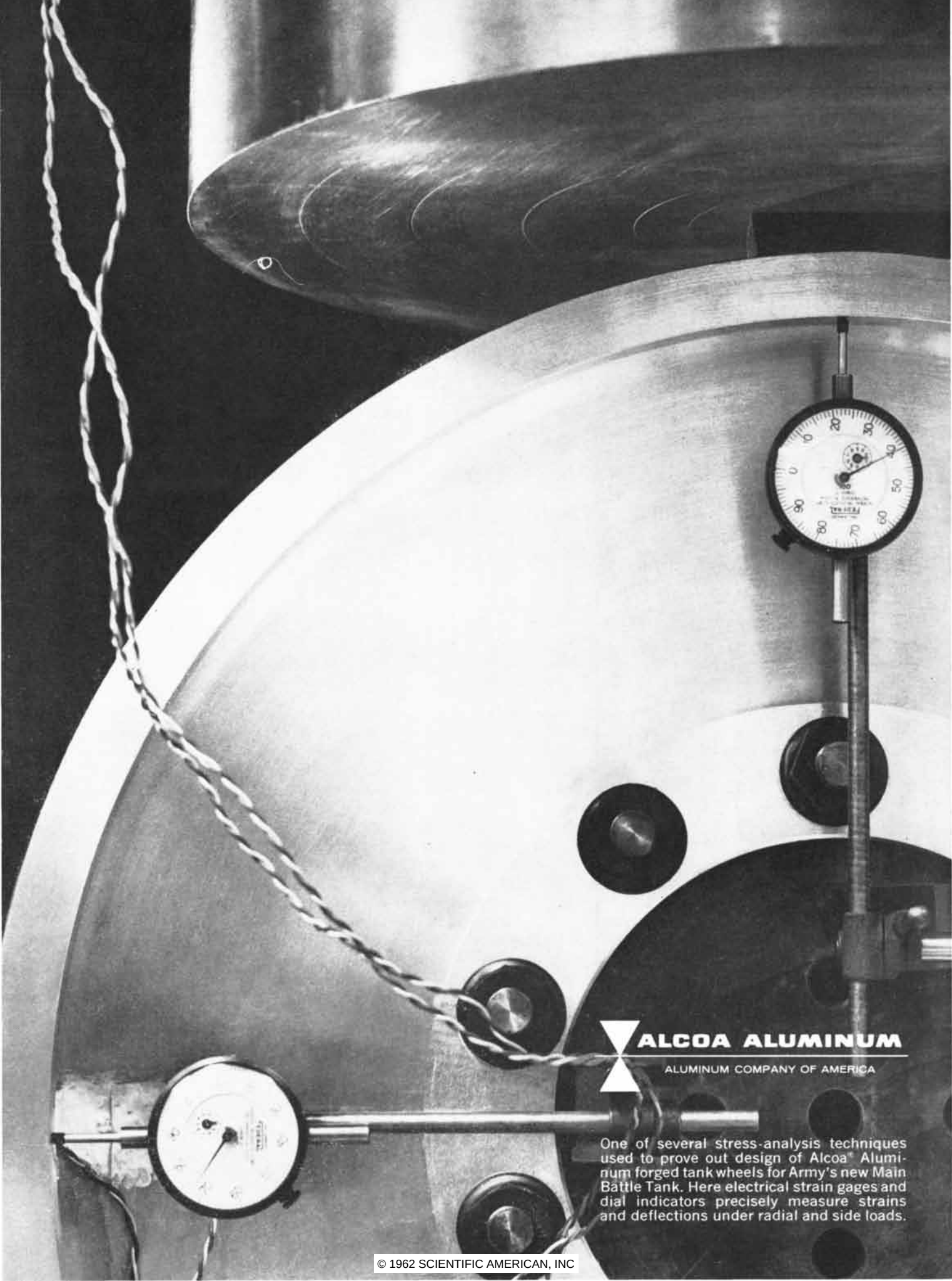
dead will be essential "for control of epidemic disease and its vectors, flies and rodents" and for "equally important, though less apparent," psychological reasons. Citing a study by the Office of Civil Defense Mobilization, the authors concur in the view that "the demolished city must be fenced in or cordoned and placed under quarantine."

The "*planning* for a potential disaster on a global scale," the authors conclude, already lays a chronic stress on individuals and society for which "famine, slavery and plague" provide more relevant historical experience than wars. They urge that physicians explore "a new area of preventive medicine, the prevention of thermonuclear war."

The Effects of Weapons Tests

Two reports with somewhat different points of view toward radiation from fallout (and other sources) have been published in the past few weeks. The Federal Radiation Council, a group set up to advise the President on radiation health problems, has concluded that "nuclear testing through 1961 has increased by small amounts the normal risks of adverse health effects." One of the "principal purposes" of the council's report, according to *The New York Times*, was "to help end the public confusion and fears resulting from the varying and often contradictory estimates made by individual scientists." The second report, by the National Advisory Committee on Radiation, a body that advises the U.S. Surgeon General, pointed to "important gaps within current [radiation] surveillance operations," called for improvement of "radiation protection standards" and, "most important of all," for the development of "safe, effective countermeasures against all radiocontaminants of public health importance." "At present," said the committee, "the nation's countermeasure capability is inadequately developed and largely uncoordinated. It is a serious weakness which demands prompt correction."

In the Federal Radiation Council report it is estimated that the average U.S. radiation dose for a single year from fallout due to all tests through 1961 ranges from 10 to 25 millirems (a unit designed to take into account both the physical properties of radiation and its



ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

One of several stress-analysis techniques used to prove out design of Alcoa® Aluminum forged tank wheels for Army's new Main Battle Tank. Here electrical strain gages and dial indicators precisely measure strains and deflections under radial and side loads.

biological effects). Natural background radiation gives a dose of 100 millirems in the same period, and the "radiation protection guide" (RPG) for the general population is 170 millirems. This last is a figure set by the council and described by the Surgeon General as "the total radiation dose in one year considered to be an acceptable risk—that is, a risk of adverse radiation effects which is judged to be low enough to be justified by the need to release radioactive materials in connection with nuclear energy operations." Over a 30-year period the fallout dose (for all pre-1962 tests) is only 60 to 130 millirems as against 3,000 from natural background and 5,000 "allowed" under the RPG.

Since even small quantities of radiation are thought to have harmful effects, both somatic and genetic, the council estimates the damage that may be produced in the U.S. population by the above fallout levels. In the next 70 years, it finds, fallout radiation may be responsible for between zero and 2,000 cases of leukemia, compared with between zero and 84,000 cases expected in the same period from natural radiation. For bone cancer the comparable numbers are between zero and 700 cases for fallout; between zero and 14,000 for natural background. As to genetic effects, the number of "gross physical or mental defects" caused by fallout in the next generation is placed at 110. For all future generations the number is 3,000, of which 2,000 are attributed to the radioactive isotope carbon 14. "Any further testing," the report points out, "will of course increase the exposure."

Not mentioned in the council's summary tables, although it is discussed in the body of the report, is the radioactive isotope iodine 131. This isotope has a short life, decaying by half every eight days. If present in fallout, however, it finds its way into the human diet through milk, and it tends to concentrate in the thyroid gland, particularly in infants. There sufficiently large amounts of radiation can cause cancer. According to the report, "doses to the thyroid [in infants] from the major past tests were estimated to have ranged from 100 to 200 millirems per year during and immediately following periods of testing," but "it is likely that there was much geographic variation and in some limited areas of the U.S. the average thyroid doses were probably many times the national average." The RPG for radioiodine dose is 500 millirems.

In testimony last month before the Joint Congressional Committee on Atomic Energy it was revealed that fallout from the recent tests carried out by the U.S.S.R. in the Arctic returned to earth much sooner than fallout from the tests conducted by the U.S. near the Equator, and that therefore iodine 131 represented an unexpectedly large fraction of the total radioactivity during the period of the tests and the weeks following. The fallout was particularly intense in the Middle Western region of the U.S., and some infants there are believed to have received as much as four-fifths of the RPG of radioactive iodine.

Largely because the half life of iodine 131 is so short, effective countermeasures are available against the effects of the isotope. These are discussed at some length in the report of the National Advisory Committee on Radiation. Infants, nursing mothers and pregnant women in a contaminated area can drink powdered or canned milk until the iodine in the area decays to safe levels. Moreover, threatened individuals can take large doses of ordinary, nonradioactive iodine, thus saturating their thyroid glands and preventing the uptake of radioactive iodine. The latter measure is not recommended for large groups but rather for a limited number of people who might, for example, be exposed in a nuclear-reactor accident.

Although countermeasures exist, clear-cut legal authority and responsibility for putting them into effect do not. This was brought out before the Joint Committee by Russell H. Morgan, professor of radiology at Johns Hopkins University and chairman of the National Advisory Committee on Radiation. If the U.S.S.R. resumes testing soon, Morgan pointed out, the dose of radioactive iodine will probably exceed the RPG in several cities, but no agency or other branch of the Government has the responsibility for countermeasures, nor has any policy been formulated on the matter.

In the case of another constituent of fallout, the widely discussed strontium 90, the Advisory Committee report says that "there are no countermeasures... which fulfill all of the primary requirements of effectiveness, safety and feasibility." (Strontium, chemically akin to calcium, is deposited in bone. Because of its long half life—28 years—it continues to produce radiation during the lifetime of the affected individuals.)

The Advisory Committee concludes that the Public Health Service does not have sufficient funds to discharge its major responsibilities in the field of radiation: (1) to develop adequate countermeasures against strontium 90 and other potentially important radioactive species, (2) to expand monitoring fa-

cilities for radioactivity, (3) to speed up the detection and reporting of dangerously high levels of radioactivity and (4) to conduct the research necessary for the formulation of adequate radiation protection standards. These activities will require a budget of $25 million in the fiscal year 1962–1963 (the Administration has requested $16 million), and "increasing amounts each year thereafter until an annual budget of $100 million is reached by 1970."

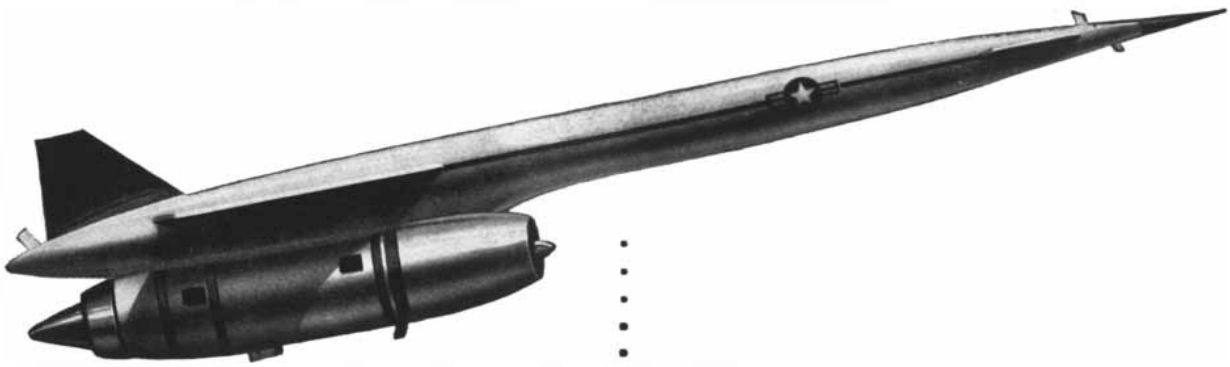
Freezing Out Ulcers

Surgeons at the University of Minnesota are treating duodenal ulcer simply by freezing the patient's stomach solid for an hour. The procedure destroys cells that secrete pepsin and gastric acids, both of which irritate the ulcers and prevent healing. More than 40 patients have been successfully treated at Minnesota, where the method has almost completely replaced the nerve-cutting operations and the partial or complete removal of the stomach that had formerly constituted standard therapy for ulcers not healed by diet or drugs. Surgery is still preferred for ulcers of the stomach proper, both because gastric-ulcer patients tolerate the freezing process less well and because of the risk of the ulcers becoming cancerous.

In the freezing technique, described in *The Journal of the American Medical Association* by Owen H. Wangensteen and several colleagues, the patient swallows a rubber balloon through which is circulated alcohol cooled to minus 20 degrees centigrade. Most people do not find the procedure uncomfortable, and its effect on gastric secretion lasts for many months, if not indefinitely. At the same time the stomach remains capable of normal peristalsis and emptying.

Co-operation in Science

The pattern of scientific co-operation established by the International Geophysical Year is currently being vigorously promoted by the U.S., Japan and the U.S.S.R. The U.S. and Japan are planning a broad program of collaborative scientific scholarship. The program, which will be unique among scientific exchanges between two nations, is being organized by a joint committee of U.S. and Japanese scientists. At a meeting in Washington in May the committee worked out proposals for co-operation in five areas: (1) exchange of scholars in the sciences, (2) exchange of scientific and technical information and materials, (3) scientific investigations of the Pacific



Putting Teeth in the "Hound Dog"

The GAM-77 "Hound Dog" air-to-surface missile is armed automatically by a Mallory program timer after launching from a plane. The all-solid-state Mallory timer can be set from the plane to start the arming process after a "Hound Dog" is unleashed. Nowhere is dependability of components more vital than in this missile, made for the Air Force by North American Aviation.

Mallory makes many other kinds of ultra-dependable solid-state devices—both as separate building blocks and complete functional assemblies—to make things happen in the right sequence, to sense and respond to stimuli, to channel power where it's needed. Some of these devices already are giving the important commands in all sorts of military electronic systems, and many are calling the shots into outer space.

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Imagination in electronics and metallurgy

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Ocean, (4) animal and plant geography and ecology of the Pacific area and (5) cancer research. Although funds have not yet been appropriated for the program, the meetings of the committee are sponsored by the two governments.

Dmitri I. Blokhintsev, a leading Soviet physicist and head of the Joint Nuclear Research Institute of the Communist-bloc countries, has proposed that the U.S. and the U.S.S.R. join in building an accelerator capable of producing subatomic particles with energies of a trillion electron volts. The largest accelerators now in operation are the 30-billion-electron-volt machines at the Brookhaven National Laboratory and the European Center for Nuclear Research (CERN) in Geneva.

President Kennedy has made a new appeal for the U.S. and the U.S.S.R. to co-operate in space research. Such co-operation, which was originally suggested by Premier Khrushchev after the orbital flight of John H. Glenn, Jr., has so far only been in the discussion stage. It is proposed that the two nations collaborate on projects in the exploration of space, satellite communications and the observation of weather by satellites.

Universal Genetic Code?

Unquestionably the most exciting development in biology in the past year has been the breaking of the genetic code. The code is embodied in the hereditary molecule deoxyribonucleic acid (DNA), which carries the plans for the thousands of proteins manufactured by the living cell. These plans are expressed in a "four-letter alphabet" in which the letters are the four molecular units called bases contained in DNA. The break came originally from experiments in which extracts of colon bacilli were combined with synthetic ribonucleic acid (RNA) containing known amounts of the four bases. This RNA substituted for "messenger RNA," which normally carries the genetic message from DNA to the ribosomes, the cellular particles where proteins are assembled. With the code for one species of bacteria deciphered, the question arose whether or not the same genetic language would apply to all living cells.

Striking evidence that the code may indeed be universal is reported in the May issue of the *Proceedings of the National Academy of Sciences.* It has been found that when the ribosomes of the colon bacillus are supplied with RNA extracted from the tobacco mosaic virus, the ribosomes synthesize a protein that is almost precisely like the protein units

ANOTHER IN A SERIES DEPTH MANAGEMENT IN ACTION

POWERFUL SOUND FROM ANAHEIM

Sound systems to warn U. S. cities of attack . . . communications for Cape Canaveral, Hamilton Air Force Base and for Thor Missile bases . . . stereophonic sound in more than half the theaters in the U. S. — these are just a few examples of products engineered and manufactured by Altec Lansing Corporation, Anaheim, California. This LTV company also produces electro-pneumatic transducers for high intensity sound testing. Other Altec developments include loudspeaking telephone conference systems . . . condenser microphones . . . and transistorized repeater and termination bays used in the Air Force's project Quick Fix. These new products — and modern facilities such as the company's anechoic test chamber where several tons of glass fiber isolate outside sound environment — are a far cry from the early experiences of Altec Lansing's President Alvis Ward, a member of the team that produced the world's first successful "talking pictures." Throughout his career, Mr. Ward has been a key contributor to the science of sound reproduction and has at the same time guided Altec Lansing to a position of industry leadership. By combining this caliber of management in depth with proved technical competence in aerospace, electronics, communications and consumer products, LTV is furthering U. S. goals for progress, security and national well-being.

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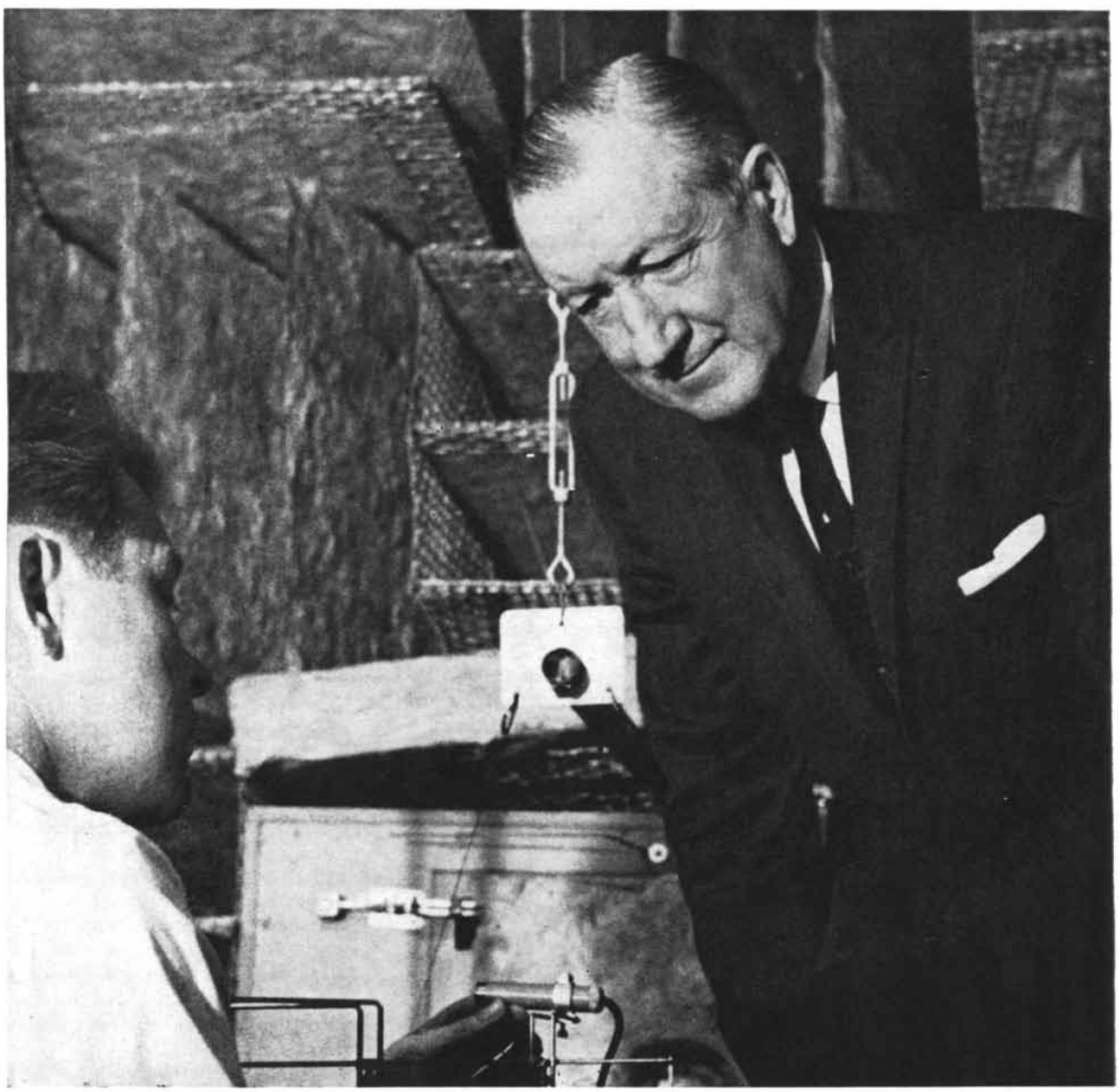


that compose the jacket of the virus. Evidently the bacterial system is able to "read" correctly the hereditary message embodied in the RNA of a virus that normally functions in a totally different biological environment, that provided by cells of the tobacco plant.

The experiment represented a collaboration between Akira Tsugita and Heinz L. Fraenkel-Conrat of the Virus Laboratory at the University of California and Marshall W. Nirenberg and J. Heinrich Matthaei of the National Institute of Arthritis and Metabolic Diseases. Nirenberg and Matthaei were leaders in breaking the genetic code.

Filling the Van Allen Belts

One of the chief anxieties expressed by many scientists over the high-altitude explosions in the current U.S. nuclear test series concerns the disruption of the Van Allen radiation belts. Predictions vary widely as to the time that will be required for the belts to be reconstituted, and no one seems to know just how the process will take place.

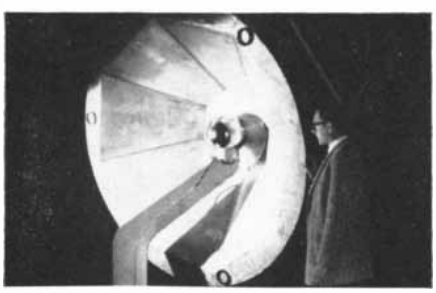
As a matter of fact, the normal mechanism by which particles are fed into the belts is still something of a mystery. It is generally agreed that the particles come from the sun, but how they get into the belt has not yet been ascertained. In a recent issue of *Nature* C. C. Chang of the Aerospace Corporation has outlined a possible injection and trapping mechanism.

Studies of the "wind" of electrically charged particles from the sun had shown that it compresses the earth's magnetic field on the "windward" side and forms a smooth, sharply defined interface between the field and particle stream. In effect the boundary acts like an elastic sheet, reflecting the charged particles that strike it. Recent mathematical analysis of the condition at the interface, however, reveals two "neutral points," or kinks, in the surface near the earth's magnetic poles, where the magnetic field is weak. Chang proposes that particles leak into the region of the outer Van Allen belts through these weak spots. Unlike the rest of the boundary, the neutral points are not stable. They oscillate, compressing and expanding the geomagnetic field and adding energy to the particles that have leaked in.

Satellite experiments, according to Chang, seem to have confirmed the existence of the solar wind and of the sharp boundary or interface between plasma and magnetic field. The postulated oscillations of the interface have not yet been directly detected.

NEW CARGO CHAMP. U. S. Air Force, flying a new Boeing C-135B turbofan cargo-jet, recently established ten new world cargo lift and speed records. These marks, certified by National Aeronautics Association, included lifting 66,000 pounds to altitude of 47,171 feet, and carrying same payload over 1,250-mile closed course at 615.81 miles an hour. This new Boeing jet logistic transport has a cargo capacity of 82,000 pounds, and can haul 126 troops nonstop over the longest intercontinental routes. C-135Bs are used to fulfill the Military Air Transport Service's primary mission of airlifting missiles, cargo and troops worldwide.

Capability has many faces at Boeing



SPACE VEHICLE control systems are tested at Boeing with this satellite attitude control simulator. Optical sensor system controls attitude through reference to light-source simulating starlight. Other Boeing space research involves propulsion, guidance, space vehicles and systems.

MINUTEMAN, right, is U. S. Air Force's solid-fuel ICBM, which will be stored in underground blast-resistant silos ready for immediate launch. Boeing is Minuteman weapon system integrator.

DASH is U. S. Navy's Drone Anti-Submarine Helicopter, designed to operate by remote control from a destroyer. Shown here on unmanned test flight, DASH, designed and built by Gyrodyne Company of America, is powered by a 270-hp Boeing T50 gas turbine engine. Boeing gas turbines, designed for reliability and easy maintenance, are used in land, sea and air applications.

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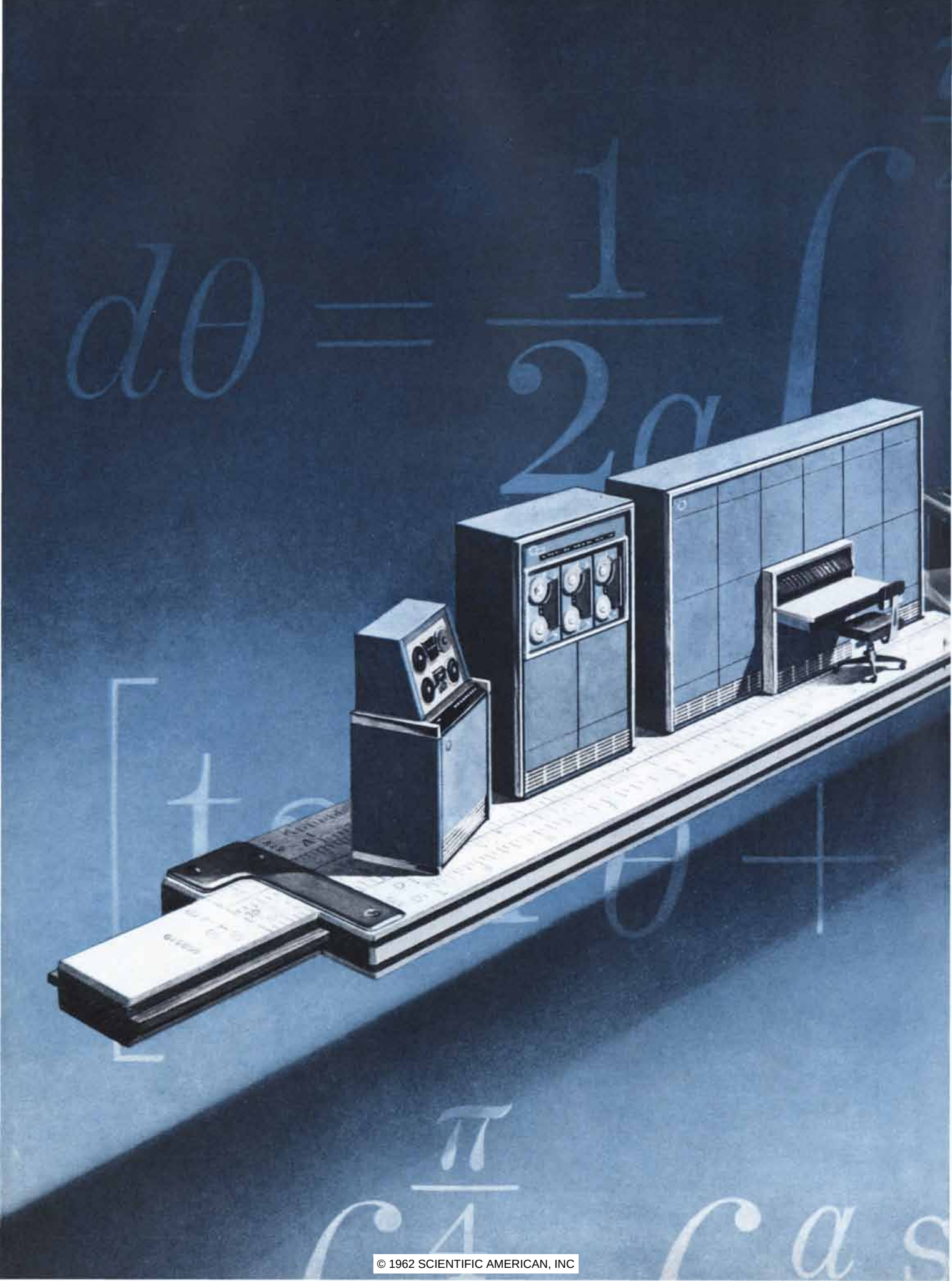

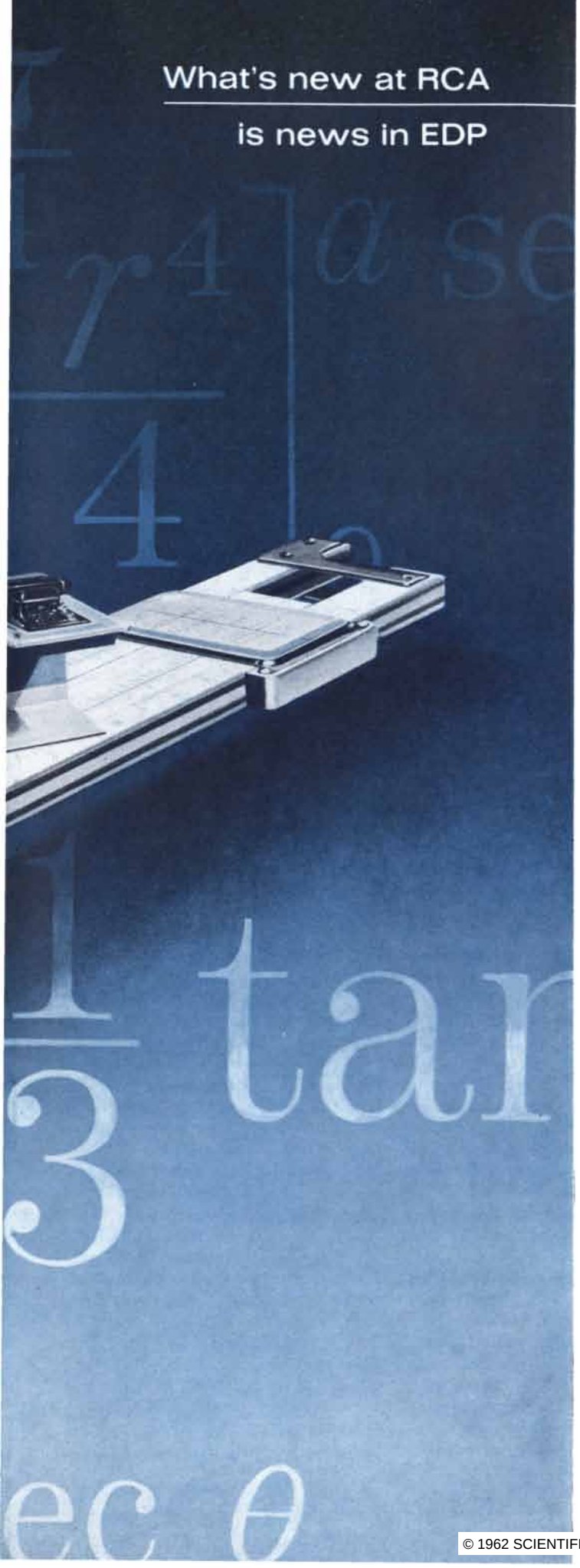

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INCLUSION COMPOUNDS

They are substances in which a molecular structure encloses atoms or molecules of another kind. They are finding uses in industry and play a role in the chemistry of the living cell

by John F. Brown, Jr.

For half a century chemists speculated that certain molecular structures might enclose other structures of suitable size and geometry. It was not until the late 1940's, however, that this form of molecular architecture was actually shown to exist. Then, as so often happens when the time is ripe, the discovery was made almost simultaneously by several different research groups. The combination is known as an inclusion compound. By 1952 examples of all six basic types of inclusion compound had been found, and since then their characteristics have been intensively studied.

Inclusion compounds are chemical combinations in which one component fits into a cavity in the other. When the size and shape of the cavity in the "host" molecule just match the form of the "guest," a combination of appreciable strength can occur. No ordinary chemical bonds between the atoms of the host and guest are needed. In well-fitted inclusion structures, in which many atoms of the host molecule are close to those of the guest, a sizable total binding force is provided by the interactions of the outer electrons in the shells of the host and guest atoms. (Such binding forces are known as dispersion forces.) The structural arrangements that allow this snug "hand in glove" fitting of molecular shapes differ from one family of inclusion compounds to another. We shall discuss the various families in turn.

Molecular Traps

It has been known for a century that quinol, or hydroquinone, widely used as a photographic developer, produces curious "complexes" when crystallized out of certain solutions. These complexes contain one molecule of liquid or gas for each three of quinol. They are perfectly stable in the dry state at room temperature, and have no smell of the occluded gas, even when it is the odoriferous hydrogen sulfide or sulfur dioxide. When the complex is melted or dissolved in water, the occluded gas is immediately evolved, showing that it is not held by stable chemical bonds.

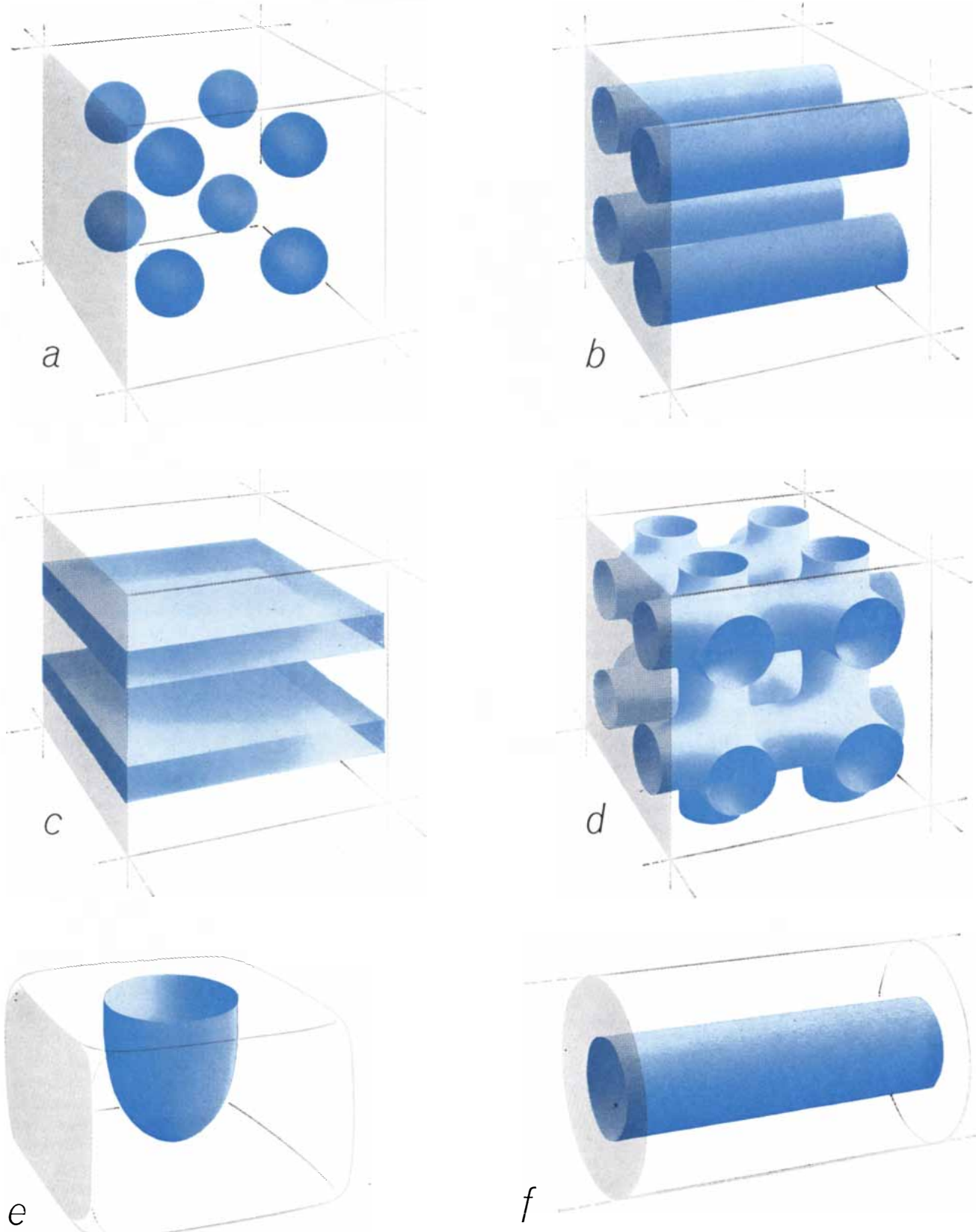
Between 1947 and 1950 H. M. Powell of the University of Oxford reported the structures of various quinol complexes. He found that the host molecules are linked by hydrogen bonds between oxygen atoms (that is, by bonds in which a hydrogen atom acts as a bridge between two oxygen atoms) to form a pair of interlocking three-dimensional networks. The networks do not, however, completely fill the available space. The cavities remaining are roughly spherical and about four angstrom units in diameter. (An angstrom is one hundred-millionth of a centimeter.) Each cavity is bounded by two circles of six hydrogen-bonded hydroxyl groups and by the benzene rings of six quinol molecules. The guest molecules lie trapped in these cavities [*see top illustration on page 84*]. Powell suggested the apt term "clathrate" (from the Latin word *clathratus,* which means enclosed by the bars of a grating) to describe this type of combination.

The quinol clathrates are formed only by molecules that can fit into the four-angstrom cavities of the host crystal. In addition to hydrogen sulfide, H_2S, and sulfur dioxide, SO_2, these include methyl alcohol (but not its closest chemical relatives, water and ethyl alcohol); formic acid, HCO_2H (but not acetic acid, CH_3CO_2H); and acetonitrile, CH_3CN (but not any other nitrile). Decisive proof that the clathrate formation depends on molecular form rather than on chemical bonding is indicated by the fact that even the inert gases argon, krypton and xenon are capable of forming stable quinol complexes.

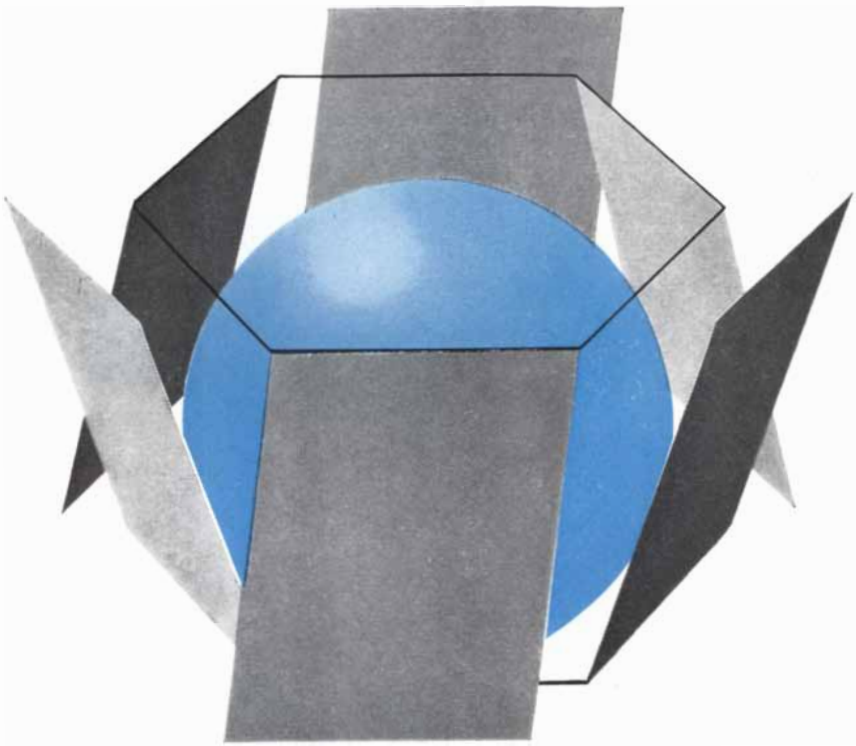
Quinol is by no means unique in its ability to form inclusion compounds. Hundreds of substances that combine in this way with solvents are known, and it appears that a large fraction of them are clathrates. Various inorganic salts can also form clathrates. An example is the complex of nickel cyanide ammine with benzene.

Many substances soluble in water contain "water of crystallization" when they crystallize out of solution. Called hydrates, most of these substances are not clathrates but contain water molecules attached by the usual chemical bonds. The substances with which water does form true clathrates are largely gases or low-boiling-point liquids, and the complexes are generally known as gas hydrates.

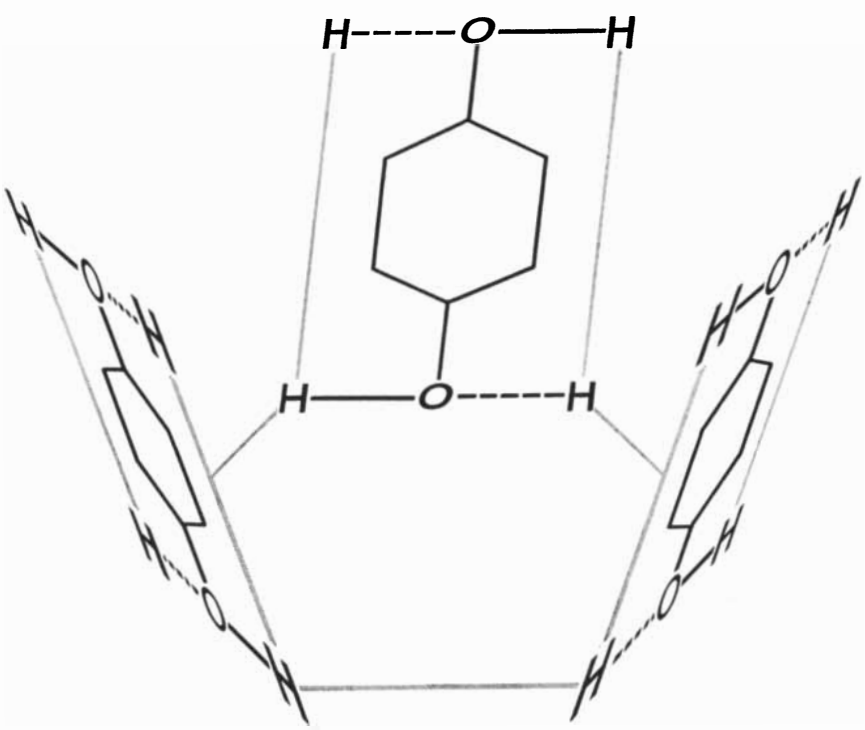
Such hydrates fall into two groups. The first usually contains six guest molecules combined with 46 water molecules; the second, one guest molecule for each 17 water molecules. The guests in the first group are small molecules such as chlorine, bromine, sulfur dioxide, hydrogen sulfide, methane, ethane, methyl chloride or methylene chloride. (The chemical formulas for these eight molecules are respectively Cl_2, Br_2, SO_2, H_2S, CH_4, C_2H_6, CH_3Cl and CH_2Cl_2.) The guests in the second group of gas hydrates are slightly larger molecules, such as chloroform, ethyl chloride, methyl iodide, difluorobromochloromethane or propane. (The formulas are $CHCl_3$, C_2H_5Cl, CH_3I, CF_2BrCl and C_3H_8.) The gas hydrates of both groups are simple crystals with low melting points. They are generally prepared by forcing the gas



INCLUSION COMPOUNDS are known in six different forms, depending on the architecture of the "host" structures and the shapes of the cavities they enclose. Clathrates (*a*) are produced when "guest" molecules fit into separate spherical chambers within a crystal lattice. Canal complexes (*b*) are formed when the host is a crystal lattice having tubular cavities. Layer complexes (*c*) are crystals with alternating layers of guest and host. Molecular sieves (*d*) are formed by crystals that contain interconnecting chambers and passageways. Intramolecular hollow space complexes (*e*) are formed when the host is a large molecule containing a concavity. Linear polymer complexes (*f*) are produced when guest molecules fit into the tube formed by a pipelike host molecule.



QUINOL COMPLEX is a clathrate. The quinol molecules (*rectangles*) fit together in sets of six to form an interlocking network. The guest molecules enclosed by six quinol molecules are seen in color. The cavity holding these guests is roughly spherical and about four angstrom units in diameter. No chemical bonds connect the guest molecules with their host.



QUINOL MOLECULES in a quinol complex are linked by hydrogen bonds between oxygen atoms (*O*). The cavities of the complex are bounded by hydroxyl groups (*OH*) and by the benzene rings of the quinol molecules. The diagram shows three molecules and their bonds.

to dissolve in water under pressure and then chilling the solution until it freezes.

X-ray crystallographic studies by M. von Stackelberg and his collaborators at the University of Bonn, by Walter F. Claussen at the University of Illinois and by Linus Pauling and Richard E. Marsh at the California Institute of Technology have shown that in these clathrates the water molecules are linked together, through hydrogen bonds, mostly in rings of five molecules rather than the rings of six molecules typical of ordinary ice. These five-molecule rings are joined together to form dodecahedrons (12-sided figures). Since space cannot be filled completely by any packing arrangement of dodecahedrons, some interstitial spaces must remain. It is these that hold the guest molecules [*see illustration on opposite page*].

One major application of gas-hydrate formation is now under study by the Koppers Company, Inc. It has long been known that fresh water can be obtained from sea water by partial freezing. The ice crystals that form are pure water; the salt remains behind in the brine. A limitation of this process as a practical means of desalination is the cost of refrigeration. This can be reduced by creating a gas-hydrate "ice" that forms at a higher temperature than does ordinary ice. In the Koppers process propane is added to cold sea water, creating the hydrate $C_3H_8 \cdot 17H_2O$, which freezes at 42 degrees Fahrenheit. The hydrate crystals are filtered off and warmed under pressure. When the crystals melt, the propane separates as an immiscible liquid, leaving pure water behind.

Very similar to the gas hydrates are the hydrates of certain salts containing hydrocarbon chains linked to sulfur or nitrogen atoms. They are known technically as trialkylsulfonium and tetraalkylammonium salts. One example is the compound $2(n\text{-}C_4H_9)_3S^+F^- \cdot 40H_2O$. The crystal lattice formed by this substance is similar to that in the gas hydrate containing 46 water molecules, except that six of the water molecules are replaced by the two ions of sulfur and two of fluorine, and the cavities are filled by the six hydrocarbon chains (C_4H_9) rather than by six gas molecules.

Another example is the hydrate with the formula $2(i\text{-}C_5H_{11})_4N^+F^- \cdot 76H_2O$. This is a surprising substance, 68 per cent water, that remains an ice until heated to 88 degrees F. Proteins also form highly hydrated crystals, containing as much as 90 per cent water, or thousands of water molecules for each giant molecule of protein. It may well be

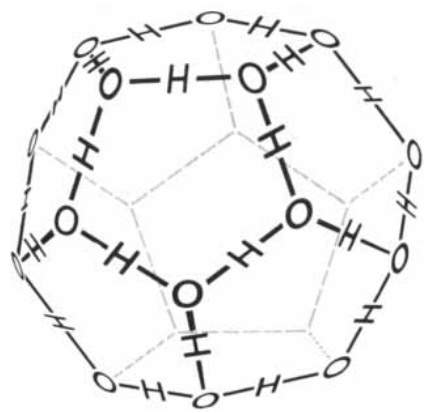
that the protein holds these water molecules in modified clathrate structures not unlike those in the hydrates of the sulfonium and ammonium salts.

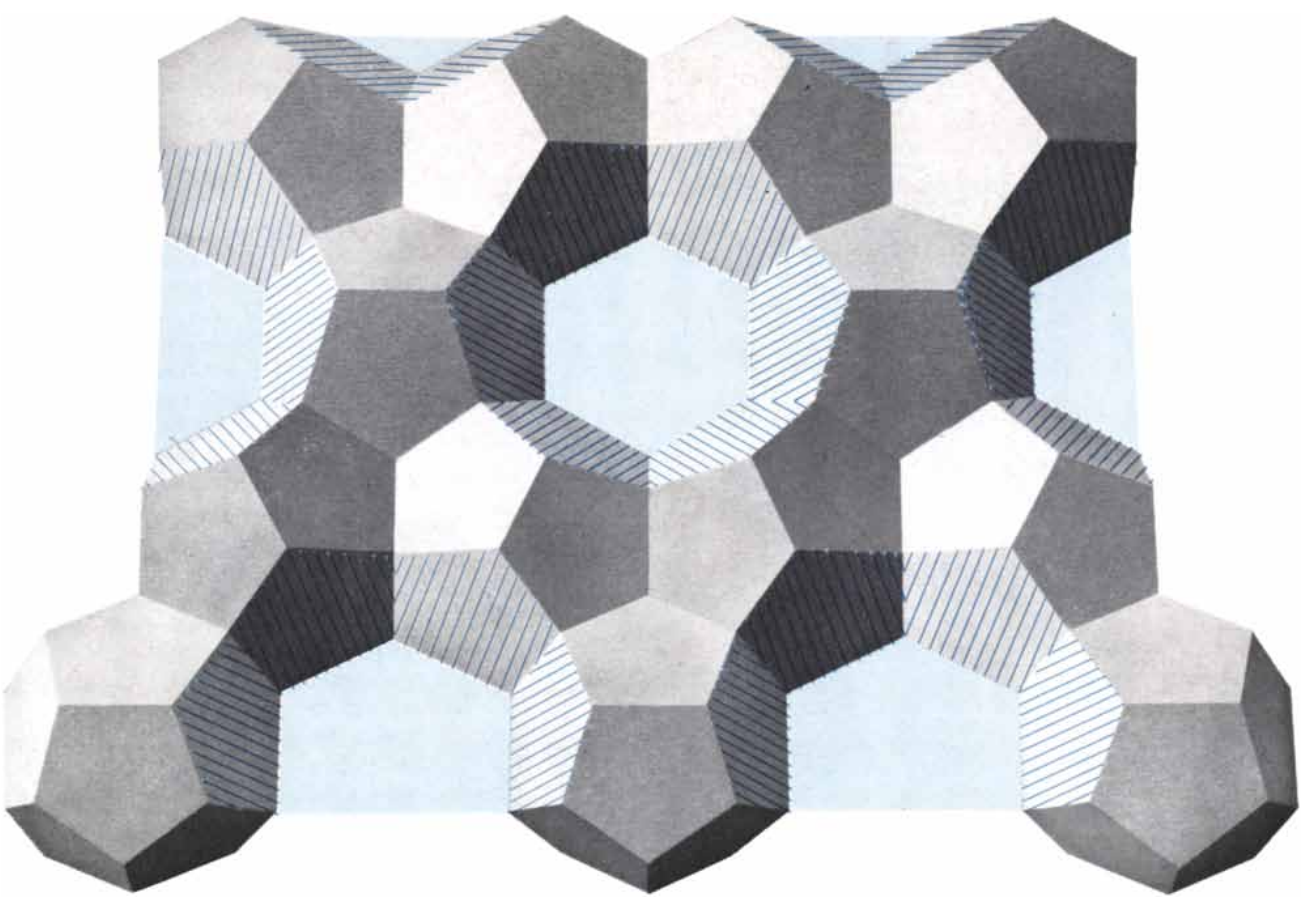
Molecules in Tubes

A rather different sort of structure has been found in the crystalline inclusion compounds formed by urea, thiourea, deoxycholic acid, starch and a few other substances. Here the cavities in the host crystal consist of long tubes in which the guest molecules lie end to end. This type of inclusion compound is called a canal complex. The best known of the canal complexes are those formed by urea; they were discovered in 1940 by the German chemist M. F. Bengen. The extraordinary specificity of urea in complexing almost exclusively with straight-chain hydrocarbons and their derivatives attracted the attention of several research groups in the 1940's, and the canal-complex structure was established at the end of the decade by the German chemist W. Schlenk, Jr., and by Albert E. Smith of the Shell Development Company in the U.S.

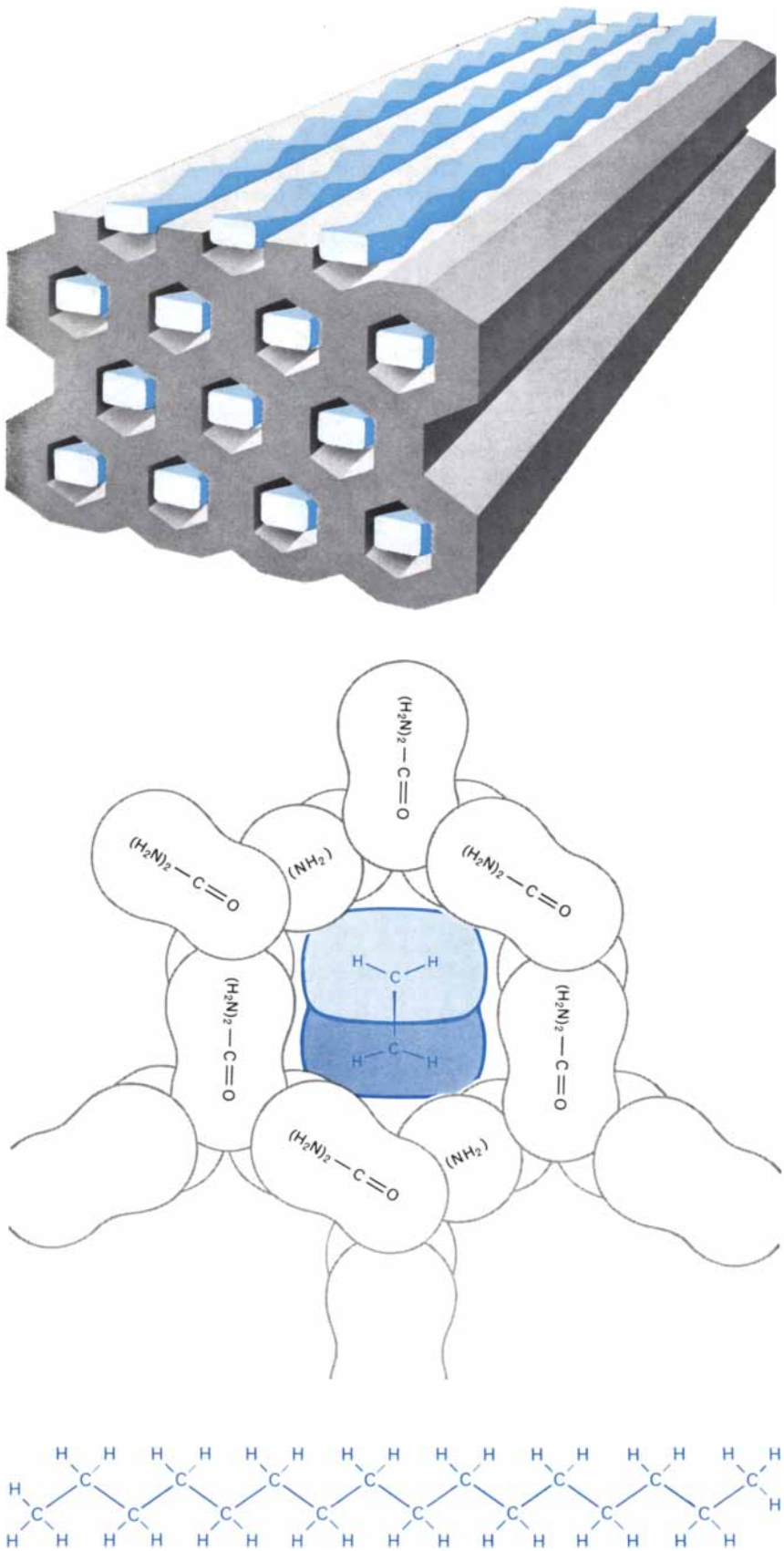
In the urea canal complexes, the molecules of urea, $CO(NH_2)_2$, are held together by hydrogen bonds between the nitrogen and oxygen atoms. The interconnected urea molecules are arranged in much the same way as the wax in a honeycomb, leaving long tubular cavities in which the guest molecules reside [*see illustration on next page*]. The inside diameter of the canals is about five angstrom units, which is just the right size to accommodate the straight-chain hydrocarbons, the fatty acids or derivatives of both. Any such substance having a chain length of more than six carbon atoms will complex with urea at room temperature, and some substances that are only three or four atoms long will complex at low temperatures.

Thiourea, $CS(NH_2)_2$, the sulfur analogue of urea, also forms canal complexes. In these honeycombs, however, the canal diameter is seven angstroms instead of five because of the greater size of the sulfur atom. The substances that can pack into these seven-angstrom holes, thereby forming thiourea canal complexes, constitute a rather capricious and unpredictable group. It includes some of the simpler ring-shaped hydrocarbons (cycloparaffins) as well as a number of polymethylated and poly-





GAS HYDRATES are clathrates composed of water molecules and molecules of a gas or a low-boiling-point liquid. The water molecules link together through hydrogen bonds in rings of five. These rings are combined in dodecahedrons like the one at top right. Since dodecahedrons cannot be made to pack together precisely, cavities (*color*) are formed into which the guest molecules fit.

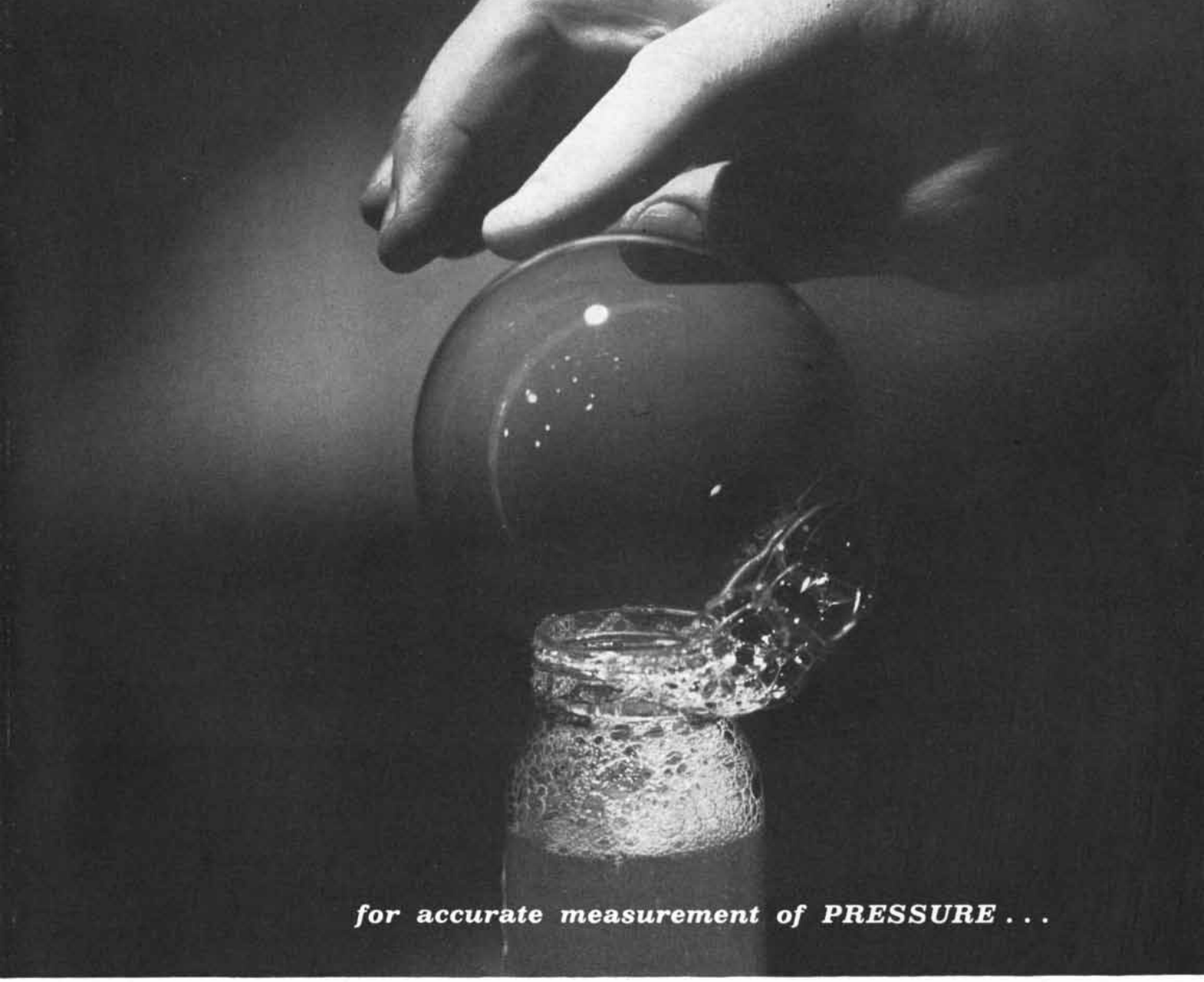


CANAL COMPLEX is formed when guest molecules lie end to end in tubes within a crystal. A canal complex with urea molecules as the host is shown in the drawing at top. The guests are in color. The molecules of urea, seen in the middle drawing, are held together by hydrogen bonds between nitrogen and oxygen atoms to form a honeycomb-like structure. Linear hydrocarbon chains, in bottom drawing, can fit into the cavities of the honeycomb.

chlorinated hydrocarbons—that is, hydrocarbons with methyl groups or chlorine atoms projecting from the central chain. But it does not include the straight-chain, paraffin-like hydrocarbons that complex so well with urea.

Several dozen patents describing practical uses of the urea and thiourea complexes have already been issued, and the list is growing steadily. The majority are based on the ability of inclusion compounds to sort out molecules on the basis of shape and thus effect separations of mixtures. For example, the paraffinic constituents of lubricating oil, which have an undesirable tendency to solidify in cold weather, can be removed by mixing the oil with urea and allowing the urea-paraffin complex to form. Conversely, many cycloparaffins (naphthenes and terpenes) can be separated from gasoline stocks, or from the essential oils of plants, by treatment with thiourea. The canal complexes have also attracted attention as a means of storing easily oxidized materials, such as unsaturated fatty acids or vitamin A. While they are held as guest molecules in canal complexes these sensitive substances cannot be attacked by atmospheric oxygen. Other patents claim the use of urea complexing to convert sticky, semisolid detergents into easily handled powders, and similar uses of thiourea complexing to facilitate handling of chlorinated insecticides such as chlordane.

Although the guest molecules in a canal complex are inaccessible to attack by external reagents, they are still capable of reacting with each other. Several years ago it occurred to some of us at the General Electric Research Laboratory that such reactions might yield rather unusual products, since the walls of the canal would impose severe limitations on the ways in which the reacting molecules could approach each other. Conceivably, in a reaction in which small monomer molecules are linked to form a polymer, there might be only one way in which the reacting monomers could join together, and this would result in a polymer with a very orderly, or stereospecific, structure. Investigations in our laboratory by the author and Dwain M. White showed that this was indeed the case. Using brief irradiation with a one-million-electron-volt beam of electrons as a means of initiating polymerization within the canals, we were able to polymerize such monomers as vinyl chloride and butadiene within their urea hosts and 2,3-dimethylbutadiene, 2,3-dichlorobutadiene and 1,3-cyclohexadiene in their thiourea complexes. In all these cases the polymers



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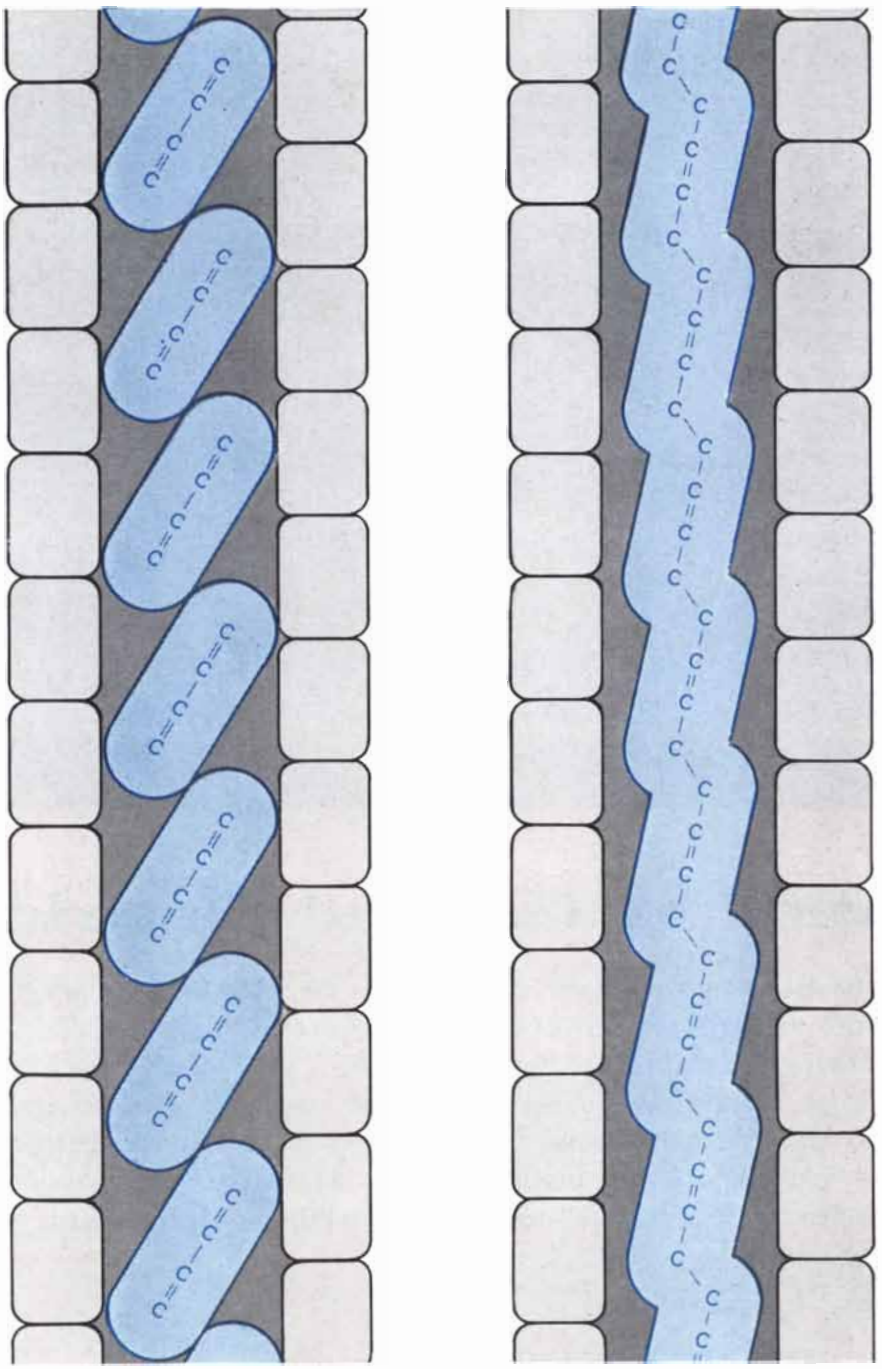
obtained were highly crystalline and had high melting points, in sharp contrast with normal polymers obtainable by irradiation of the liquid monomers, thus showing that stereospecific polymerization had occurred. The four-carbon monomers joined together exclusively at the terminal carbon atoms to produce what are called 1,4-*trans* addition polymers [*see illustration below*]. Evidently canal complexes can act as molecular templates, the smooth, straight holes in a canal host giving rise to smooth, straight molecules of polymer.

Inclusion-compound formation is by no means restricted to crystals. Even in cases where the cavities in the host are built up from separate molecules, there are often indications of host-guest relations in concentrated solutions, comparable to those occurring in the crystal. For example, the formation of micelles (aggregates of soap molecules that produce opalescence in concentrated soap solutions) can be inhibited by the addition of urea, implying association of the urea molecules with the hydrocarbon groups of the soap. It has also been suggested that the inactivation, or denaturation, of proteins by strong urea solutions, results from inclusion-compound formation with the hydrocarbon groups of the protein. Localized canal-complex formation probably also accounts for the action of bile in increasing the solubility of fats in the digestive tract. One constituent of bile, deoxycholic acid, is noted for the stability of the canal complexes that it forms with simple organic molecules.

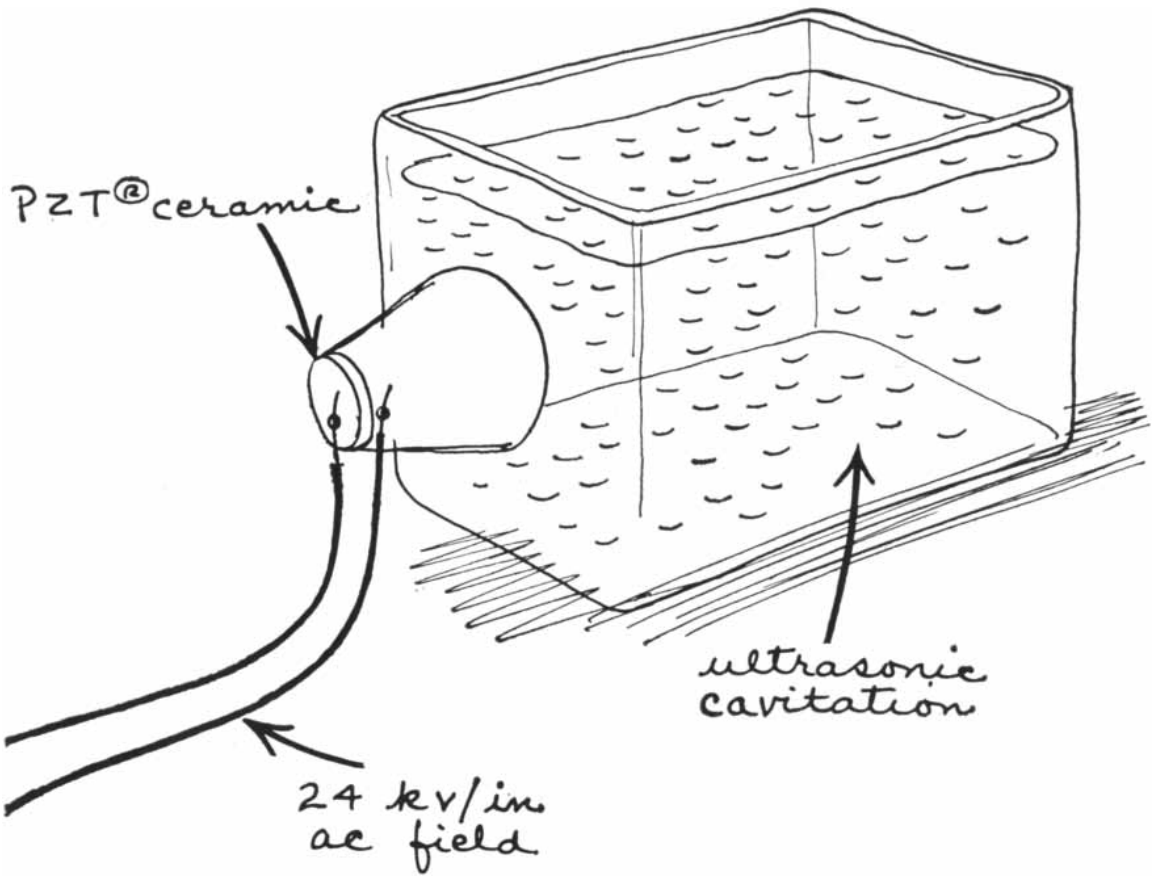
There is abundant evidence that hydrate-like "iceberg" layers exist around many ions, inert gases and protein molecules in aqueous solution. Recently Pauling has suggested that the anesthetic action of certain gases of low chemical reactivity (for example, chloroform and cyclopropane) may result from hydrate formation. There is a remarkably close parallel between the anesthetic activity of these substances and the stability of their crystalline hydrates. Xenon, which enters into no combinations except clathrates, is an effective anesthetic. It is proposed that "microcrystals" of gas hydrate form on certain proteins in the brain and inhibit their functioning.



POLYMERIZATION of the guest molecules in a urea canal complex is obtained by irradiating the inclusion compound with X rays or high-energy electrons. Since the shape of the cavity acts as a template, the four-carbon monomers (butadiene) in drawing at left can join only at their terminal atoms. At right is the orderly polymer (polybutadiene) thus produced.

The Starch-Iodine Reaction

A remarkable family of inclusion compounds can be formed with iodine as the guest substance. It has been known since early in the 19th century that starch and iodine form an intensely colored, blue-black complex. That the complex is a soluble inclusion compound of the canal type has been known for only a decade or so, mainly as a result of work by Karl Freudenberg and Friedrich D. Cramer at the University of Heidelberg and by Dexter French and Robert E. Rundle at Iowa State University. Their studies show that the iodine atoms are joined together to form a long, straight polyiodide chain and that the starch molecule, which is a linear polymer composed of glucose units, forms a spiral wrapping around these chains [*see top illustration on page 90*]. Neither the helical configuration of the starch molecule nor the chain of iodine atoms is stable except in inclusion structures of this general type. The starch helix will form, however, around guests other than iodine, and the iodine chain will occupy hosts other than starch. For example, the free fatty acids that often occur along with starch in plants can make the starch take the shape of a hollow helix. Moreover, sev-



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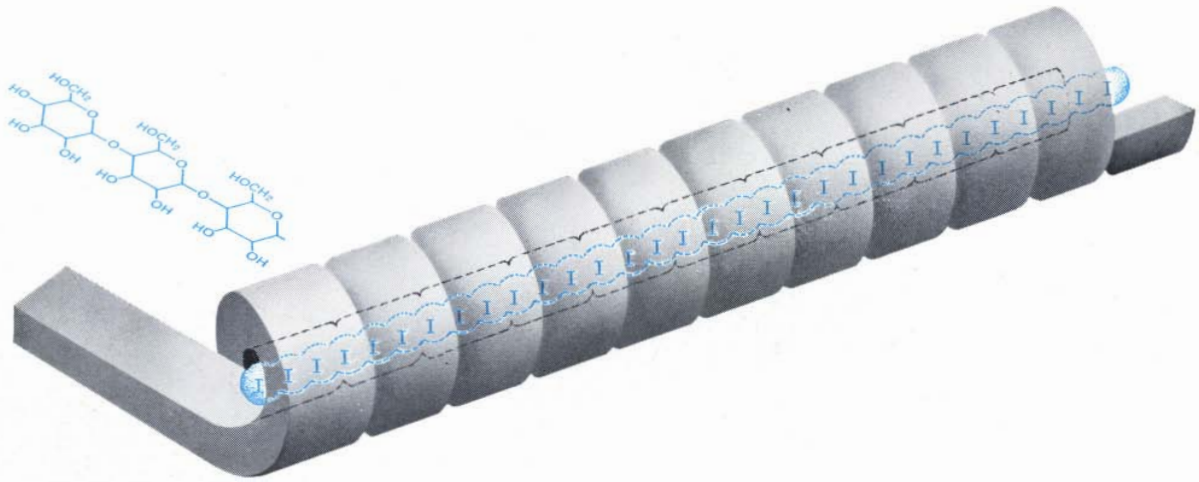
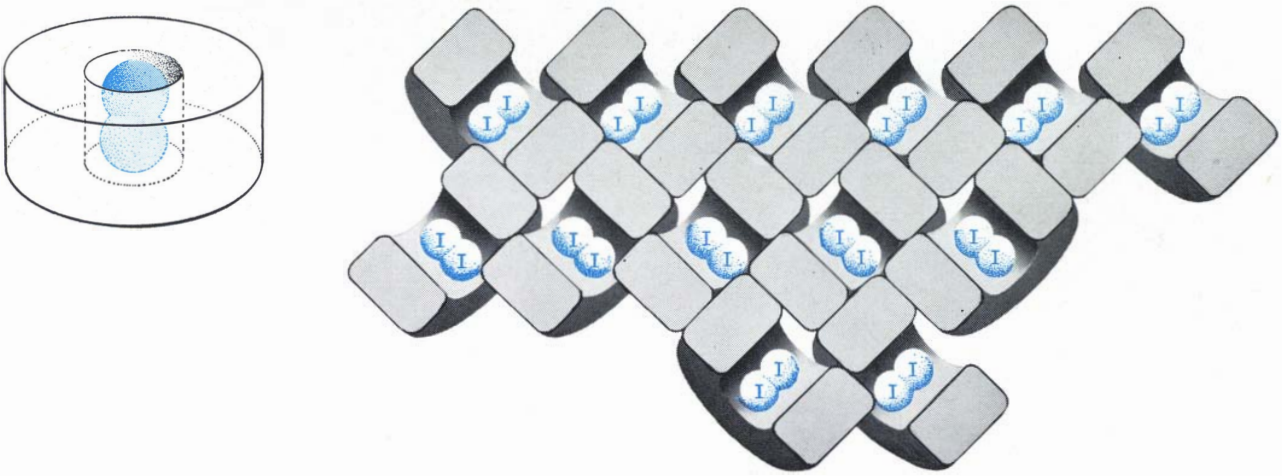


CYLINDRICAL STRUCTURE in a starch-iodine complex results when a polyiodide chain is enclosed in the cavity formed by a helical molecule of starch. Each turn of the helix contains six glucose units. The guest molecule is a linear chain of iodine atoms.



CRYSTAL PACKING ARRANGEMENT in a molecular iodine-cyclohexadextrin clathrate results when the doughnut-shaped molecules of cyclohexadextrin enclose separate iodine molecules. This complex can also exist as separate molecules in solution.

TUBULAR PACKING ARRANGEMENT in an iodine-cyclohexadextrin complex results when polyiodide chains are enclosed in the cavities of cyclohexadextrin molecules lying side by side. The complex can also exist as separate molecules in solution.

eral other canal hosts, such as cyclodextrin, polyvinyl alcohol and barbituric acid, can stabilize the linear polymers of iodine.

It happens that the behavior of electrons in a linear polyiodide chain resembles that of the electrons in a row of metal atoms. Some of the electrons are free to move back and forth along the chain; this accounts for the intense absorption of light by the starch-iodine complex. The electrons are not free to move perpendicular to the chain, however. This property has been utilized in the preparation of Polaroid filters for polarizing light. In these filters a sheet of the polymer polyvinyl alcohol is treated with iodine to produce the linear polyiodide inclusion compound and is then stretched to orient the iodine chains. Such sheets will absorb the component of light polarized parallel to the direction of stretch and allow only the component that is polarized at right angles to come through.

Perhaps the most striking of the soluble substances that form inclusion compounds are the cyclodextrins, which have been extensively studied by Cramer. The cyclodextrins are rigid, doughnut-shaped molecules formed by joining glucose units together in rings. Thus they are the cyclic analogues of amylose (starch), which contains the same glucose units joined together in long chains. Three cyclodextrins are known. These contain six, seven and eight glucose units and have internal diameters of about six, eight and 10 angstroms respectively. All three cyclodextrins combine avidly with any molecule that can fit wholly or partially into these holes. Most of the complexes can also be crystallized out of solution. In the solid state they resemble either the clathrates or the canal complexes. Both forms can be obtained with the six-membered cyclodextrin acting as host to iodine. The clathrate contains separate iodine molecules (I_2) and has the characteristic red-brown color of ordinary iodine solutions. The canal complex, containing polyiodide chains, is blue-black.

Tailor-made Hosts

The applications of inclusion compounds for separating mixtures of molecules of different shape, or as templates for guiding the direction of chemical reactions, all depend on the selectivity of the host-guest interaction. Inclusion-compound formation does not occur unless there is a fairly good match between the guest molecule and the cavity in the host. This selectivity imposes limitations

on the widespread use of inclusion compounds in these applications. Among the simple synthetic systems only a few dozen inclusion hosts are known, and these cover only a narrow range of cavity shapes.

One approach to the tailoring of host cavities to any desired form was discovered some years ago by Frank H. Dickey at the California Institute of Technology. He found that when silica gel was formed in the presence of certain dyes and subsequently extracted to remove the dye, the remaining gel had a strong and specific adsorptive capacity for the dye that had been present during its formation. Gel made in the presence of butyl orange, $(C_4H_9)_2NC_6H_4N=NC_6H_4SO_3Na$, was a much better adsorbent for that dye than for propyl orange, $(C_3H_7)_2NC_6H_4N=NC_6H_4SO_3Na$, and vice versa. Because of this selectivity in their adsorption power, these gels were called synthetic antibodies.

Silica gel has an irregular three-dimensional network structure in which silicon atoms are connected by oxygen atoms and occupy much the same positions with respect to one another as do the hydrogen-bonded oxygen atoms in water. When the silica-gel network is still incompletely connected, it is flexible enough to conform to the subtle differences in shape presented by different kinds of guest molecule. After the cross-linking of the network is complete and the gel has been dried, the guest can be extracted, leaving behind a phantom of its shape. The synthesis of these tailor-made hosts is in some ways just the inverse of a canal-complex polymerization. There the cavity in the complex was used as a template for guiding the polymerization of the guest molecules. Here the guest molecules are used as templates for guiding the polymerization of the host.

Inclusion Systems in Nature

Half a century ago the German chemist Emil Fischer proposed that shape-dependent, "lock and key" interactions might explain the extraordinary selectivity of the chemistry that takes place in living cells. The basis for this idea can be described as follows. Chemists had found that when they determined the structure of relatively simple organic molecules, they could explain their reactions in terms of reactive groupings of atoms ("functional groups") in the molecules. In nonbiological systems, that is, in the chemist's flasks, compounds carrying the same functional groups reacted very much the same way. Thus a reagent that combined with the hydroxyl group in one alcohol would generally react with all alcohols; and the adsorbent that could remove one amine from solution was generally capable of adsorbing any amine. In living systems, however, this was not the case. Each individual alcohol, amine and acid had its own set of transformations. Evidently something more than just the nature of the functional groups was involved. The only reasonable explanation was that this extra something was the over-all shape of the molecule. Such shape-specificity is now readily demonstrable for a wide variety of biochemical processes —for example, in antigen-antibody interactions and in the hundreds of reactions that are catalyzed by enzymes. If it were not for the sensitivity to molecular shape of these processes, living organisms would never be able to accomplish the task of assembling their amazingly intricate molecular structures from complex mixtures of small molecular fragments. In order to account for this dependence on molecular shape, it has long seemed a reasonable hypothesis that much of the chemistry of the cell proceeds with the help of hand-in-glove-fitted structures.

In almost all cases the host molecules involved in these shape-dependent biological processes are proteins. Thus the proteins probably represent by far the largest and most important group of substances that form inclusion compounds. Unfortunately there is still no case in which the molecular structure of a substrate-plus-protein complex has been determined, so that the details of the combination are still unknown. There is a prevalent feeling, however, that weak chemical bonds, such as hydrogen bonds and electrostatic attractions, are probably quite often involved, in addition to the binding due to nonlocalized dispersion forces that arise from the precision of the shape-matching. In other words, the substrate-protein complexes may have closer synthetic analogues in the alkylsulfonium and alkylammonium salt hydrates, where the host-guest binding results from electrostatic forces in addition to shape-matching, than in the gas hydrates or urea canal complexes, where the binding results from shape-matching alone. In any event, the discovery and detailed understanding of the synthetic inclusion compounds have provided powerful support for the hypothesis that such lock-and-key structures can indeed account for biochemical specificity, and hence that inclusion structures play a central role in the functioning of living organisms.

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61 stories over Manhattan, this gleaming stainless steel gargoyle was part of the first major test of stainless steel in American architecture.

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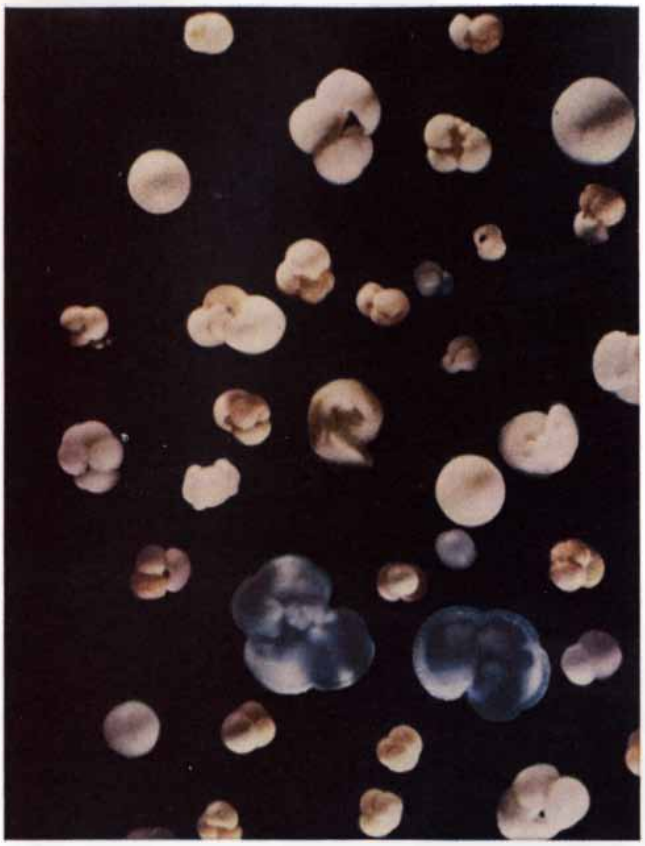
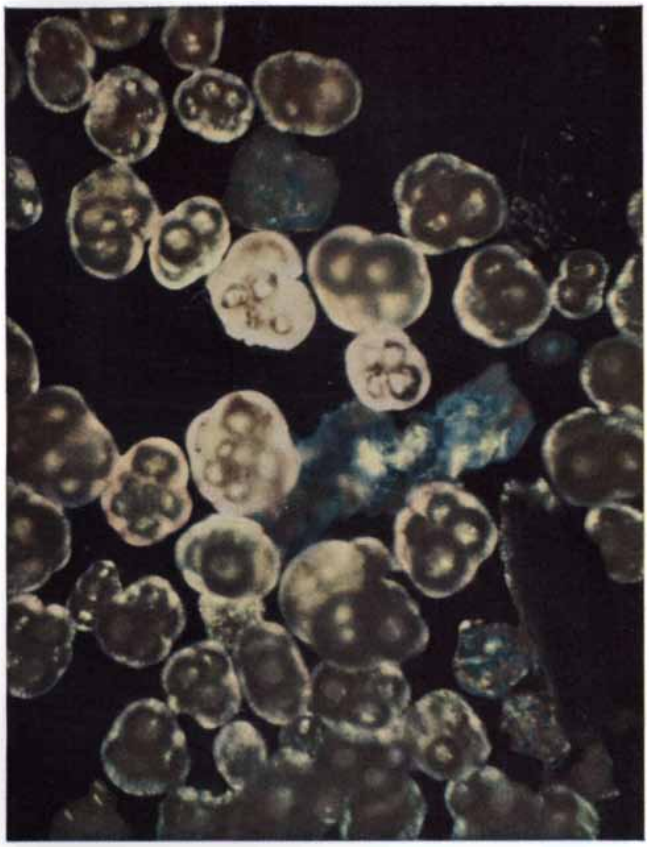


FORAMINIFERA are the most important microfossils in the study of earth history. Various planktonic species produced the fossil shells shown here at a magnification of about 20 diameters.



GLOBIGERINA PACHYDERMA, a foraminifer, lives in the Arctic Ocean. In this photomicrograph light from below shows details of chambers in the shells. Magnification here is some 60 diameters.

DISCOASTERS, extinct perhaps a million years, are useful as guide fossils. Forms with six rays shown here lived about 40 million years ago. They are magnified approximately 1,000 diameters.

DIATOMS are sometimes abundant in sediments and sometimes missing. These were illuminated by polarized light. Magnification is 200 diameters. Photomicrographs were made by Roman Vishniac.

Micropaleontology

Some fossils are so small they can be identified only with the aid of a magnifying glass or a microscope. They label sedimentary layers and provide excellent clues to ancient changes in climate

by David B. Ericson and Goesta Wollin

The words "fossil" and "paleontology" usually evoke pictures of dinosaur bones or other good-sized pieces of vertebrate skeleton. This article is concerned with micropaleontology, which deals with fossils of entirely different magnitude. They are the shells, or, more properly, the skeletons, of minute aquatic animals. None of these microfossils can be recognized without the help of a strong magnifying glass; some must actually be examined in the electron microscope. Their minuteness makes them especially useful for geological research. They can be brought up unbroken—and in enormous numbers—by a narrow coring pipe or even by an oil-well drill. Found both in the ocean floor and in dry-land formations that were once covered by water, microfossils have long served oil prospectors as stratigraphic markers. More recently they have begun to furnish important information about processes of change in the structure of the earth's surface and in the earth's climate.

To meet the needs of the micropaleontologist an organism must have characteristics other than small size. First, of course, the organism must build a skeleton, or some hard part durable enough to fossilize under normal conditions of sedimentation. The fossils in a group should be distinguished as to genus and preferably species. This implies some complexity of organization. Species that flourished during the shortest periods of time, and over the greatest geographical area, are the best geological indicators. They make it possible to differentiate sharply among layers of sedimentary rock of different age and to match strata in widely separated parts of the earth.

In order to obtain evidence of past climate and other environmental conditions the investigator must think of fossils as once living animals with specialized adaptations to their particular surroundings. He then tries to reconstruct those surroundings by analogy with the ecological requirements of near relatives of the ancient organisms that are alive today. As might be expected, the method becomes more difficult as the evolutionary distance between fossils and living organisms increases. A paleoecologist must be a good detective and find meaning in all sorts of apparently trivial and irrelevant observations. Certain potentially useful microfossils are just beginning to attract serious study. Previously they were ignored because they are so very small. The coccoliths, disk-shaped plates of calcium carbonate, are one example. They are planktonic, which means that the ocean currents in which they float have carried them to many quarters of the globe and that they have been settling to the bottom for some 500 million years. One cubic centimeter of sediment can contain 800 million of them; they must be enlarged 800 diameters to be seen at all. Because they were found in the topmost layer of sediment on the ocean floor, it was realized that the organism depositing them must be extant. For a long time what the organism was remained a mystery; the finest collecting nets could not catch it. Eventually it was located not in a man-made trap but in the filtering apparatus of the common marine animal called *Salpa*. Recently the electron microscope has revealed that coccoliths possess an astonishingly complex structure. When they have been more thoroughly described and classified, they should be helpful in correlating sedimentary strata from continent to continent as well as in the oceans.

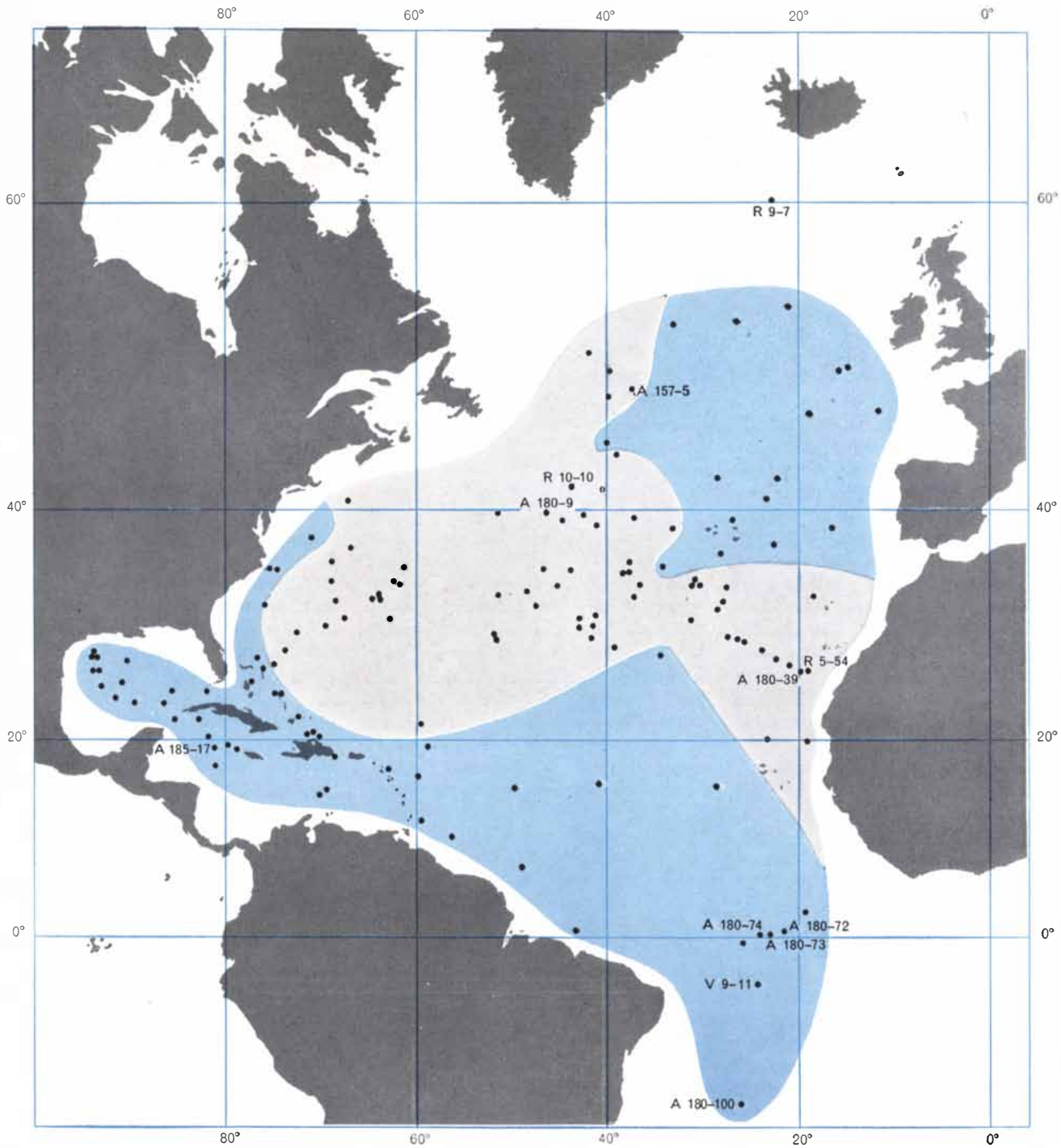
Another group of tiny organisms, now extinct, were the star-shaped discoasters. A little larger than coccoliths, their world-wide distribution in deeper sediments suggests that they too were planktonic. Although known for almost 100 years, they have not been applied in stratigraphy because of the mistaken notion that all known species lived continuously from 60 million years ago to the time of their disappearance. In reality they evolved fairly rapidly, and some species make excellent guide fossils. The earliest discoaster stars had as many as 24 rays, or points. By 20 million years ago the number of rays had declined to six, and the last forms had only five slender rays. The exact time of their extinction is unknown, but if, as is suspected, it was just before the Pleistocene (the geological period of the last ice age), five-rayed discoasters will occupy an important position as reliable indicators for this important boundary in geologic time.

In their day-to-day work micropaleontologists deal chiefly with diatoms, radiolaria, conodonts, ostracodes and foraminifera. All of these except the diatoms are large enough to be studied in a low-power microscope at a magnification of between 30 and 100 diameters—an important consideration when hundreds of samples must be examined each day, as is the practice in some oil-company laboratories.

Among the microfossils the diatoms and the radiolaria compete for the first place in beauty. Both secrete shells of opal (silica combined with some water). In the lacy skeletons of radiolaria the opal looks like clear spun glass; in diatom shells it takes on a jewel-like quality, often displaying a many-colored fire that must be seen to be appreciated. Many species of diatoms live exclusively in fresh water, whereas all radiolaria live in salt water. In consequence diatom fossils are somewhat more informative; from the species found in a sedimentary

layer it is usually possible to tell whether the sediment was formed in a lake or in the sea. There are a great many species of diatoms and radiolaria; diatoms can occur locally in such fantastic numbers that they produce fairly thick layers of sediment, known as diatomite, consisting almost entirely of their fossils. The opal skeletons of both diatoms and radiolaria, however, tend to dissolve in water, and they cannot be counted on to show up in a particular region. Often they are missing from just those places where an index fossil is most needed.

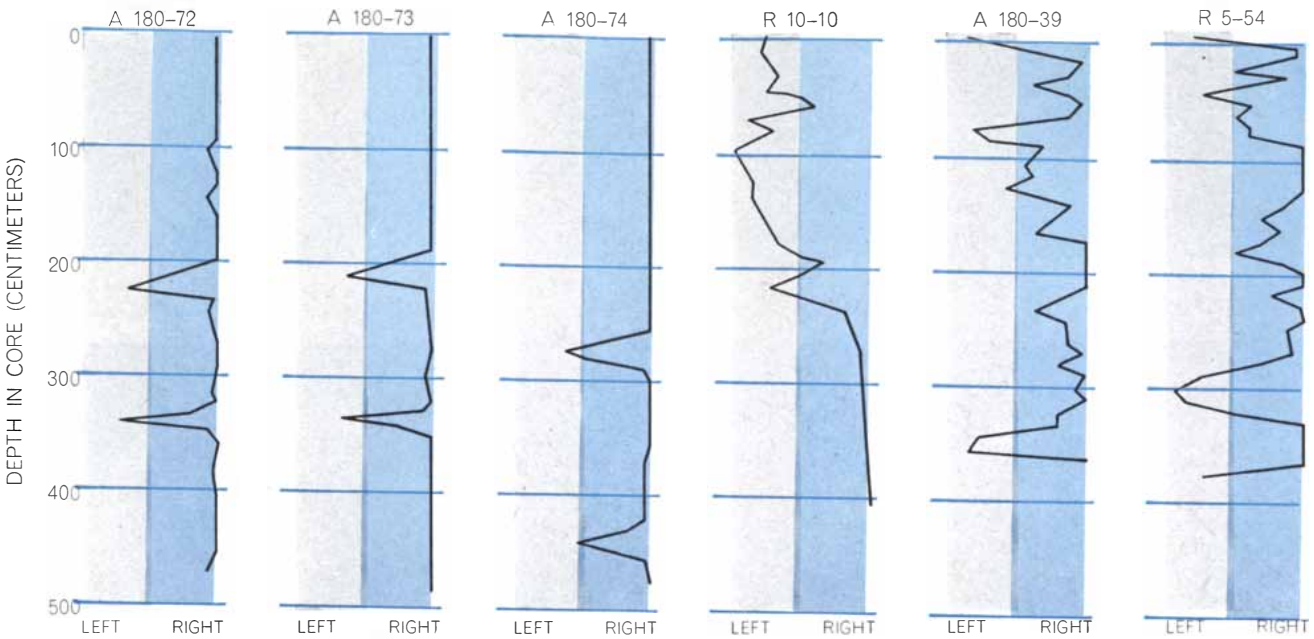
Conodonts are small tooth-shaped or platelike objects with one or more points. Like vertebrate teeth, they are made of calcium phosphate. Although many "genera" and "species" have been described since they were discovered more than a century ago, no one knows what kind of animal produced them. Whatever it was, it became extinct some 240 million years ago during the Triassic period. The variation in the form of conodonts from level to level in older sediments makes them particularly use-



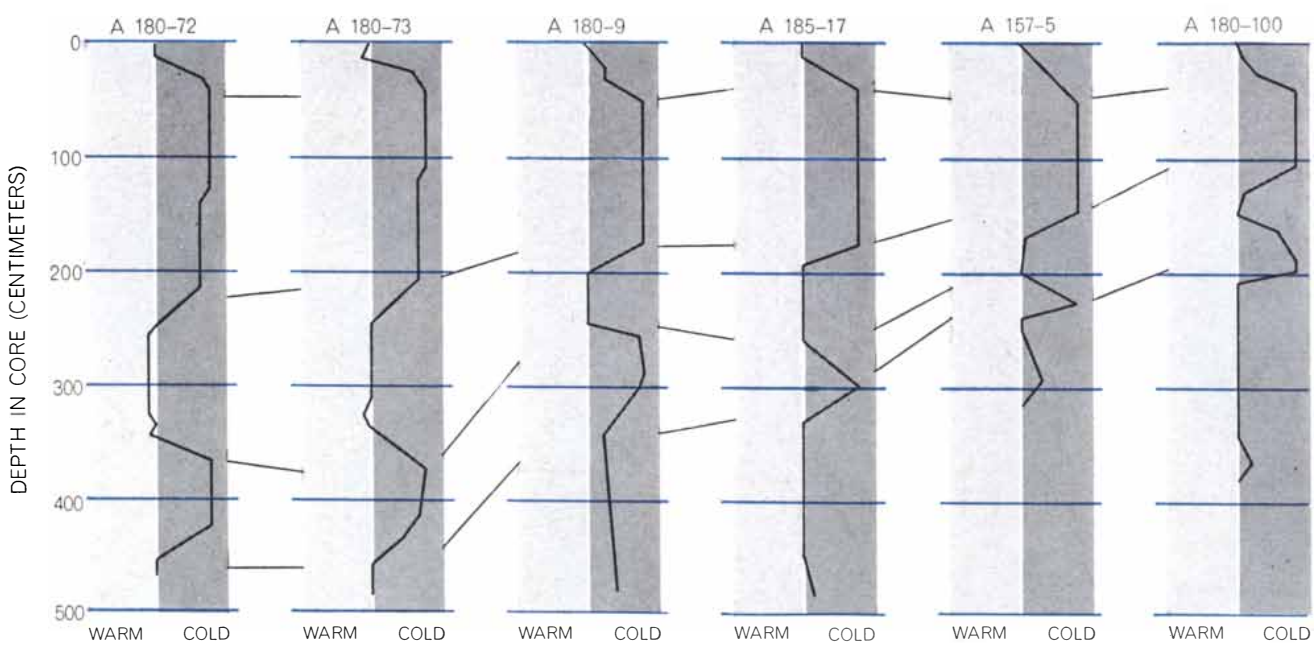
COILING DIRECTIONS of living *Globorotalia truncatulinoides*, a planktonic foraminifer, define three provinces in the Atlantic Ocean. Most of the spiral-shaped shells of this species found on the sea floor coil to the left in the gray region and to the right in the colored areas. The dots mark sites where cores have been taken. The letters and numbers identify the cores diagramed on the following pages. Core V 9–11, brought up just south of the Equator, carries the Pleistocene record back at least 600,000 years.

ful to the petroleum geologist. Because of their small size they often come up undamaged in rock cuttings from oil wells or exploratory holes.

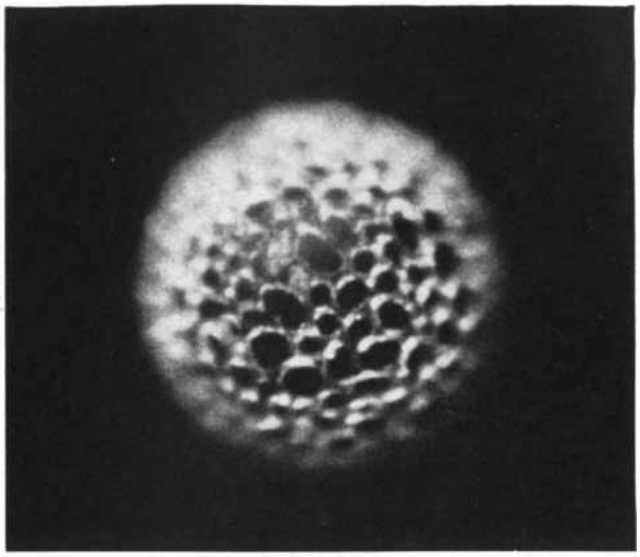
The ostracodes present no mysteries. These odd little relatives of crabs and lobsters are very much alive today and flourish wherever there is enough water, whether it is fresh, brackish or salty. They are the only crustaceans that have two valves, or shells, which makes them look like tiny clams. The valves vary in length from half a millimeter (a fiftieth of an inch) to three or four millimeters. They first appear in the geological column in sediments deposited at least 450 million years ago in the Cambrian period of the early Paleozoic era. In the course of evolution the shells have varied greatly in shape and ornamentation, and many species have lived only for short intervals of geologic time. Knowledge of the present distribution of living genera in open salt water, sounds, estuaries, lagoons and lakes helps in analyzing past conditions when similar genera show up in ancient sediments.



CHANGES IN COILING DIRECTION of *Globorotalia truncatulinoides* with depth in cores make it possible to correlate cores from different locations. The correlation is readily apparent in the three cores A 180–72, –73 and –74. Cores A 180–39 and R 5–54 also show correlation. Samples of shells were studied every 10 centimeters or so from top of cores to bottom. Variation in each diagram is from 100 per cent left-coiling at left to equal ratio in the middle to 100 per cent right-coiling at right. The older shells are deeper.

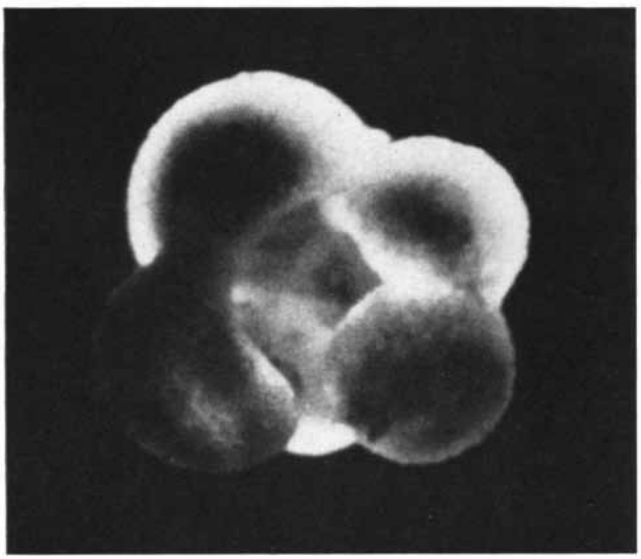


CLIMATE CURVES are based on relative number of warm- and cold-water forms of planktonic foraminifera found in each of six deep-sea sediment cores. "Warm" and "Cold" indicate warm and cold climates compared with present-day climate, which is vertical line in center of each diagram. Thin lines connect faunal changes believed to have occurred at the same time in the various locations. Obviously rates of sedimentation have differed widely. Such curves provide the data for establishing a chronology of the ice ages.

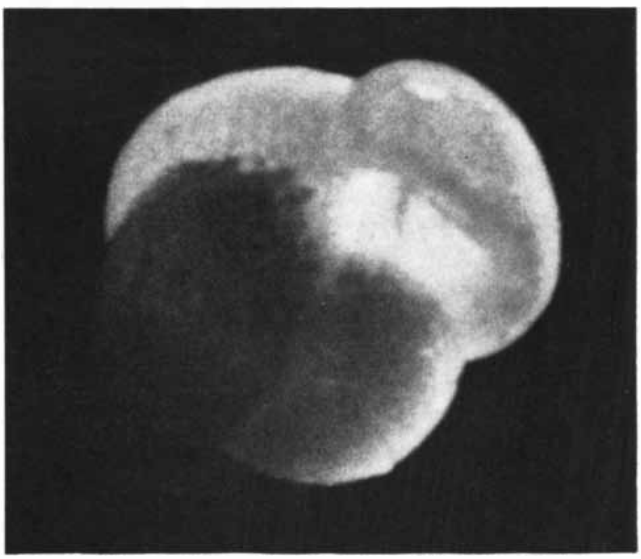


RADIOLARIA produce lacy skeleton that looks like clear spun glass. It is made of opal, which tends to dissolve in water.

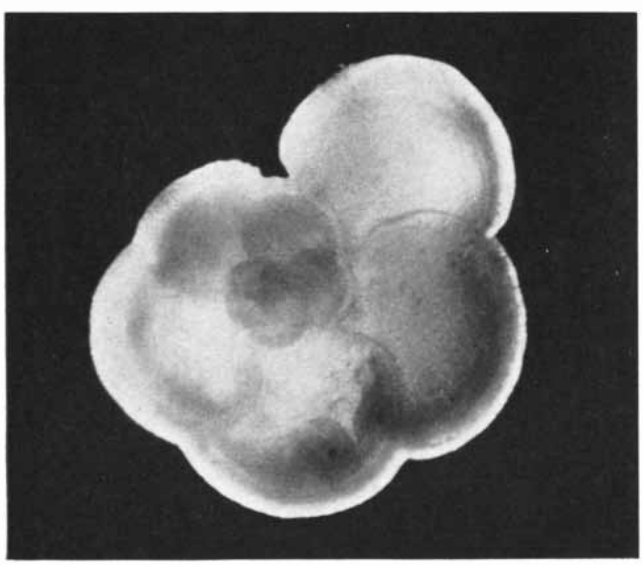
OSTRACODES are related to crabs and lobsters but have two valves, or shells, that closely resemble shells of tiny clams.



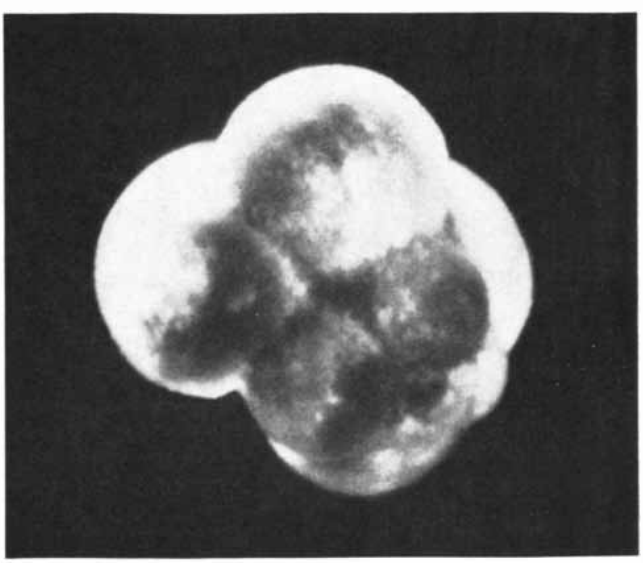
GLOBIGERINA BULLOIDES is found in cool to cold water. This and forms that follow are all species of planktonic foraminifera.



GLOBIGERINA INFLATA is a cool-water form found in middle latitudes. It occurs only in sediments of the Pleistocene epoch.



GLOBOROTALIA MENARDII is found in waters of mid-latitudes and tropics. All Pleistocene forms of this species coiled to left.



GLOBIGERINA PACHYDERMA is a climate indicator for northern seas. Shells on this page are enlarged 60 to 120 diameters.

The ostracodes have only one drawback: they are not nearly so numerous as the universal favorites among microfossils, the foraminifera.

The very popularity of foraminifera greatly enhances their usefulness. Over the years a mountain of information of all sorts has accumulated, and most of it is readily available. Descriptions of genera and species have been brought together in an enormous catalogue published by the American Museum of Natural History, which now includes 69 volumes and is growing constantly as descriptions of new species are added.

The foraminifera are protozoa, or single-celled animals, that build tests (shells) of various materials. On the basis of the mode of construction the animals are divided into two large groups. Calcareous species construct tests of calcium carbonate precipitated directly from sea water; arenaceous species build their shells of sand grains, flakes of mica, sponge spicules or even small discarded calcareous tests of other species, any of which they can cement together with secretions of calcium carbonate or iron salts. The size of the shell varies widely with the species. Some long-extinct giant foraminifera exceeded 15 centimeters (six inches) in diameter. The majority of fossil foraminifera range from .2 millimeter to two millimeters.

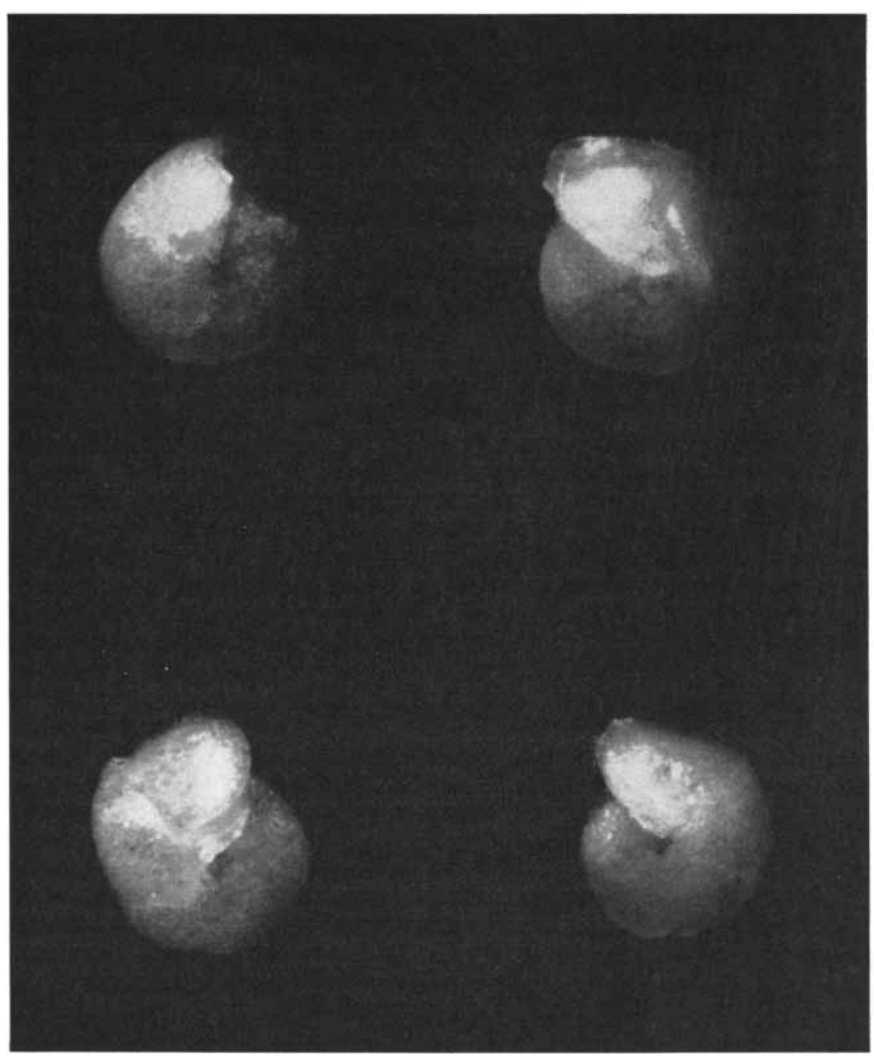
The architectural unit of the test is the chamber. A few species have only one chamber, but most build anywhere from two to several hundred. On this basic principle of structure the foraminifera improvise endlessly. To duplicate all the strangely shaped chambers and their intricate arrangements would tax the ingenuity of a topologist. Geometric versatility has made possible all the thousands of different species that have come and gone during the past 500 million years.

Almost all the foraminifera species live on the ocean bottom. Although some attach themselves permanently to rocks, most of them potter along at a few millimeters per hour, pushing themselves by means of pseudopodia extruded through minute pores in the shells. Clearly this way of life does not make for wide distribution. Beginning some 100 million years ago in the Upper Cretaceous period, however, a few types became planktonic. Although they constitute only about 1 per cent of the known species, the enormous volume of living space open to them has permitted great proliferation: individuals of the planktonic forms make up almost 99 per cent of the fossils found in ocean sediments. In some places accumulation of the shells has produced thick deposits of chalk. The white cliffs of Dover and Normandy are such deposits, now uplifted and partly eroded. Today large areas of the bottom of all the oceans are receiving a slow but constant rain of discarded tests of planktonic foraminifera, which make up on the average 30 to 50 per cent of all bottom sediments.

Shells of the important planktonic species have fairly simple forms. The dominant theme is a series of chambers arranged in a spiral. As the animal grows it adds chambers of steadily increasing size. In most species the general form resembles that of a small shell. Like snail shells, some tests coil to the left and others coil to the right, the two kinds being mirror images of each other.

Because of the rapid succession of distinctive species throughout successive geological ages, foraminifera are ideally suited to the needs of the petroleum geologist, who must deal with many kinds of thick sedimentary rocks, some of them heavily folded and faulted. If one were asked to invent a class of ideal fossils for identifying and matching strata, it would be hard to improve on the foraminifera. It is small wonder that most of the hundreds of paleontologists working for oil companies devote full time to the study of these microfossils.

Foraminifera are a good deal more than tags for sedimentary rocks. To workers in pure geology, and particularly to those in the hybrid branch known as marine geology, they furnish invaluable keys to the remote past. So many samples of ocean sediment have been examined by now and their microfossils classified that it is possible to chart the approximate distribution of the most common species of planktonic foraminifera. The charts show that some species live only in low latitudes, others are most abundant in middle latitudes and



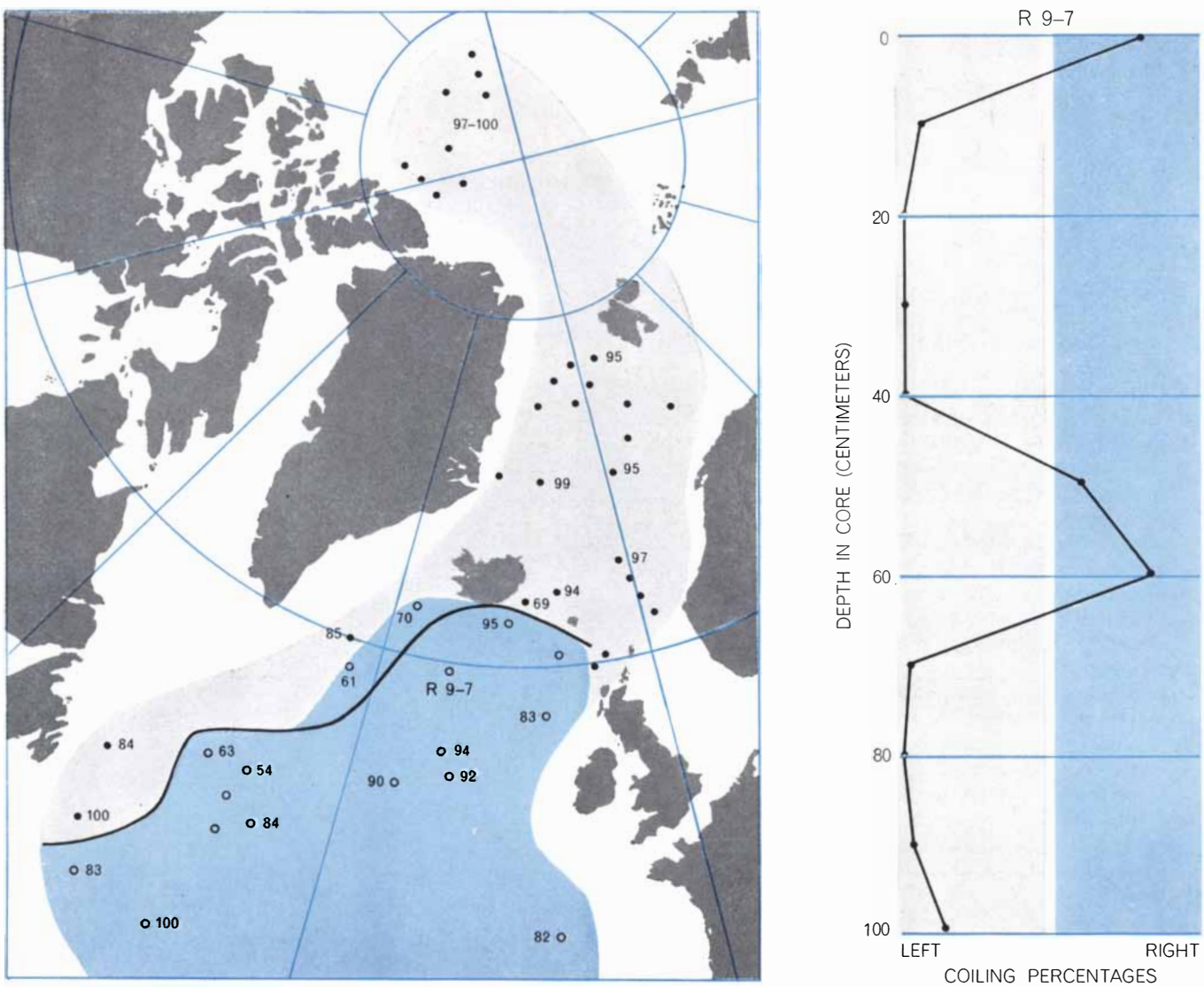
LEFT- AND RIGHT-COILING SHELLS of *Globorotalia truncatulinoides* appear at left and right respectively. Coiling direction is apparently associated with climatic conditions.

still others live in high latitudes. (One species, *Globigerina pachyderma*, ranges up to the North Pole.) Evidently water temperature plays an important part in the distribution of the various species.

If so, the animals must live near the surface; only there does the temperature vary significantly with latitude. The fact that living foraminifera are caught in plankton nets towed through the photic zone (the sunlit top 100 meters of the ocean) seems to bear this out. But the surface samples long presented something of a problem. Their shells are thin-walled and transparent, whereas shells of the same species taken from the bottom are almost all heavily encrusted with calcium carbonate or calcite.

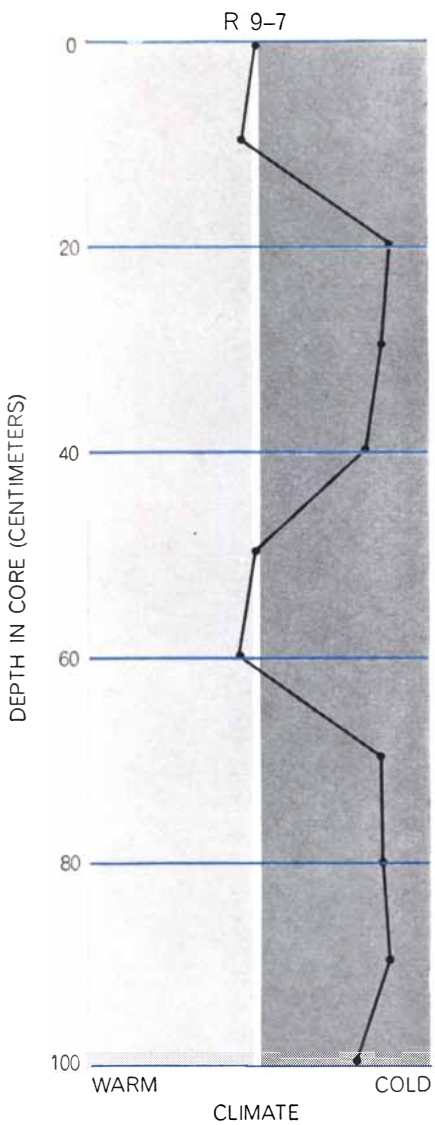
Until recently it was supposed that the material precipitates on the empty tests after they settle to the bottom. This hypothesis had fatal flaws, however. For one thing, oceanographers generally agree that at depths of several thousand meters in the ocean calcium carbonate dissolves far more rapidly than it precipitates. Our laboratory at the Lamont Geological Observatory of Columbia University finally undertook a close examination of the distribution of calcite on individual shells, which furnished the clue to the correct explanation. We discovered that calcite is thickest on the earliest formed chambers and diminishes steadily in the chambers farther out on the growth spiral. This can only mean that the living foraminifera precipitate the calcite and that the thin-walled specimens in the photic zone are immature.

Recently Allan W. H. Bé of Lamont has caught heavily encrusted tests containing living foraminifera by towing plankton nets at depths of more than 500 meters. They provide the final proof that at least some species mature and reproduce well below the photic zone. Evidently the embryos rise to the photic zone, fatten on diatoms and other photosynthetic organisms there and then sink to a lower level, where they complete their life cycle. The pattern does not conflict with the idea that temperature variations in the upper layers of water determine the geographical distribution of various species; each individual passes a critical period of its life in the photic zone. On the other



CLIMATE AND COILING DIRECTION of *Globigerina pachyderma* seem to be closely correlated in northernmost Atlantic and adjacent seas. Right-coiling of living pachyderma (*colored area on map*) is associated with warmer water, left-coiling (*gray area on map*) with coldest water. Position of the isotherm marking an average surface temperature of 7.2 degrees centigrade in April (*black line on map*) closely follows border of right-left provinces. Open circles indicate dominance of right-coiling at tops of cores; closed circles mean left-coiling. Percentages of shells coiling in dominant direction are shown for some cores. Curves at right

hand, it suggests a possible explanation for a rather puzzling distribution of the species *Globorotalia menardii.* Fossils of this group are extremely abundant in sediments south and southwest of the Canary Islands, whereas they are entirely absent from the region to the north and northeast. Yet the Canaries current flows southwestward through the area and would sweep all *G. menardii* out of the region south of the islands if they spent their entire lives in the photic zone. We believe that the animals sink below the Canaries current as they approach maturity and enter a deep countercurrent that returns them and the new generation of embryos to the northeast. As yet no one has attempted to detect the countercurrent directly, but mathematical analysis of deep circulation in the Atlantic suggests it should be there.

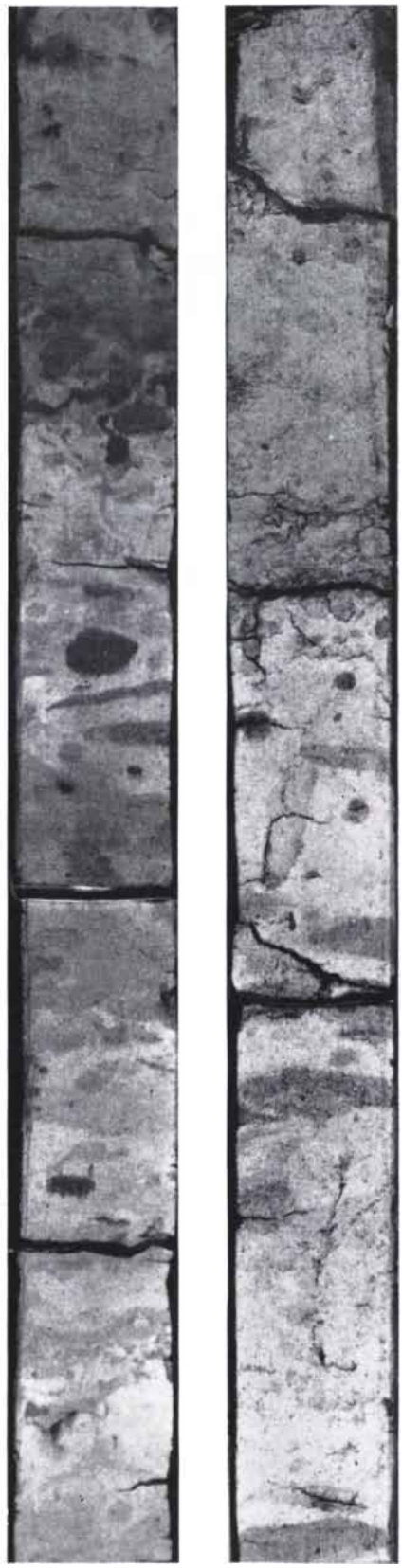


show (*left curve*) relative percentages of left- and right-coiling *G. pachyderma* at 10-centimeter intervals in core R 9–7, and abundance of cold and warm forms of all other planktonic foraminifera in core (*right*).

The discovery that foraminifera live part of their lives deeper than 500 meters has an important bearing on recent attempts to estimate ancient water temperatures from measurements of oxygen isotopes in fossil shells. The technique is based on the fact that in warmer waters there is a slight preponderance of heavier isotopes in the shells and in cooler waters a slight preponderance of lighter isotopes. If the relative abundance of the isotopes is to be significant, the depth at which the shells incorporated their oxygen must be known. Deep waters at every latitude are quite cold.

Since warm-water and cold-water species have not changed greatly in the past million years or so, the micropaleontologist can use the fossils to obtain a quite objective picture of changing climatic conditions during the period. Cores of sediment from ocean bottoms furnish a continuous record of geological and climatic events in contrast with the garbled record available from the distorted layers of rock on dry land. From our study of planktonic foraminifera in more than 1,000 cores in our laboratory, we feel that we have been able to arrive at the first accurate set of dates for the most recent glacial and interglacial periods. Carbon-14 analysis of the fossils shows that the last ice age ended 11,000 years ago instead of 20,000 years ago, as had previously been thought. The new date, now generally accepted, may change some ideas about the rate of human evolution. Judging from the average rate of sedimentation, the last part of the last glaciation began approximately 60,000 years ago, after an interstadial period (an interglacial of short duration) of 30,000 years [*see illustration on next page*]. The preceding glacial period lasted only 20,000 years, whereas the interglacial before it appears to have gone on for 110,000 years. This is as far back as reliable core data go, although a single core from the equatorial Atlantic appears to carry the Pleistocene record back at least 600,000 years.

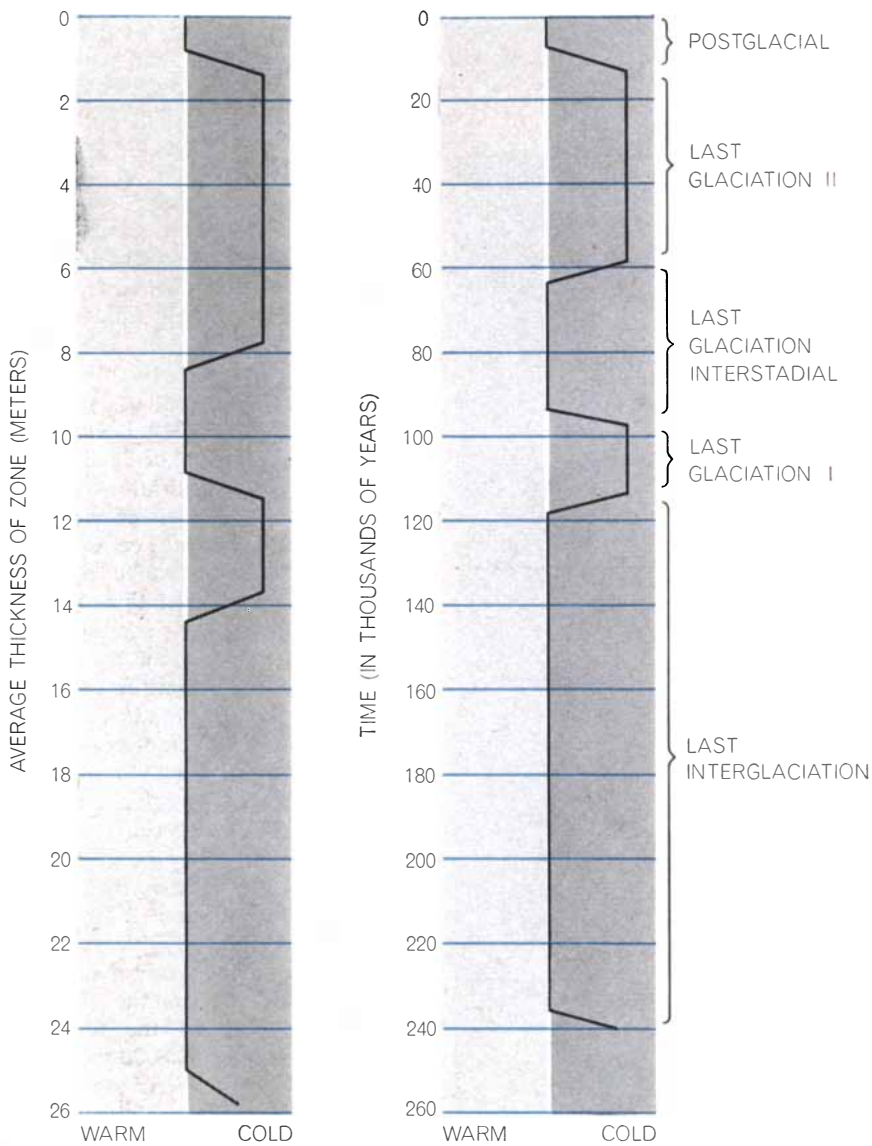
Since the last glaciation ended 11,000 years ago, and since the minimum interglacial period seems to have been 30,000 years, it would seem that man can look forward to at least 20,000 more years of the present mild climate, if not to even warmer weather. If a warmer climate should melt the glaciers that remain today, the sea level would rise, but probably no more than 10 meters or so. This would be a considerable nuisance—it would put much of New York City under



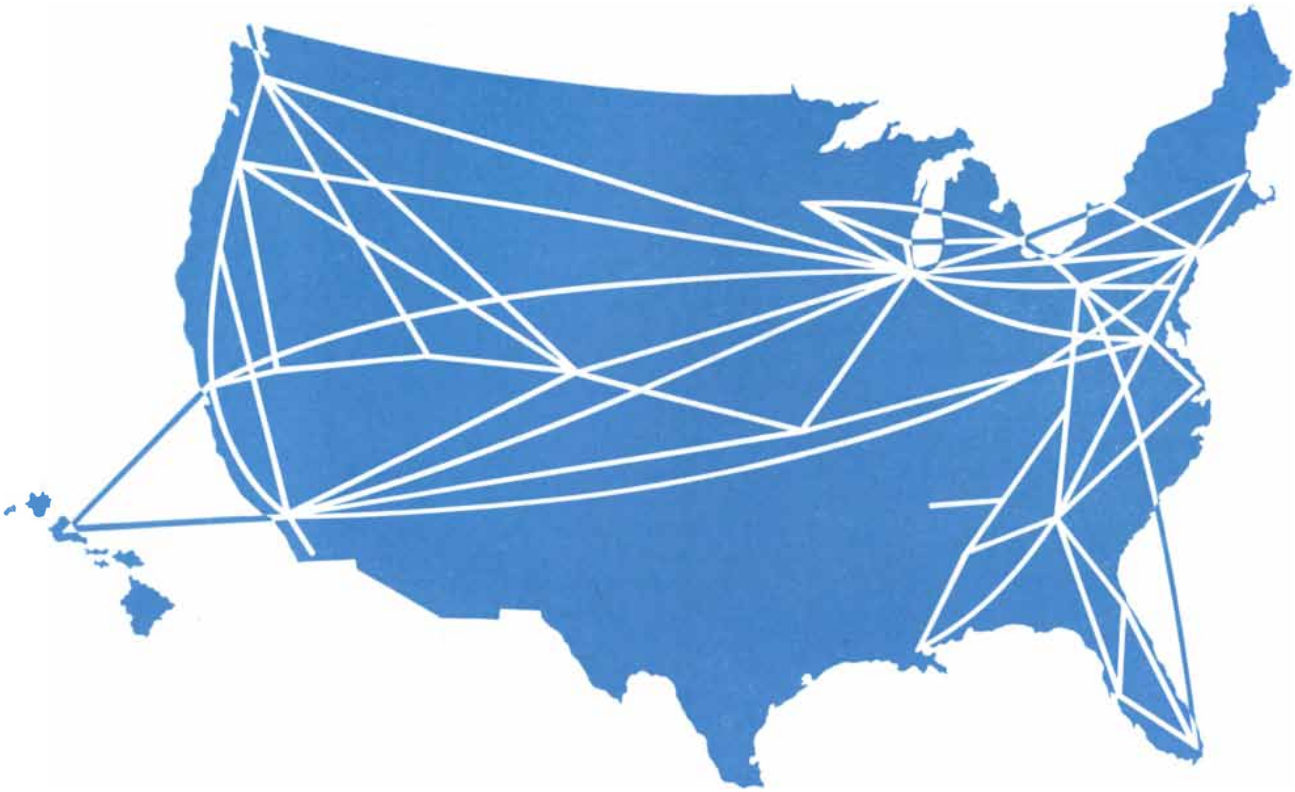
DEEP-SEA CORES represent a vertical cross section of ocean-bottom sediments. These are small parts of cores A 180–72 (*left*) and A 180–73 (*right*). Sometimes layers are quite apparent in cores; at other times no layers can be seen with the naked eye, but the microscope reveals sharp changes in the fossil contents of the undersea sediments.

water, for example—but it would hardly threaten the existence of mankind.

Arriving at accurate dates for the late Pleistocene would have been far easier if it were true, as geologists formerly believed, that marine sediments accumulate everywhere at the rate of one centimeter per 1,000 years. Then each sample core would represent the same time scale. Our studies of hundreds of cores show that the rate of accumulation can be that slow, but in many places it is as much as 50, 100 and even 250 centimeters in 1,000 years, depending largely on the underwater topography. "Turbidity" currents, consisting of silt-laden water denser than surrounding water, frequently run down even gentle ocean-bottom slopes, depositing several meters of mud in a few hours in some places; in other places they may scour away sediments accumulated over thousands of years [see "The Origin of Submarine Canyons," by Bruce C. Heezen; SCIENTIFIC AMERICAN, August, 1956]. Another phenomenon responsible for large variations is slumping, in which the sediments simply slide away down a



CHRONOLOGY FOR LATE PLEISTOCENE (*right*) is drawn from micropaleontological studies of planktonic foraminifera in 108 deep-sea sediment cores and on extrapolations of the rate of sedimentation from 37 carbon-14 dates in 11 of the cores. The authors consider this the most accurate timetable available for the past 240,000 years. Present-day climate is at center line of diagrams. The average-thickness curve (*left*) shows greater rate of sedimentation during glaciations than during interglacial or interstadial periods. This is caused by lowering of seas, which exposes continental shelf. Rivers thus carry material from continents out to edge of shelf and dump land sediments into deep sea, whereas in warmer times sea is higher and continental sediments are deposited on shelf.



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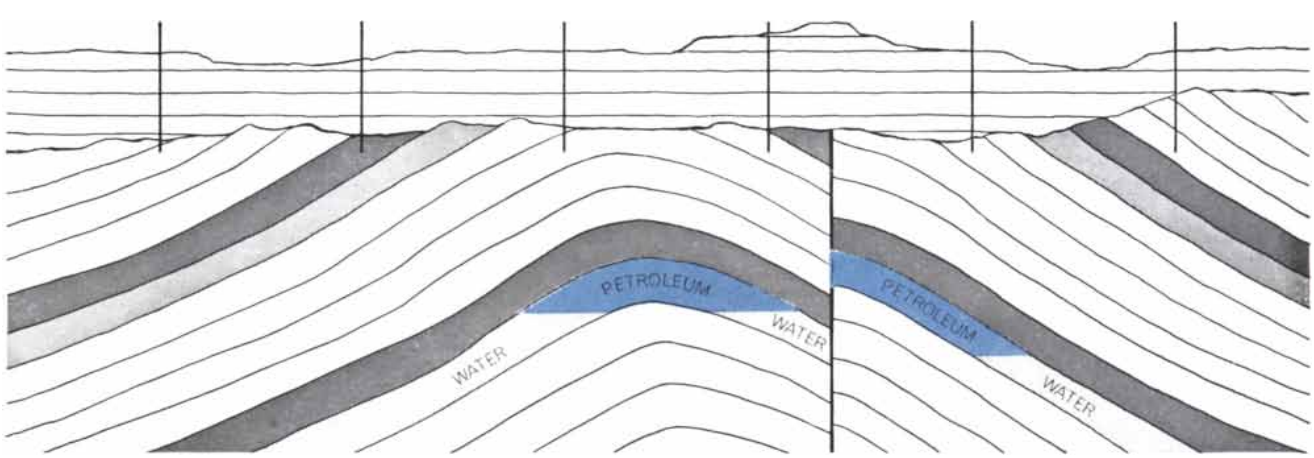
steep slope. The removal of upper layers of sediments by these processes is not all bad, however; it has brought 100-million-year-old fossils near enough to the sea floor to be reached by our coring tubes. So far we have not brought up a core in which the entire upper part of the Pleistocene record has been removed, leaving the older ice-age sediments intact. Several cores of this type, or longer cores from places already sampled, would carry our time scale back to the beginnings of human evolution.

The coiling direction of shells of *Globorotalia truncatulinoides* is proving extremely useful in matching sediments from various locations. In our laboratory we have discovered that the ratio between right-coiling and left-coiling shells varies from place to place in such a way as to define three distinct geographical provinces in the North Atlantic [*see upper illustration on page 99*]. Carbon-14 dating of samples from cores shows that the present pattern of distribution has persisted for about 10,000 years. Evidently some environmental factor has maintained the pattern in spite of the mixing effect of general ocean circulation. Going back in time by determining coiling ratios in fossil samples taken every 10 centimeters in cores, we find that the pattern of distribution changed rather suddenly from time to time during the late Pleistocene, presumably in response to changing currents or shifting water masses. Although we cannot yet say just what the changes were, we can match layers in different cores by means of the coiling-direction ratios. Petroleum geologists in Europe and India have applied this same method to other species to match strata penetrated by oil wells.

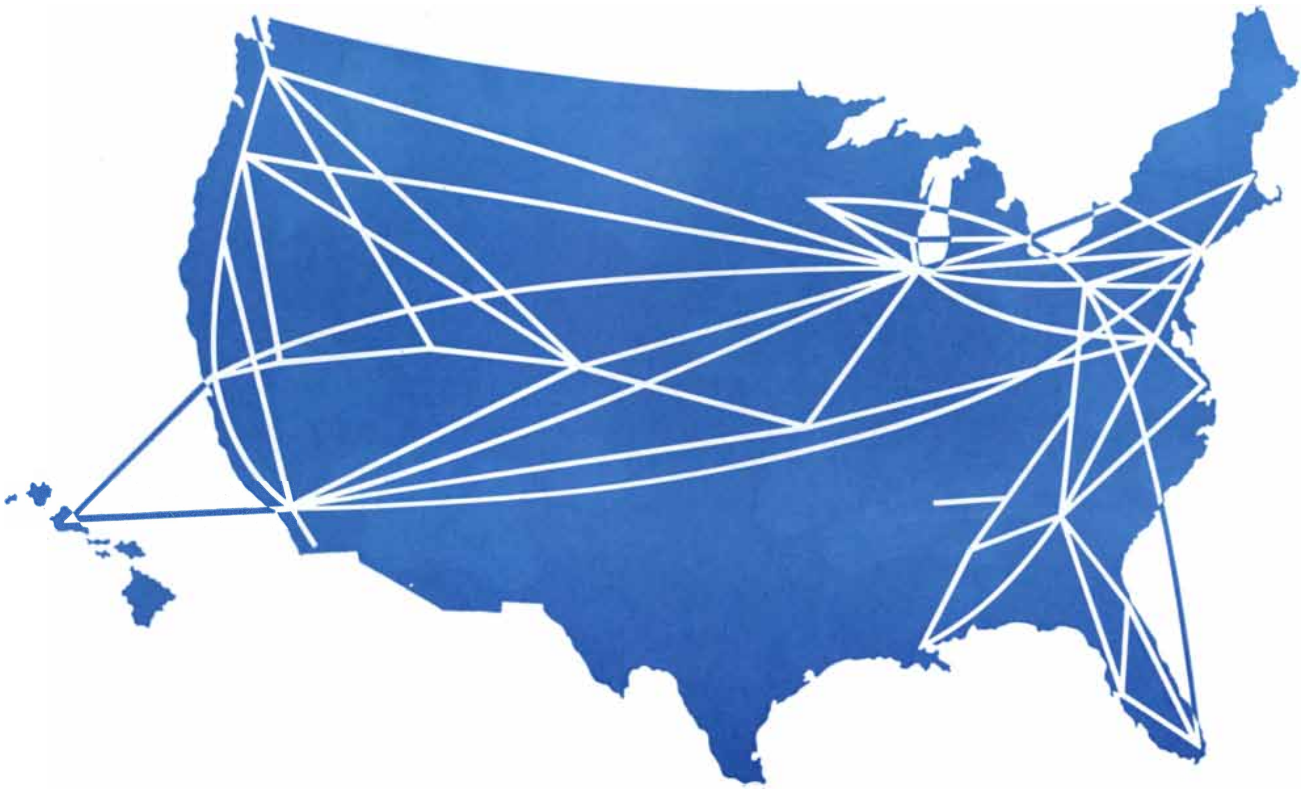
In the case of *Globigerina pachyderma*, the dominant direction of coiling follows closely the temperature of surface water in the northernmost Atlantic. Again we find evidence of shifts in the boundary between the left-coiling (cold water) and right-coiling (warm water) populations. Here we believe the shifts were determined directly by temperature changes in the late Pleistocene [*see illustration on pages 102 and 103*]. The coiling changes in a typical core show a period of cold climate preceded by a time of mild climate during which right-coiling was as strongly dominant as it is today. In this lower zone of the core and at the top of the core we find abundant fossils of various other warm-water species; these are absent in the intervening zone of left-coiling. (A direct causal relation between coiling direction and temperature is hardly conceivable. If both the direction of coiling and the temperature tolerance are determined genetically, the two characteristics may be associated because their genes are linked.)

Such changes in coiling direction of *Globigerina pachyderma* at lower levels in sediment cores provide insight into oceanographic conditions in the North Atlantic during the late Pleistocene. For example, left-coiling dominates from top to bottom of all cores taken in the area of present-day left-coiling. This indicates that the inflow of relatively warm Atlantic water into the Norwegian Sea was never greater in the late Pleistocene than it is today. Again, the change to left-coiling directly below the tops of cores in the area of present-day right-coiling implies that the inflow of warm Atlantic water decreased during the last glaciation. As yet we cannot tell whether this resulted from a decrease in energy of the general circulation of the North Atlantic or from the lower sea level that accompanied the glaciations. The latter would make the submarine ridge between Iceland and Scotland a more effective barrier to influx. We hope that further study of the foraminifera in sediment cores will answer this and similar questions. Since ocean circulation, particularly that of the North Atlantic, must have had a powerful influence on Pleistocene climates, a better understanding of this circulation may yet provide the basis for a satisfactory theory of the cause of ice ages.

Finally, our microfossil studies have thrown new light on the origin of the Atlantic Ocean. No cores from any ocean have yielded fossils older than the late Cretaceous period, about 100 million years ago. It is particularly suggestive that the rather thorough sampling of the bottom of the Atlantic during the past 15 years has yielded no older fossils. Can we conclude from this that the Atlantic basin came into existence in its present form at some time during the Cretaceous period? To admit this possibility is to question the widely held belief in the permanence of continents and ocean basins. For a definitive answer we shall probably have to wait until samples have been raised from one or more deep borings in the Atlantic. In the meantime the accumulating evidence suggests that a drastic reorganization of that part of the earth's surface now occupied by the ocean basins took place about 100 million years ago.



CROSS SECTION OF OIL POOL shows "slim holes," or exploratory bore holes (*vertical lines*), passing through a series of nearly horizontal sediments and into folded, faulted and partly eroded beds of an earlier era. Two beds of same dark gray tone are both shale, which is likely to lie over oil. Microfossils from bottoms of slim holes show relative ages of beds and thereby reveal existence of fold and fault. The deeper shale bed is of course much older. Although slim holes have not struck oil, they have shown presence of a dome that in this case contains oil, as well as the fault that has moved part of the oil-bearing stratum upward.



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Single-stranded DNA

The molecule of the hereditary material deoxyribonucleic acid (DNA) normally consists of two interwoven strands. The discovery of a form with only one strand promises to clarify how the molecule replicates

by Robert L. Sinsheimer

Until 1953 most geneticists believed that the molecule of deoxyribonucleic acid (DNA), the hereditary material of cells and most viruses, consisted of a single strand of repeating units. In that year James D. Watson and F. H. C. Crick made a fresh analysis of the available information about DNA and proposed that the molecule is a two-stranded structure. They suggested that the strands wind around each other in a double helix and that each strand is the molecular complement of the other. In addition to fitting the observed facts about DNA structure, which were derived largely from X-ray diffraction studies, the Watson-Crick model had the great virtue of indicating how each strand could direct the replication of a complementary strand; in this way the two-stranded parent could produce two identical two-stranded daughters. The model satisfactorily met the tests to which it was put and before long was widely accepted.

Therefore to come suddenly on a virus that evidently has as its genetic material a single-stranded form of DNA is about as unexpected as it would be to find a unicorn in the ruminant section of the zoo. The first reaction is disbelief. Consequently a considerable body of evidence had to be accumulated before one could say with confidence that a single-stranded DNA had been found.

This strange DNA first turned up in our laboratory at the California Institute of Technology in 1958. We had been collecting small viruses in order to study their physicochemical characteristics. We hoped that basic features of virus infectivity and replication could be observed more clearly in small structures than they could in larger ones. Our collection of small viruses included φX174, a minute bacterial virus first isolated in France some 25 years ago. The Greek phi as a prefix identifies the virus as a phage (short for bacteriophage); X indicates that it belongs to Subgroup 10; 174 is simply a serial number.

The φX174 virus preys on the colon bacillus (*Escherichia coli*). Within less than 20 minutes after infecting a bacterial cell, the virus brings about the reproduction of hundreds of its kind, destroying its host in the process. The host lyses (breaks open) and sets the newly formed viruses free.

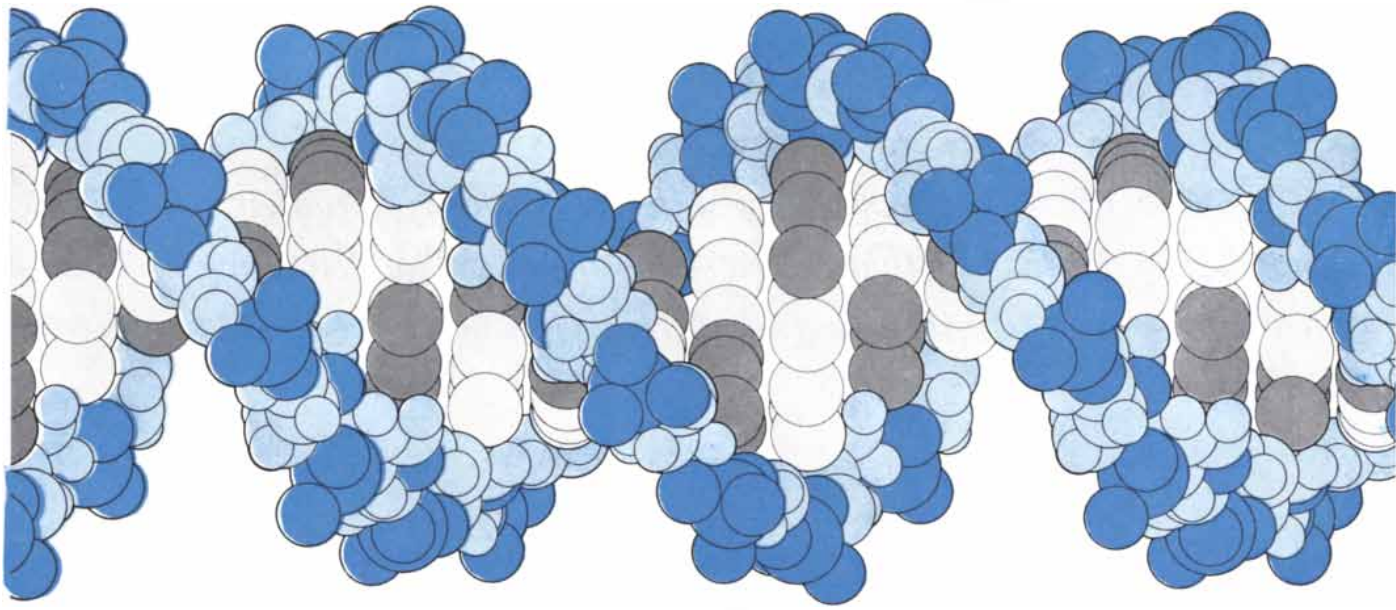
The φX174 virus is comparable in size to the smaller animal and plant viruses, such as poliomyelitis virus or the virus of the Southern bean mosaic disease. These latter viruses, however, contain ribonucleic acid (RNA) as their genetic component rather than DNA. Although the two nucleic acids RNA and DNA bear a family resemblance, they are distinctively different substances. From the evidence to date virus RNA is always single-stranded, and in this respect it is closer to the single-stranded DNA of φX174 than to normal DNA. The φX174 virus is roughly spherical, has a diameter of about 25 millimicrons (a millimicron is a billionth of a meter) and a weight about six million times that of the hydrogen atom. The DNA in φX174 constitutes about a fourth of this total weight. In electron micrographs made in our laboratory and by Cecil E. Hall and Elizabeth C. Maclean at the Massachusetts Institute of Technology, φX174 appears to be built up of 12 identical knobs arranged symmetrically as if on the faces of a dodecahedron [*see illustration on next page*]. Hall has proposed that each knob is in turn made up of five identical subunits that are composed chiefly of protein.

Let me go back now and trace the steps that led us to conclude that the DNA of φX174 must be single-stranded. To begin with, chemical tests established that the nucleic acid fraction of the virus was DNA and not RNA. This was not surprising, because at that time all bacterial viruses were believed to contain DNA. Since then at least one has been discovered that contains RNA. We were perplexed, however, when other tests showed that the DNA of φX174 differed in surprising ways from the normal two-stranded form. For example, the ultraviolet absorption of normal DNA is almost constant over a temperature range from zero to 80 degrees centigrade. Then, just above 80 degrees, which is the critical melting temperature for two-stranded DNA, the ultraviolet absorption rises abruptly. In contrast, the ultraviolet absorption of φX174 DNA begins to rise at 20 degrees and increases steadily until the temperature reaches about 90 degrees [*see upper illustration on page 112*].

We next subjected the φX DNA to the action of various chemicals. We found that a certain enzyme readily attacks the chemical bonds of this DNA, breaking it up into fragments of low molecular weight. Normal DNA resists the action of the enzyme for a considerable period, before gradual breakdown is observed.

Normal DNA also resists the action of formaldehyde. In φX DNA sites reactive to formaldehyde are evidently exposed, and the result of the reaction can be followed by measuring changes in the extent to which the treated molecule absorbs ultraviolet radiation. It was important to be sure that this reaction with formaldehyde was not some artifact of the process of extracting the DNA from the virus. Fortunately we were able to show that the same changes in ultraviolet absorption take place when the intact virus is treated with formaldehyde [*see lower illustration on page 112*].

The strongest evidence that the DNA



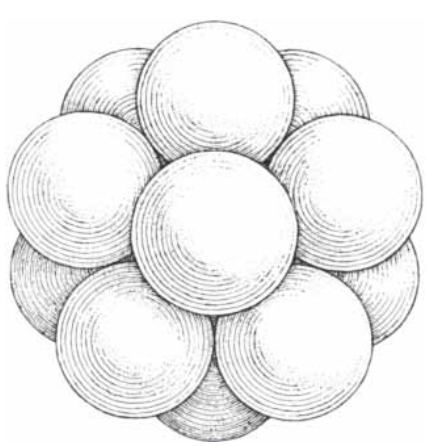
TWO-STRANDED DNA, consisting of two intertwined helices, is the normal form of the gene-bearing molecule, according to the model proposed by James D. Watson and F. H. C. Crick in 1953. Each strand consists of phosphate units (*dark color*) and deoxyri-

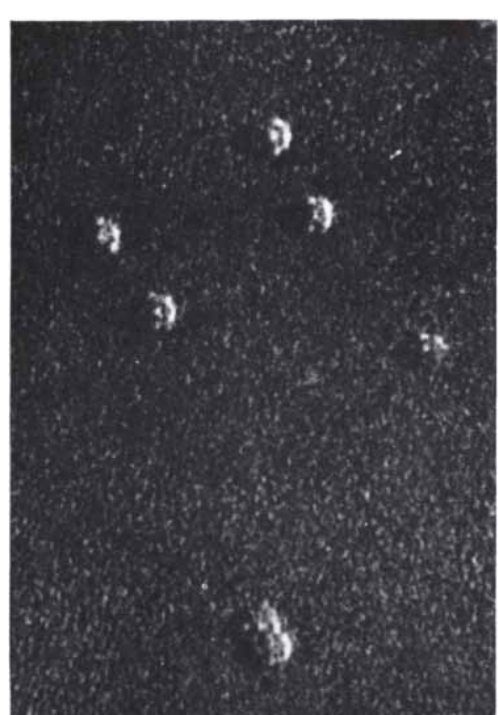
in φX174 is not double-stranded is found in its chemical composition. Like normal DNA, the DNA of φX174 is a chain of three kinds of subunits: (1) phosphate, (2) deoxyribose (a sugar whose molecule contains five carbon atoms) and (3) any one of four "bases": adenine, thymine, guanine and cytosine. One of the important clues to the two-stranded structure of normal DNA is that the number of adenine units always equals the number of thymine units and the number of guanine units always equals the number of cytosine units. In the model proposed by Watson and Crick, wherever adenine occurs in one strand of the molecule it is paired with thymine in the complementary strand; similarly, guanine is paired with cytosine. The DNA in φX174 fails to show this equivalence. It contains adenine, thymine, guanine and cytosine in the ratio of 1 to 1.33 to .98 to .75 respectively. The simplest explanation consistent with this finding, and with the other distinctive properties of the molecule, is that the DNA is single-stranded.

Recent studies have revealed a second remarkable feature of this DNA. Not only is it single-stranded but also the single strand is closed on itself in the form of a ring. A ring structure was first suspected when we undertook to break down the molecule with enzymes in order to identify the bases at its ends. No ends could be found.

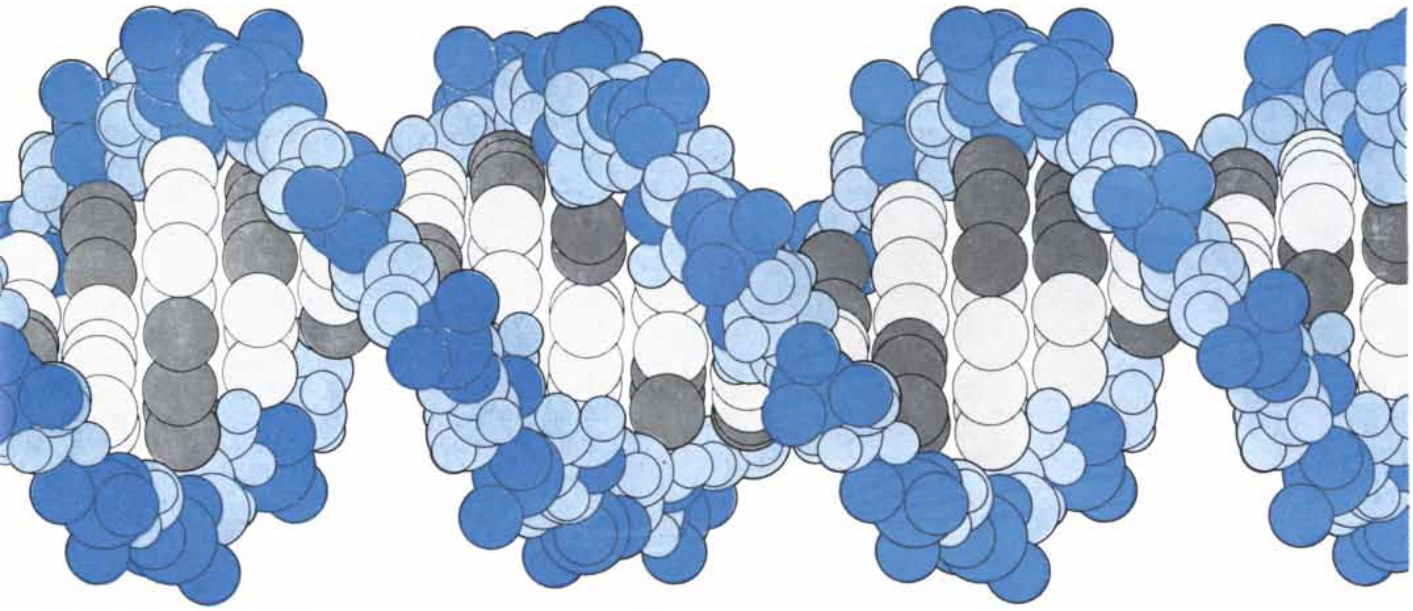
More positive evidence has come from making φX DNA sediment out of solution by spinning it at high speed in an ultracentrifuge. In such experiments measures must be taken to prevent parts of the DNA molecule from reacting with other parts and thereby creating folded molecules with different sedimentation rates. Even when this precaution was taken, we found that most preparations of φX DNA separated into two sharply defined fractions. Moreover, we found that only the DNA in the fraction that sedimented faster was capable of infecting specially treated cells. (The method of measuring this capability will be described later.)

The ring-structure hypothesis led to the idea that the faster sedimenting component might represent an active ring-shaped molecule, whereas the slower moving component might be an opened-ring form that had lost its activity. To test this idea we treated the φX DNA for various lengths of time with tiny amounts of an enzyme known to cleave DNA. We found that a single





MODEL OF øX174 (*left*), the bacterial virus containing single-stranded DNA, is inferred from electron micrographs such as the one at right made at the Massachusetts Institute of Technology by Elizabeth C. Maclean and Cecil E. Hall. The apparent smoothness of the 12 spheres forming the virus is probably an artifact of metal-shadowing technique



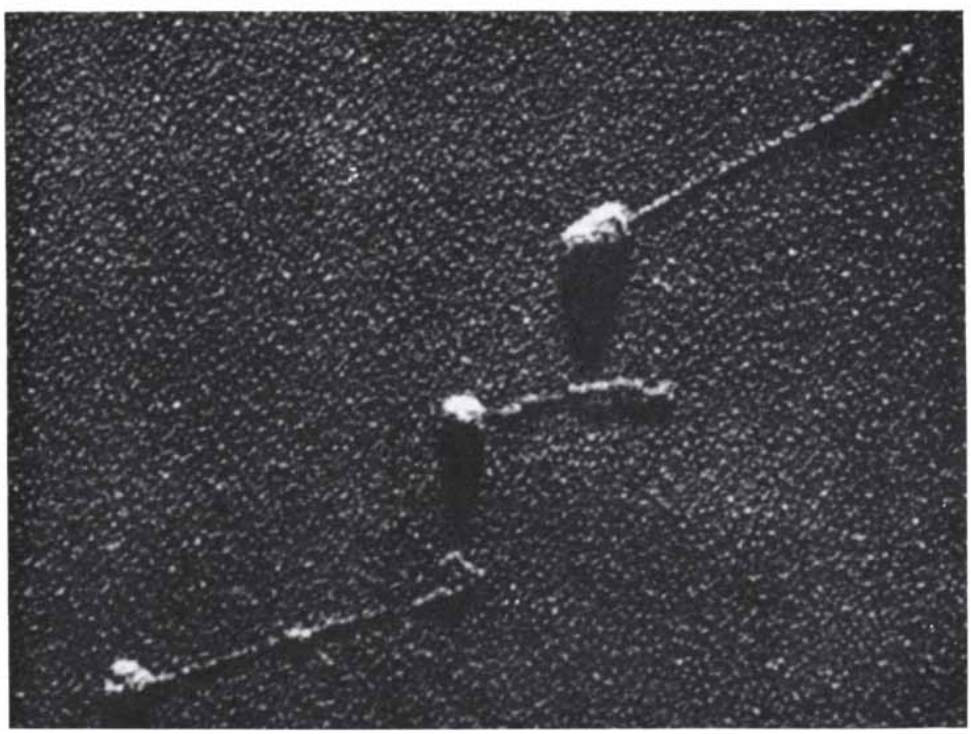
bose units (*light color*) in alternating sequence. Strands are cross-tied by bases: adenine paired with thymine or guanine with cytosine. Thymine and cytosine are shown dark gray. The particular sequence of bases establishes the genetic code in the DNA molecule.

cleavage of a DNA molecule destroyed its infectivity, and that an amount of DNA corresponding to the loss in infectivity was thereby transferred from the faster sedimenting fraction to the slower sedimenting fraction. On further treatment with the enzyme, DNA disappeared from the second fraction into fragments that sediment at various rates.

The ring shape must be of peculiar importance in the replication of this unusual DNA, but its full significance is still obscure. It should be emphasized that we do not know whether the DNA molecule alone forms a closed ring or whether it is held together by a coupling of some other substance.

In other recent studies we have sought to exploit the unusual features of φX174 and its nucleic acid and to explore some of the many questions posed by its discovery. Each φX virus contains only one molecule of DNA. Accepting the current doctrine that nucleic acid is

used in electron micrography. Spheres consist of protein molecules. In electron micrograph viruses are enlarged 180,000 times.



STRANDS OF DNA extruded from particles of øX174 appear in electron micrograph made by Maclean and Hall. Extrusion is induced by heat or by action of certain chemicals, for example urea. Each particle extrudes only a single strand, but its length can vary widely, apparently because extrusion is seldom complete. Fully stretched out, a DNA strand is about 150 times the diameter of the virus itself.

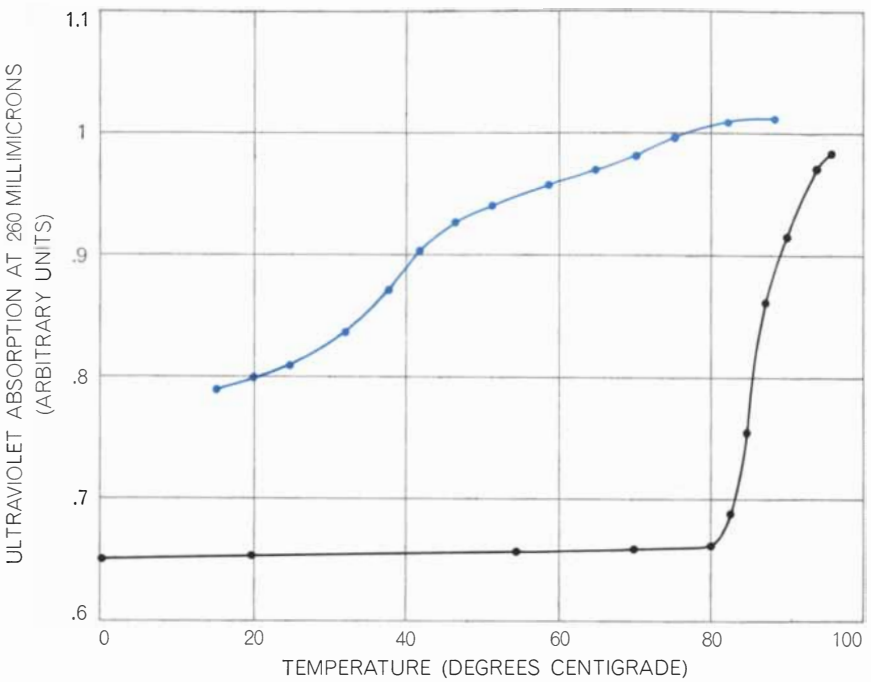
the sole hereditary material of a cell or virus, we felt that it should be possible to initiate the virus infection of a bacterium with this DNA molecule alone. It has been known for some 10 years that the protein of a bacterial virus remains outside the bacterial cell after it has accomplished its mission of breaching the cell wall. Our problem, therefore, was to get the φX DNA into its bacterial host without the help of the φX protein.

This was achieved by treating the bacteria with enzymes that dissolved part of the cell wall. Cells so treated are called bacterial protoplasts. They assume a rounded form and will burst in an ordinary culture medium because of excessive internal pressure. They can, however, be maintained intact for several hours in a special salt solution and under these conditions will continue to carry out their normal metabolic processes at a high rate, although they will not divide.

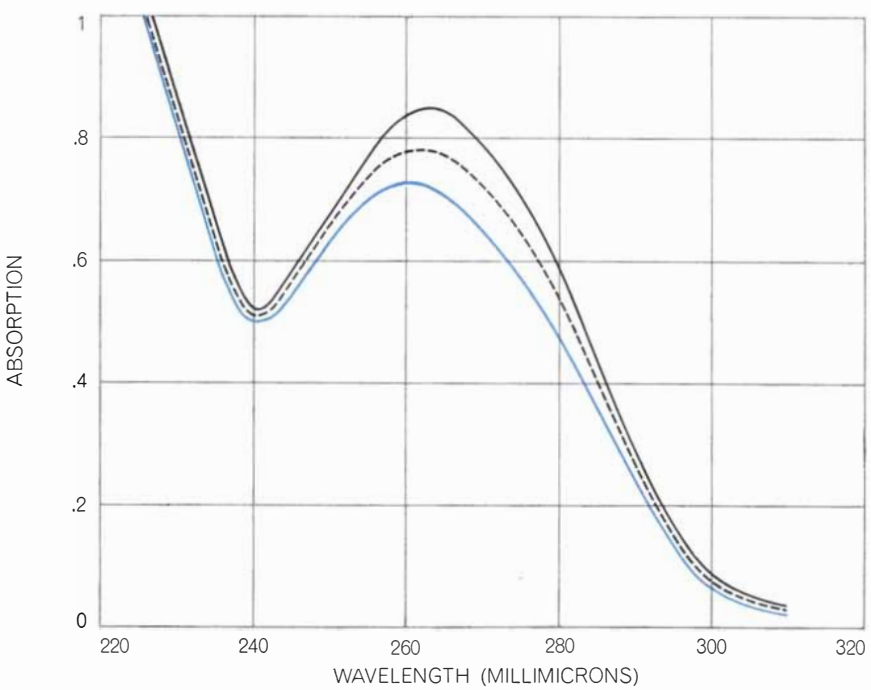
A fraction of such protoplasts become sufficiently permeable to take up the purified, protein-free DNA from phage φX174. Within about 20 minutes the infected protoplasts produce whole virus particles capable of infecting normal cells [*see upper illustration on page 114*]. Curiously, whole virus particles will not infect the protoplasts, just as free DNA will not infect normal cells.

The mechanism by which the threadlike molecule of DNA actually finds its way into the protoplasts is unknown. When the molecule of φX DNA is unraveled, it has a length about 150 times greater than the diameter of the virus itself. Normally only a few tenths of 1 per cent of the protoplasts become infected. It is possible to arrange conditions, however, so that the efficiency of infection, expressed as the fraction of DNA molecules added that result in an infected protoplast, rises to more than 25 per cent. Since each protoplast makes 100 or more complete virus particles, under these conditions more virus DNA is made than was originally added to the protoplasts. It is therefore evident that the complete viruses released from infected protoplasts are not simply the original DNA "recoated" with viral protein. We are observing the complete synthesis of virus particles, initiated by the free nucleic acid. The availability of a system in which virus infection can be initiated at a relatively high efficiency by a free nucleic acid now opens up numerous possibilities for investigation of the effects of varied chemical, enzymatic and physical agents on the functional properties of the nucleic acid.

All this leads up to an important question: How does the single-stranded DNA replicate itself? The common two-stranded DNA is believed to replicate by an unraveling of the two strands, concomitant with the synthesis of a complementary daughter strand on each of the two parental strands, resulting in the production of two double-stranded DNA molecules [*see illustration on page 116*]. An obvious hypothesis is that the replication cycle of the single-stranded DNA of φX174 involves a double-stranded stage.



MELTING POINTS of two-stranded DNA and single-stranded DNA from øX174 are reflected in ultraviolet absorption. Rise in absorption between 20 and 80 degrees centigrade indicates that øX DNA (*color*) melts slowly over a broad range, unlike normal DNA (*black*).

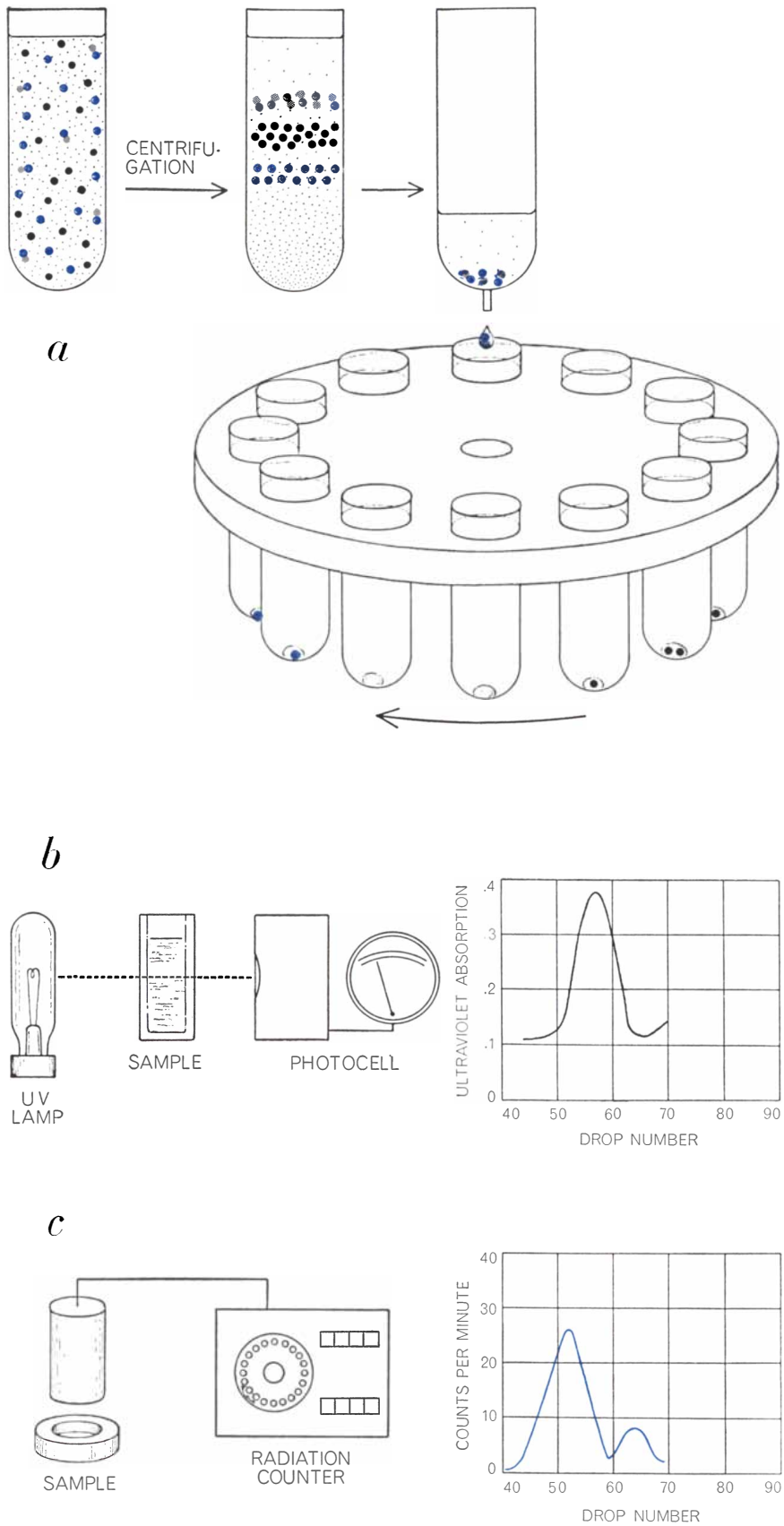


REACTION WITH FORMALDEHYDE provides another clue that øX DNA is single-stranded. Bottom curve shows ultraviolet absorption of untreated øX DNA. Middle curve is after exposure to formaldehyde for 36 minutes; top curve is absorption after 6 to 18 hours.

Support for this hypothesis has recently been obtained from the following experiment. By the use of an appropriate culture medium a preparation of φX174 was grown in which all the nitrogen atoms were of the heavy isotope N-15 and a fraction of the phosphorus atoms were of the radioactive isotope P-32. Depending on the specific replication mechanism, the φX DNA molecules later produced inside infected bacteria might incorporate these isotopes in various ways. DNA incorporating N-15 could be identified because it would be heavier than DNA containing ordinary nitrogen (N-14). DNA containing P-32 would of course reveal itself by its radioactivity. The next step was to expose bacteria to the labeled viruses and allow replication to take place. The experiment gives better results—including a higher yield of DNA—if the bacteria are artificially opened before lysis. To provide a DNA fraction of normal density for reference, ordinary φX DNA, containing ordinary nitrogen, was added to the extracted DNA as a carrier.

An elegant method has been devised for separating the molecules of a compound in which some of the molecules are labeled with heavy atoms and some are not. One places the sample in a concentrated solution of a heavy salt such as cesium chloride and spins the mixture at high speed in an ultracentrifuge. After several hours an equilibrium distribution of cesium chloride is established in the centrifuge cell, with the highest salt concentration at the outer, or centrifugal, end of the cell and the lowest concentration at the inner, or centripetal, end. As a result the density of the solution increases smoothly from the inner to the outer end of the cell, producing a gradient of density. If a sample containing components of various densities is spun in such a solution, the components will come to equilibrium in the cell at points where they exactly match the density of the solution [*see illustration at right*].

The mixture of labeled DNA and carrier DNA was centrifuged in this manner. To determine the centrifugal position of various components, the plastic centrifuge cell was carefully removed from the centrifuge rotor at the end of its spin, a fine hole was bored in the bottom of the cell and the successive drops of solution were collected separately. The first drops represent the denser end of the solution, the last drops represent the lighter end, with a regular progression in between. DNA from the parental virus could be detected by its radioactivity. The N-14 carrier DNA, present

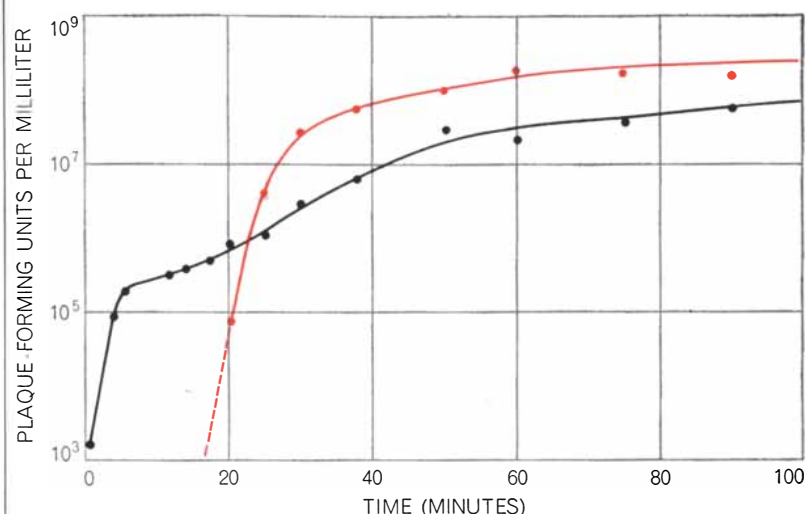


CENTRIFUGATION reveals the density of DNA fractions produced when øX174 labeled with radioactive phosphorus (P-32) and heavy nitrogen (N-15) is allowed to replicate in cells made up of ordinary atoms. The DNA (*colored dots*) removed from these cells is centrifuged in a heavy-salt solution to which unlabeled single-stranded DNA (*black dots*) has been added. The salt produces a density gradient, and the DNA fractions band at appropriate levels (*a*). Ultraviolet absorption (*b*) indicates drops rich in ordinary DNA. Radiation counter reveals labeled DNA is in two bands (*c*); the lighter is double-stranded.

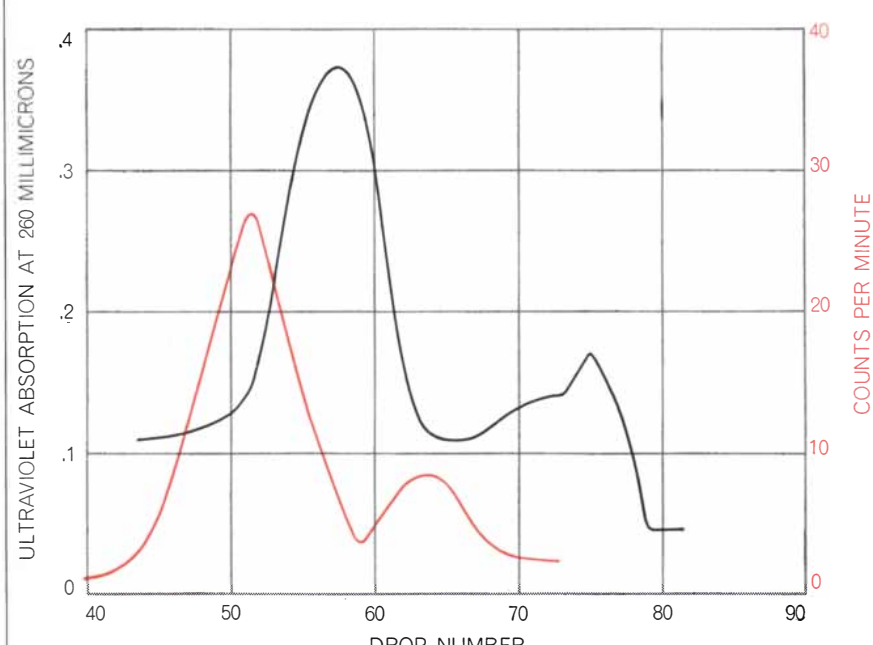
in much greater amount, could be detected by its ultraviolet absorption.

The radioactivity from the parental virus was found in two bands, one heavier than the band of the carrier DNA and one lighter. The heavier band was at the expected density for φX DNA labeled with N-15. The band lighter than the carrier DNA had the density to be expected if the parental N-15 DNA strand had paired up with a complementary N-14 DNA molecule to form a double-stranded molecule. (The density of double-stranded DNA is about 1 per cent less than that of the single-stranded form.) With increased time of infection more of the parental phosphorus appears in the lighter band.

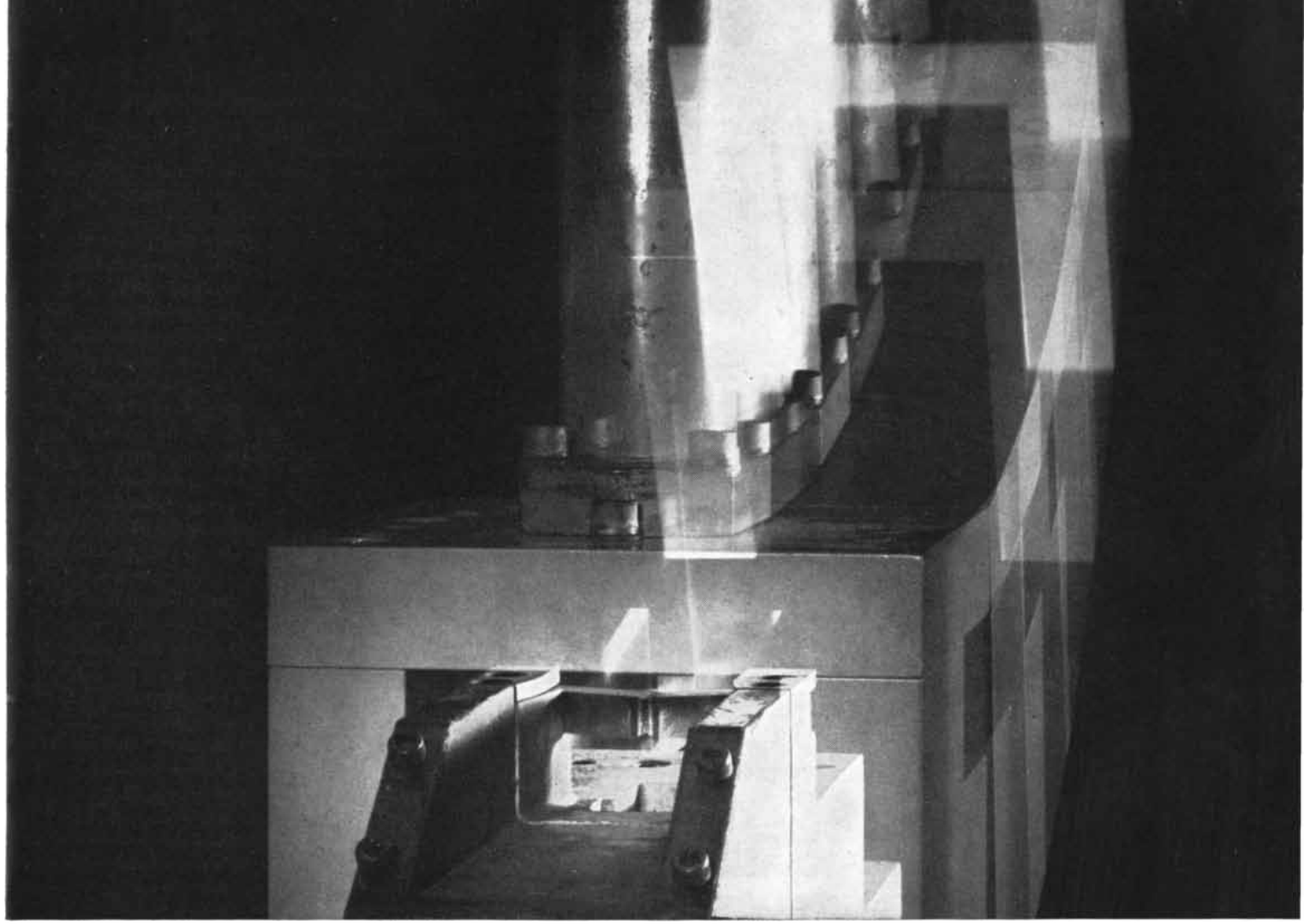
Evidently during the process of infection the φX DNA enters into an altered



REPLICATION OF COMPLETE VIRUS PARTICLES from øX DNA alone is shown by the shapes of these two curves. Bacteria with cell walls partially destroyed, called protoplasts, are infected with øX DNA. Samples of the infected culture show a secondary rise in infectivity after about 20 minutes (*black curve*), indicating the release of new virus particles. If the infected culture is subjected to osmotic shock, which halts the replication process, few new viruses can be found unless shock is withheld for about 20 minutes (*colored curve*).



CENTRIFUGE EXPERIMENT shows that newly created øX DNA, labeled with radioactive atoms and heavy nitrogen (N-15), appears in two forms, one heavier and one lighter than normal øX DNA added as a carrier. Strong ultraviolet absorption of the carrier establishes sedimentation position of unlabeled DNA. (*Also see illustration on preceding page*).



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form that we call the replicative form. Although characterization of this form has so far been indirect, because only minute amounts have been available, many of its properties suggest that it is two-stranded. For example, if the parental virus material is made even denser by the incorporation of heavy hydrogen (H-2) in addition to N-15, the replicative form is correspondingly denser, indicating that it must incorporate essentially all the parental viral DNA. The reaction to heat provides other evidence. When double-stranded DNA is heated and its orderly structure is destroyed, it becomes significantly denser. When the replicative form is heated, it too becomes denser, and to a similar degree. (When single-stranded DNA is heated, its density does not change.)

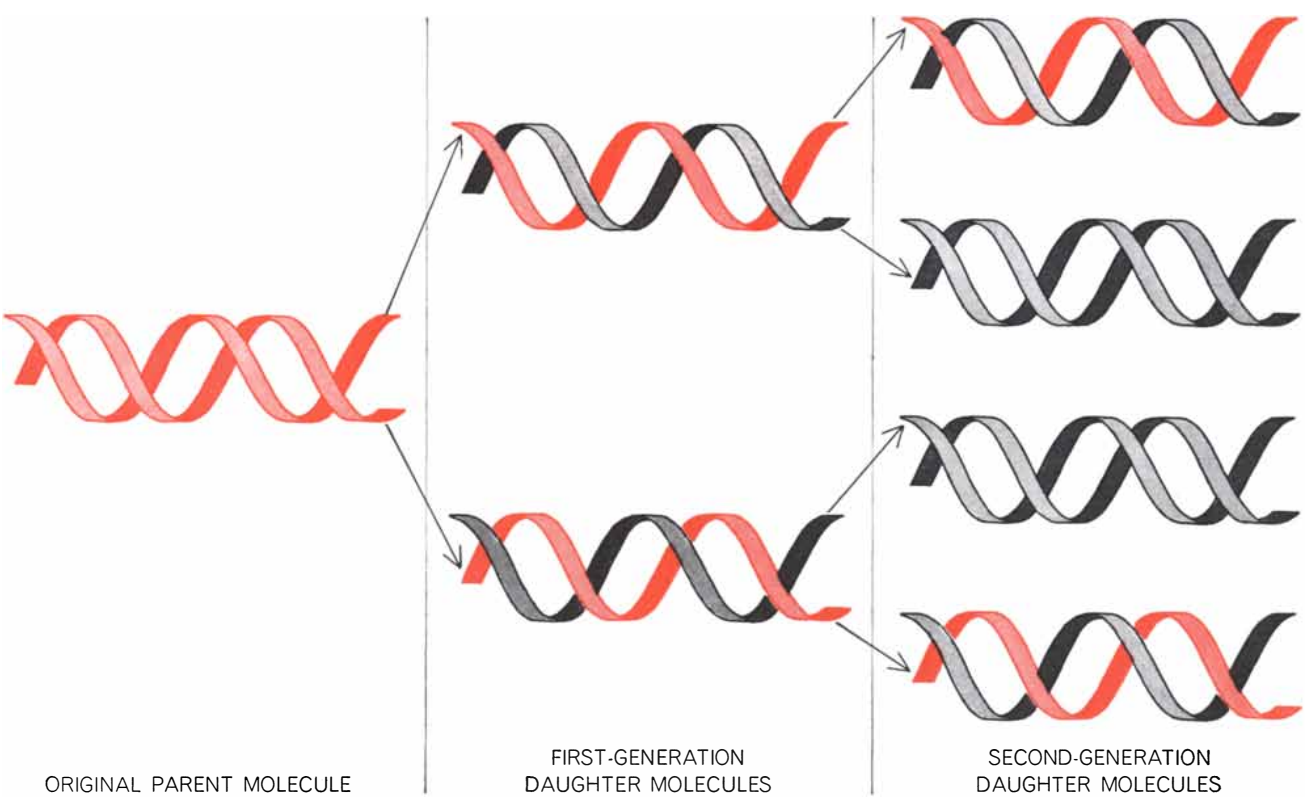
Like the single-stranded form, the replicative form will also infect bacterial protoplasts; one can therefore compare the relative effect on the two forms of various inactivating agents. As might be expected, the single-stranded form from the virus, which is known to react with formaldehyde, is rapidly inactivated by formaldehyde. The infectivity of the replicative form is essentially unaffected by formaldehyde, indicating that the amino (nitrogen-hydrogen) groups of its component bases are not accessible. To sum up, all the tests so far devised strongly suggest that the replicative form is indeed a two-stranded intermediate produced during the replication of φX174. One would expect the two-stranded form to contain matching amounts of the complementary base pairs: adenine-thymine and guanine-cytosine. If experiments now in progress show this to be the case, we can assume that φX DNA in its replicative form has a structure similar to that of ordinary two-stranded DNA.

The amount of replicative-form DNA, as measured by the amount of infective material with these distinctive properties, increases many-fold during infection. Moreover, this multiplication occurs even if the infection is carried out in the presence of chloramphenicol, an antibiotic that blocks protein synthesis and prevents the formation of progeny virus particles.

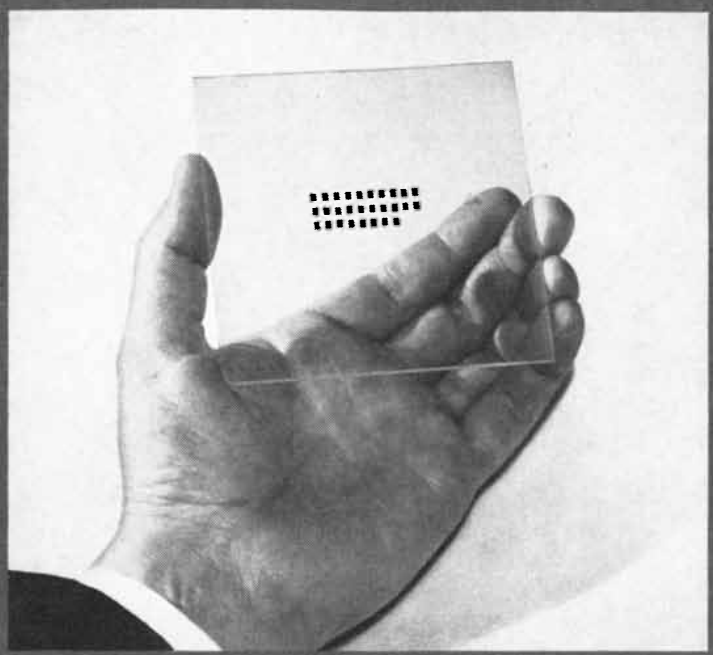
Clearly at some stage in the viral replication there must be a reversion to the single-stranded DNA state. Late in the infection many mature virus particles containing single-stranded DNA are found inside the infected cell. At no time during infection, however, is a pool of free, single-stranded DNA molecules observed. The single strands must be incorporated into progeny particles soon after they are formed. If the infection occurs in the presence of chloramphenicol so that no progeny are made, no single-stranded DNA is found.

The replicative form may in some way serve as a template from which many copies of the single-stranded form are peeled. Alternatively it may serve as a precursor of the single strands, each molecule providing one strand to be built into a virus particle while the other strand is discarded. Further research is needed to decide between these concepts.

Phage φX174 is a representative—in all probability only the first to be discovered—of a distinct class of virus with a distinct hereditary material. (At least one other virus, S13, very similar to φX174 in size, appears to contain single-stranded DNA.) A better understanding of the replication mechanism of φX174 might clarify the replication of the more numerous viruses with two-stranded DNA, and perhaps also the replication of the many RNA viruses that infect plant and animal cells. In addition, the simplicity of φX174 offers the long-range possibility that, through the use of the full repertory of modern techniques, a reasonably complete understanding of the course of virus infection can be achieved.



REPLICATION OF NORMAL DNA requires that the two-stranded helix of the parent molecule (*left*) become untwisted. Each parent strand then serves as a template for the formation of a complementary strand, with the result that one strand of the parent appears in each of two daughter molecules (*middle*). A repetition of the process yields four molecules in the second generation (*right*).



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THE MOON ILLUSION

When the moon is near the horizon, it looks bigger than when it is at the zenith. Is this because the observer raises his eyes to see the zenith moon or because he views the horizon moon over terrain?

by Lloyd Kaufman and Irvin Rock

When the moon hangs low over the horizon, it looks much bigger than when it is high in the sky. Yet in photographs its image has essentially the same size no matter where the camera finds it. Of course this is equally true of the images in the eye. The change in size is not an optical effect but a psychological one. It is therefore known as the moon illusion.

Men have recognized the moon illusion (as well as the corresponding sun illusion) since antiquity. Many explanations for it have been advanced, but only two deserve serious consideration. One can be called the apparent-distance theory and the other the angle-of-regard theory. According to the former the horizon moon looks bigger because it seems farther away; according to the latter the high moon looks smaller because the viewer raises his eyes or head to look at it.

The apparent-distance theory seems to be the older, going back at least to the second-century astronomer and geometer Ptolemy. He proposed that any object seen through filled space, such as the moon seen across terrain at the horizon, is perceived as being more distant than an object just as far away but seen through empty space, such as the moon at the zenith. If the images of these objects in the eye are in fact of equal size, the one that appears farther away will seem larger.

This follows from the geometrical relationship between size and distance [*see top illustration on page 122*]. If two objects at unequal distances from the observer form images of the same size on the retina, the more remote object must be the larger. It is well known to psychologists that an observer perceiving two equal images, and receiving sensory information that one object is farther away than the other, correctly sees the farther one to be the larger. The reader can demonstrate this fact for himself by looking at a sharply contrasted object against a uniform background long enough to form a clear, persistent afterimage on the retina. This afterimage is of course constant in size. But when the gaze is shifted between two surfaces at different distances, the image appears larger when it is projected on the farther surface.

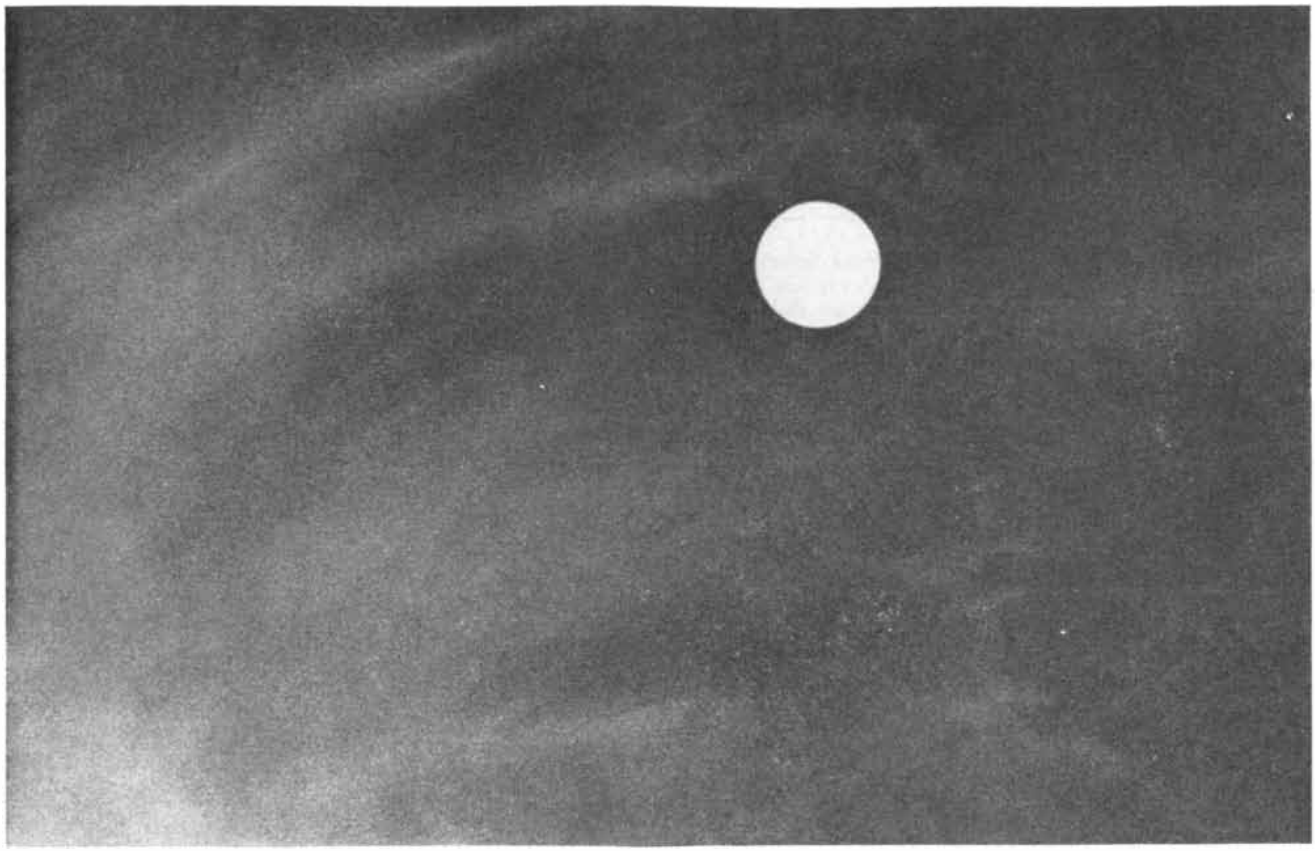
Similarly, if the moon seems farther away when it is on the horizon than when it is higher in the sky, it should look larger. Some years ago Edwin G. Boring and his colleagues at Harvard University subjected the apparent-distance theory to what he considered a critical test. He asked people to judge the relative distances of the zenith and horizon moons. Most of his subjects said the horizon moon seemed nearer—the opposite of what the theory called for. So Boring sought another explanation.

He proposed that the postural changes involved in looking at the zenith moon might somehow be responsible for the moon illusion (the angle-of-regard theory). Although he could find no explanation of why this might be so, he and his colleagues carried out a series of experiments that seemed to connect the apparent size of the moon with the elevation of the observers' eyes. They used a number of methods; the major one was designed to measure the illusion as follows. The subjects were asked to match the moon, as they saw it, with one of a series of disks of light projected on a nearby screen. Looking at the horizon moon with eyes level, most observers selected a disk one and a half or two times larger than the one they chose when their eyes were raised 30 degrees to view the zenith moon. When they tilted their heads so that they could look at the zenith moon with eyes level, their choice indicated that they experienced no illusion. Two subjects lay supine so that they could see the zenith moon "straight ahead," and, by bending their necks backward, could see the horizon moon with eyes "elevated." For them the illusion was reversed, the zenith moon appearing the larger.

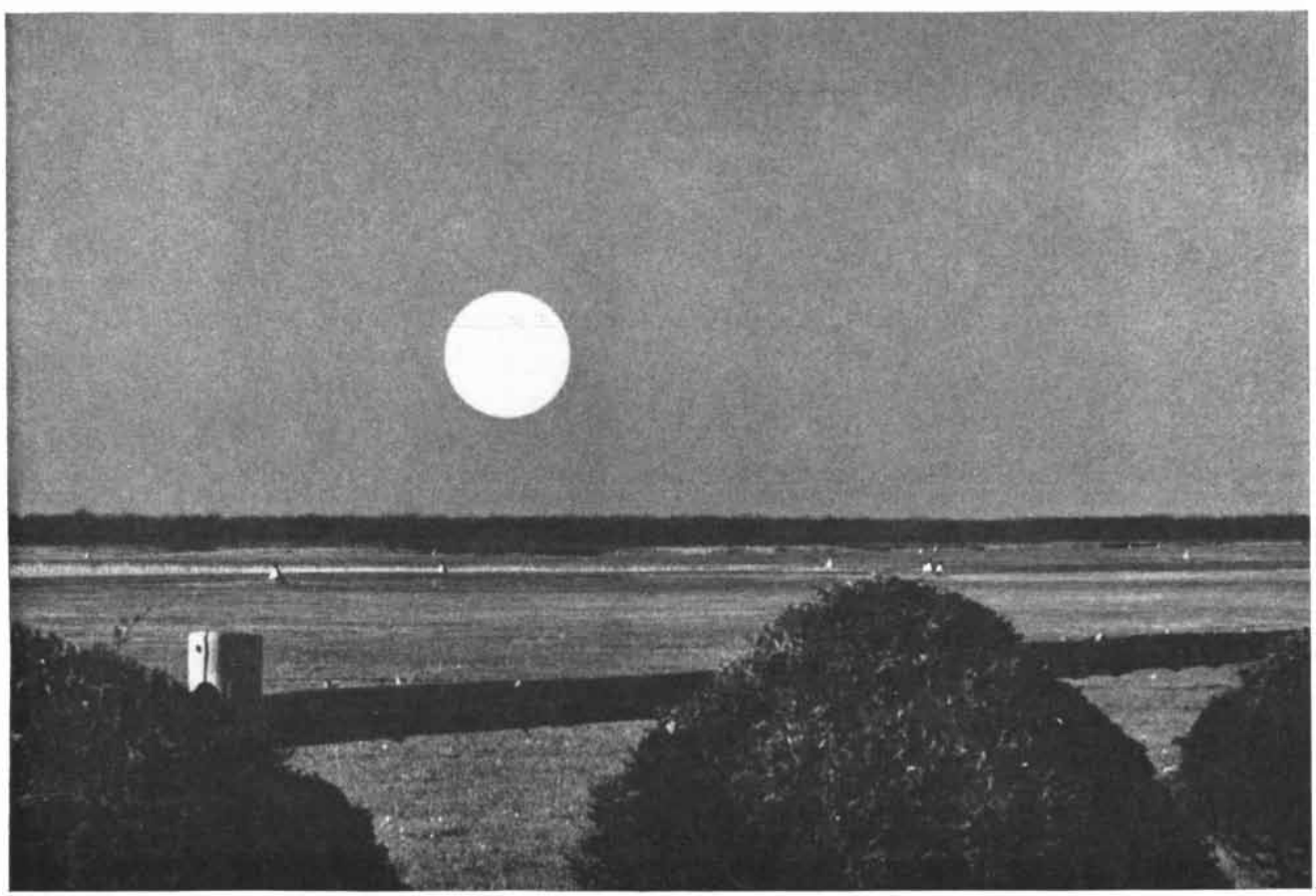
In spite of the apparent persuasiveness of these results, the authors of the present article, working at the New School for Social Research and at Yeshiva University, decided some five years ago to reopen the subject. For one thing, we ourselves saw no significant change in size whether we looked at the moon with our eyes level or elevated. For another, we questioned Boring's method of determining the moon's apparent size.

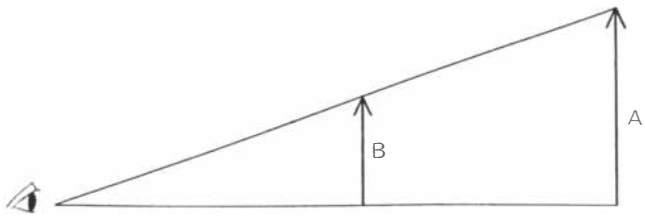
In effect he was asking his subjects to compare things that are not really commensurable. It is difficult to say how large the moon appears to be. Its virtually infinite distance gives it a large but more or less indeterminate size. The comparison disks, on the other hand, were nearby, so that the observer could easily make a judgment as to their actual size. He then had to match a circle of indeterminate size with one having a diameter of some specific number of inches. We felt that such a comparison was extremely difficult to make.

We decided to try a more direct approach, in which two artificial moons seen against the sky could be compared with each other. (The actual illusion involves the same sort of comparison, although the two real moons are separated by a considerable interval of time as well as space.) In our artificial moon appara-

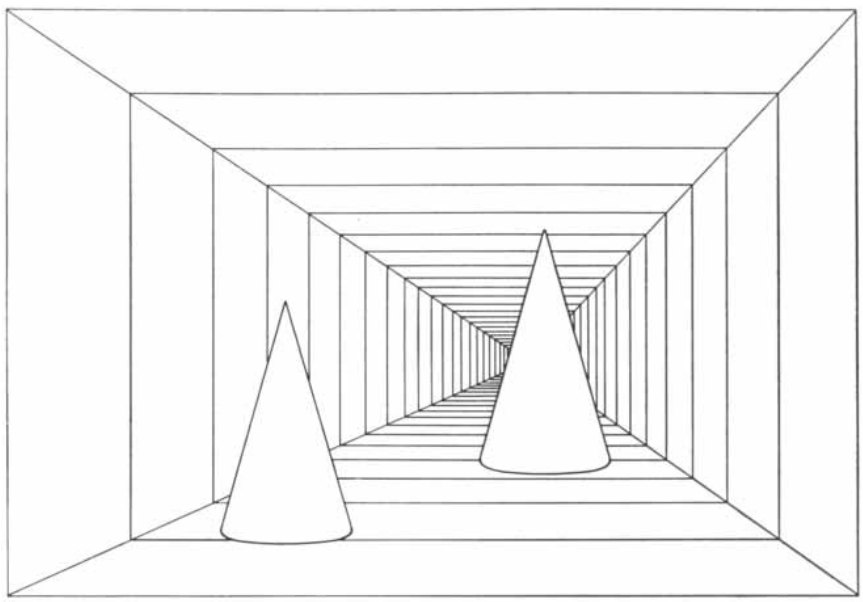


MOON ILLUSION, in which the horizon moon appears larger than the zenith moon, is simulated in these photographs. An artificial moon has been placed high in the empty sky (*above*) and another, of the same size, has been placed low on the horizon (*below*). Some people note a slight illusion even in the photographs; the illusion is a common phenomenon for most people viewing an actual scene.

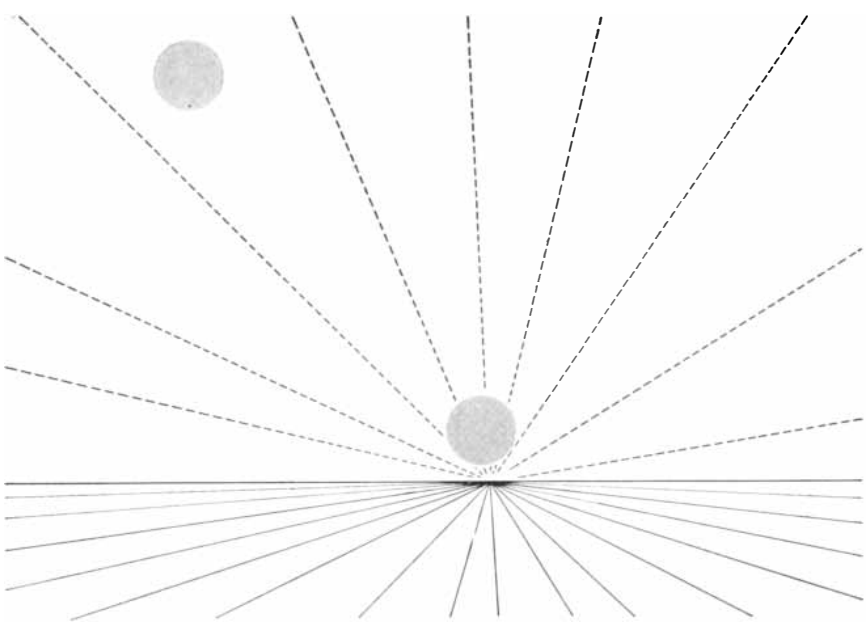




DISTANCE AND SIZE are related in the manner shown here. Although arrows *A* and *B* subtend the same visual angle at the observer's eye and therefore produce images of the same size on his retina, arrow *A* is seen to be farther away and hence actually to be larger.



DISTANCE-SIZE RELATIONSHIP is automatically taken into account by an observer. If two objects that are actually the same size are perceived as being at different distances, the one that seems to be farther away will look larger. The figure at the right is perceived as being larger than the identical figure at the left only because it seems to be farther away.



APPARENT-DISTANCE THEORY holds that this is what happens in the case of the moon illusion. The horizon moon appears to be farther away, although it is not. The viewer automatically takes the apparent distance into account. He then unconsciously applies the rule that, of two objects forming images of equal size, the more distant must be the larger.

tus light rays from a lamp pass through a circular aperture and are made parallel by a lens. The parallel rays fall on a piece of glass or a half-silvered mirror tilted at an angle of 45 degrees. An observer looking into the glass sees a bright disk against the sky, which is also visible through the glass [*see illustrations on page 124*].

With two such devices, one pointed toward the horizon and the other pointed toward the zenith, we could test the illusion both qualitatively and quantitatively. Each device was equipped with a set of circular apertures of different sizes; thus the aperture in one could be changed until the subject said that the size of the "moon" matched that in the other. The ratio of the zenith aperture to the horizon aperture gave a numerical value for the illusion. A ratio of one would mean no illusion; a ratio greater than one would indicate that the illusion was present in its usual form.

First we set out to test the eye-elevation hypothesis by our new method. In one experiment 10 subjects viewed the artificial horizon moon normally and compared it with a zenith moon that they saw either with eyes elevated or, by tilting their heads, with their eyes level. We obtained an illusion both ways. The ratio of the horizon moon's apparent diameter to that of the zenith moon was 1.48 with eyes elevated and 1.46 without eye elevation—an insignificant difference. Then we had the subjects compare two moons in the same region of the sky, one viewed with eyes level and the other with eyes elevated. The ratio between the sizes of the two moons was only 1.04. There was no illusion to speak of. We concluded that Boring's findings on eye elevation were peculiar to the methods employed.

Before abandoning the angle-of-regard theory completely, we rechecked one other phenomenon that seemed to support it. Many years ago the German psychologist Erna Schur found she could produce the illusion indoors, in a large dark space such as a zeppelin hangar, by projecting disks of light on the wall and ceiling. Moreover, Boring and Alfred H. Holway reported a sun illusion even when the subject looked at the sun through a dense filter that blanked out everything but the bright disk itself. In both cases no terrain was visible to differentiate horizon from zenith. We repeated Schur's experiment in the Hayden Planetarium in New York and got a ratio of only 1.03 between horizon and zenith. Next we set up our

artificial moon apparatus in a totally dark room and repeated our eye-elevation experiment. In this case the moons were each seen at optical infinity, one at the zenith and one straight ahead. Again the ratio turned out to be 1.03. Considering that T. G. Hermans of the University of Washington has recently reported approximately the same ratio in studying the effect of eye elevation in apparent size, and that we came very close to it (1.04) in our outdoor observations of two moons in the same part of the sky, eye elevation would appear to exert a slight effect. Why this should be so is by no means clear, but in any case it cannot really account for the moon illusion.

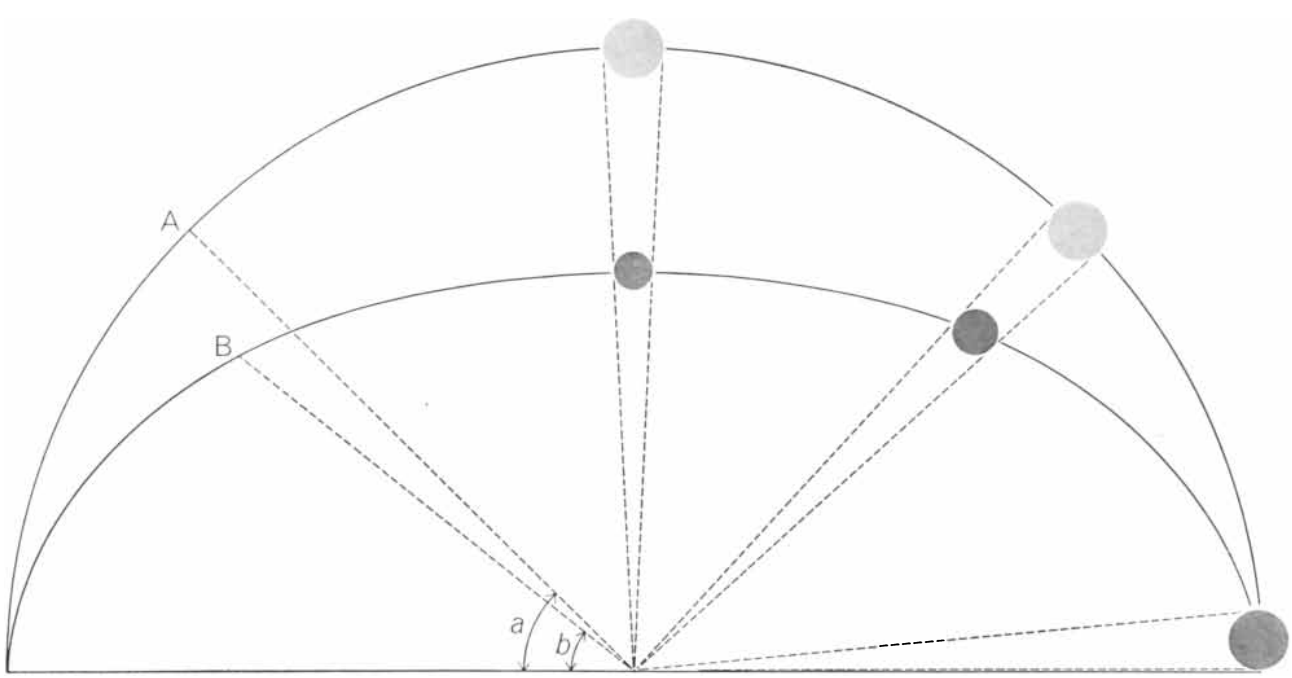
We therefore turned to the apparent-distance theory. Boring had rejected it because his subjects said that the horizon moon appeared to be nearer than the zenith moon. But, we wondered, did they really see the horizon moon as nearer? Or were they judging it to be nearer precisely because it looked bigger, effectively turning the reasoning upside down? In that case the reported distance would be a secondary phenomenon, an artifact of the very illusion it was supposed to test. To check this possibility we showed our subjects pairs of artificial moons of different diameters and instructed them to compare their relative distances. Whenever the zenith moon was larger, the subjects said it was nearer than the horizon moon; when it was smaller, they said it was farther away.

Therefore we next undertook to elicit a judgment of distance without regard to the moon. We asked people to scan a moonless sky and to try to see it as a surface. Then they were to say whether the surface seemed farther away immediately over the horizon or at the zenith. Nine out of 10 observers answered that the horizon sky was the more distant; the tenth could see no difference. From this experiment we conclude that the horizon sky does appear farther away whether the observer realizes it or not when the moon is present.

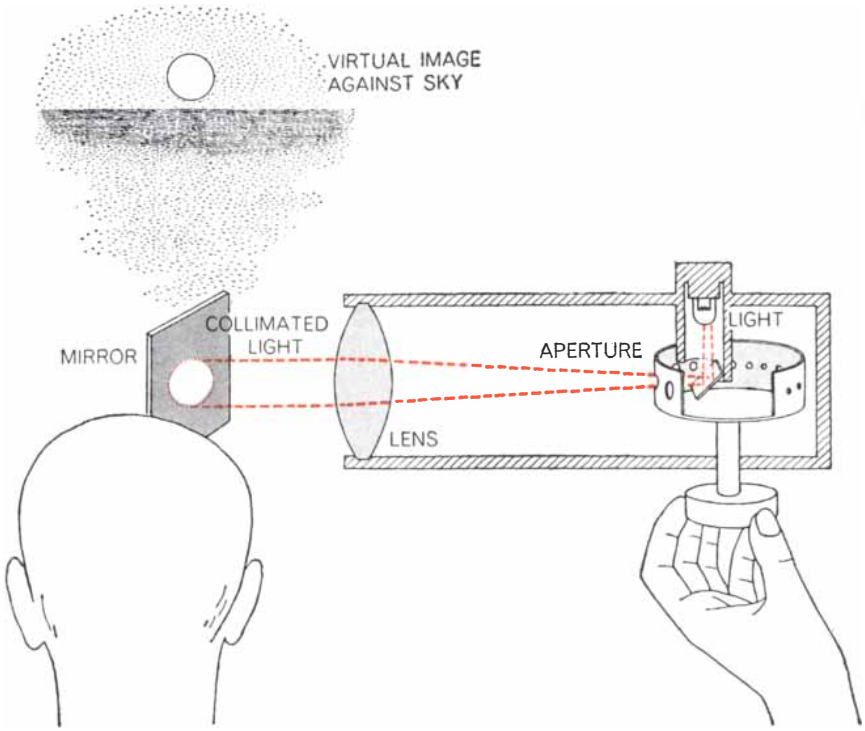
This evidence is supported by a number of observations, dating back to the English mathematician Robert Smith in 1738, on the "half-arc angle." Most people, when they are asked to point along the line that bisects the arc of sky from horizon to zenith, indicate a direction considerably less than 45 degrees from the horizontal. The vault of the heavens looks flattened, like a semiellipsoid, rather than hemispherical. Accordingly the horizon seems farther away than the zenith. If the moon is perceived on the "surface" of the semiellipsoid, it too will appear more distant, and therefore larger, at the horizon [*see illustration below*]. All this convinced us that the apparent-distance theory was perfectly tenable on logical grounds, and we set out to test it directly.

Pointing our artificial-moon apparatus at the horizon, we had observers view the "moon" through a hole in a sheet of cardboard that masked the terrain. Under these circumstances the illusion vanished: the horizon moon looked no larger than the zenith moon. Then we pointed two of our devices at the horizon; in one the moon was viewed through a mask and in the other the moon was seen over unobstructed terrain. The illusion appeared, just as the apparent-distance theory predicts; to make the two disks appear equal the masked aperture had to be made 1.34 times larger than the aperture of the moon over terrain [*see bottom illustration on page 125*]. This was quite comparable with the ratios that were obtained in the ordinary illusion experiment carried out at the same site with different subjects.

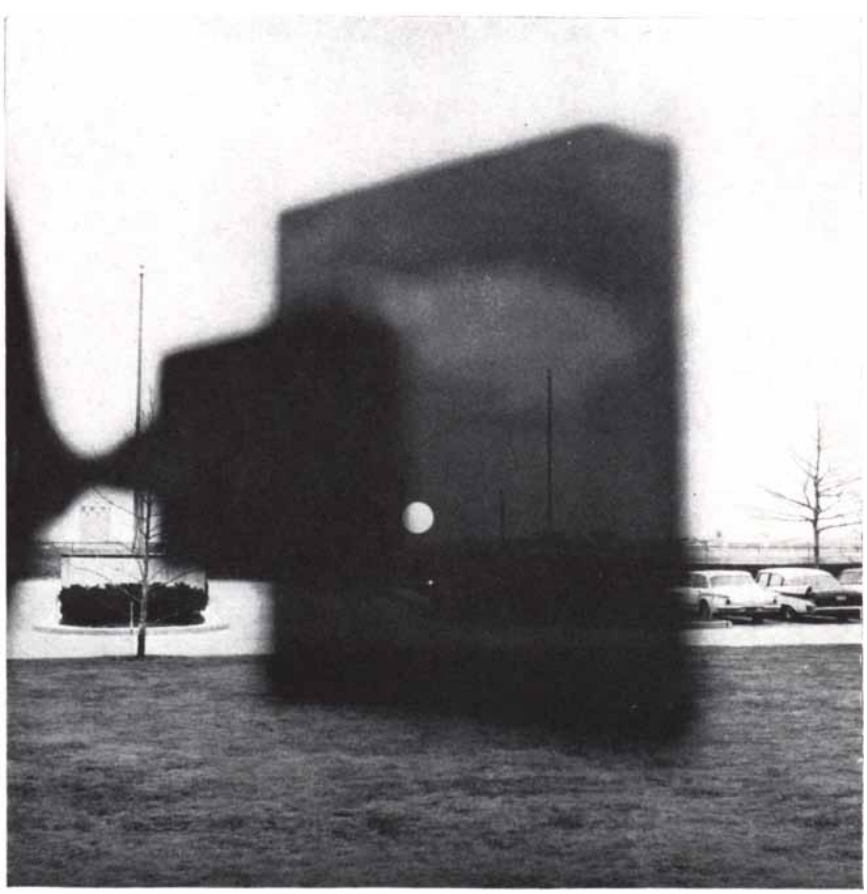
If, as was beginning to seem likely, the horizon moon looks larger only because it is seen over terrain, it should be possible to reverse the illusion by moving the terrain overhead with a mirror or prism. We arranged a mirror at a 45-degree angle so that by looking into it a subject could see the horizon and its moon high in the sky. By looking straight ahead into another mirror he saw an image of the zenith sky and moon in a



EFFECT OF APPARENT DISTANCE on the moon's apparent size is diagramed. The true positions of the moon are along the upper curve; its apparent positions, if the horizon seems more distant than the zenith, would be along the lower curve. The perceived size of the moon would accordingly vary as shown by the darker disks. Measurement of the half-arc angles (*a*, *b*) to the mid-points (*A*, *B*) of the actual and apparent arcs from zenith to horizon indicates that most people see the sky as "flattened," confirming the theory.



MOONS WERE SIMULATED by an optical apparatus, shown here schematically. Light passing through one of a series of apertures of different sizes is collimated (rendered parallel) by a lens and falls on a half-silvered mirror. An observer looking into the mirror sees against the sky, as if at an infinite distance, a virtual image of the luminous aperture.



VIEW THROUGH MIRROR shows a "moon" against the sky. The observer's eye is placed much nearer the glass than the camera that made photograph, so edge of mirror is not seen.

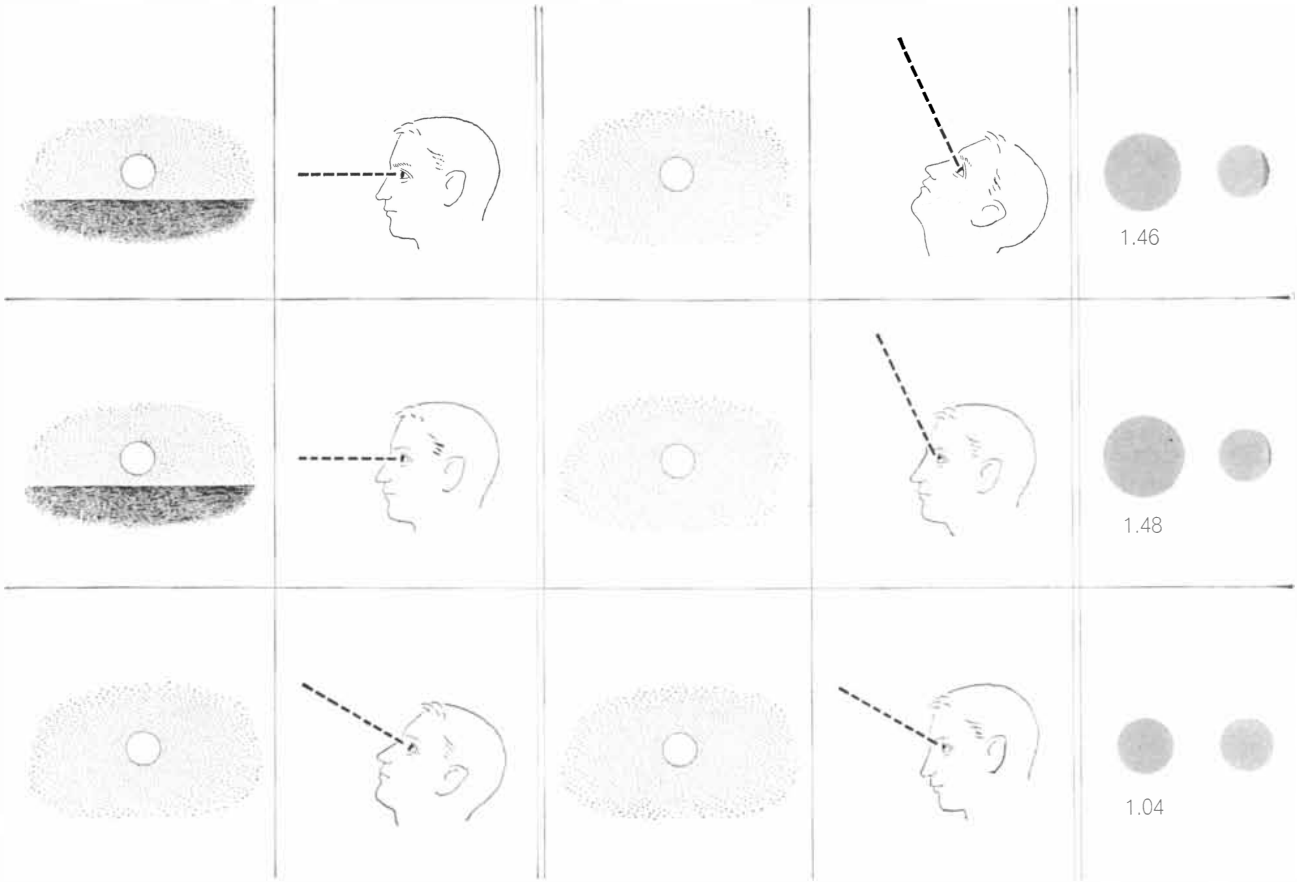
horizontal direction. As we had expected, the illusion did reverse: the moon on an overhead horizon appeared to be larger than the moon at a horizontal zenith, with a ratio of 1.34 [*see illustrations on page 126*].

At this point we could no longer doubt that terrain plays the major role in the moon illusion, but the nature of its role had not been established. Perhaps it was acting in some way other than by giving a sense of greater distance. We now located our apparatus at a site where the visible horizon was about two miles away in one direction and no more than 2,000 feet away 30 degrees to the left, providing a direct test of the effect of distance. The illusion was distinctly greater when the low-lying artificial moon was seen over the more distant horizon.

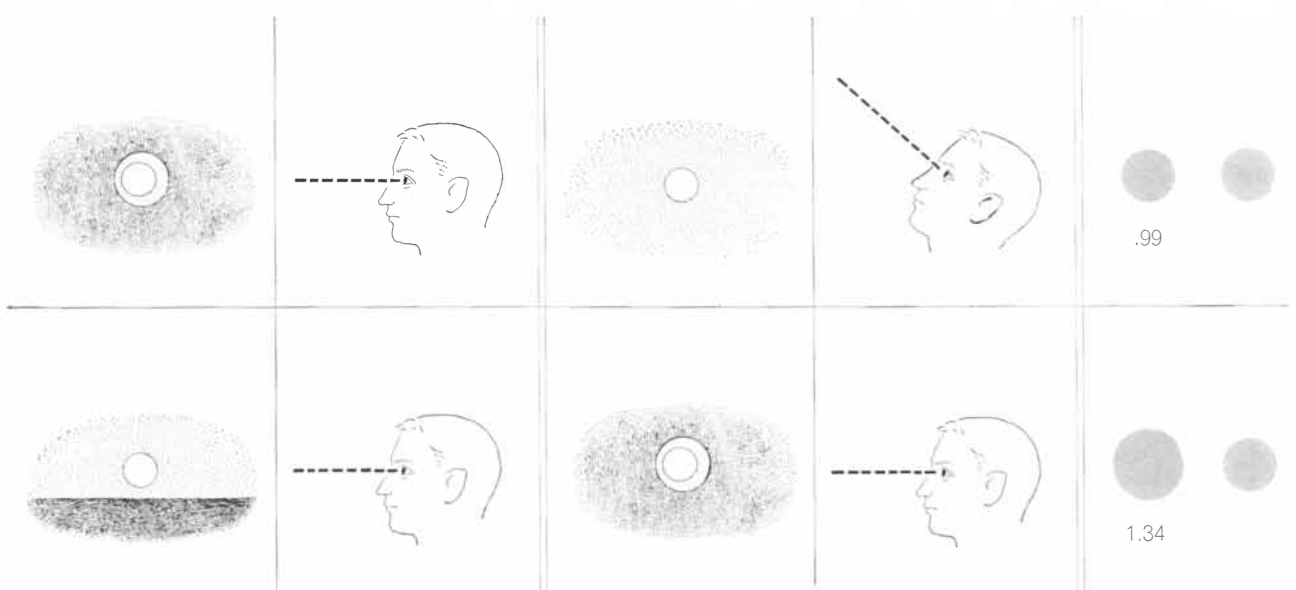
In this same experiment we also controlled for cloud conditions. Hermann von Helmholtz and others had speculated that cloudiness might increase the apparent flattening of the sky, and in fact recent observations have indicated that the half-arc angle varies inversely with the degree of cloudiness. If the effect exists, and if the apparent-distance theory is correct, then cloudiness should magnify the moon illusion.

Accordingly we split our experiment into three parts. One group of subjects viewed the artificial moons against a completely overcast sky, one against partial cloud cover and one against a clear sky. The illusion increased significantly both with distance to the horizon and with the degree of cloudiness. Taking all cloud conditions together, the illusion for the far horizon was 1.51 and for the near horizon 1.36. Combining the observations on far and near horizons, the illusion averaged 1.52 in an overcast, 1.45 under partial clouds and 1.34 in a clear sky.

A further test of the apparent-distance theory was provided by turning the horizon upside down with prisms. Inversion is known to lessen the impression of distance, and so we expected it to reduce the size of the moon illusion. Here too our expectations were confirmed: with the horizon inverted the ratio of horizon to zenith moon was 1.28; for the same set of observers under normal conditions it was 1.66. The result probably explains why people have noted a reduced illusion when they view the moon with head down, looking backward between their legs. The image would be inverted. Our inversion observations, incidentally, were



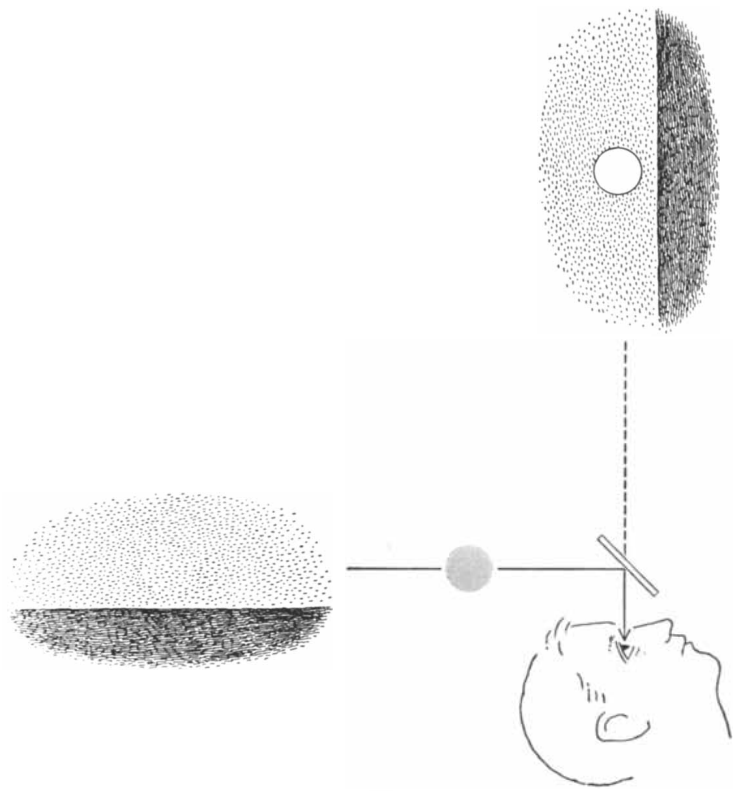
EYE-ELEVATION HYPOTHESIS was tested by having subjects view simulated horizon and zenith moons in various ways. A horizon moon was compared with a zenith moon seen with eyes level (*top row*) and also with eyes elevated (*middle row*). As shown by the ratios between the perceived sizes of the horizon and zenith moons (*right*), the illusion was present in both cases and was almost the same in spite of the different angles of regard. Then subjects were asked to compare two moons in the same part of the sky, raising their heads so that their eyes were level in one case and lowering their heads so that their eyes were elevated in the other case (*bottom row*). Changing the angle of regard had no significant effect on the size of the two moons, as shown by the 1.04 ratio.



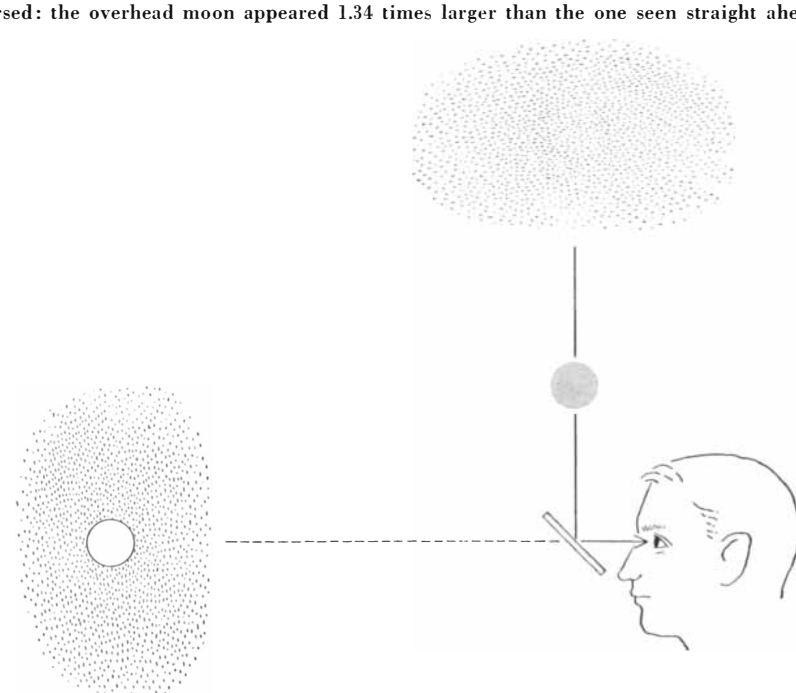
EFFECT OF TERRAIN was shown by an experiment in which the landscape beneath the horizon moon could be masked, leaving the moon visible through an aperture. When this masked horizon moon was compared with a zenith moon, there was no illusion (*top row*). When a normal horizon moon with terrain was compared with the masked horizon moon, substantial illusion resulted (*bottom row*).

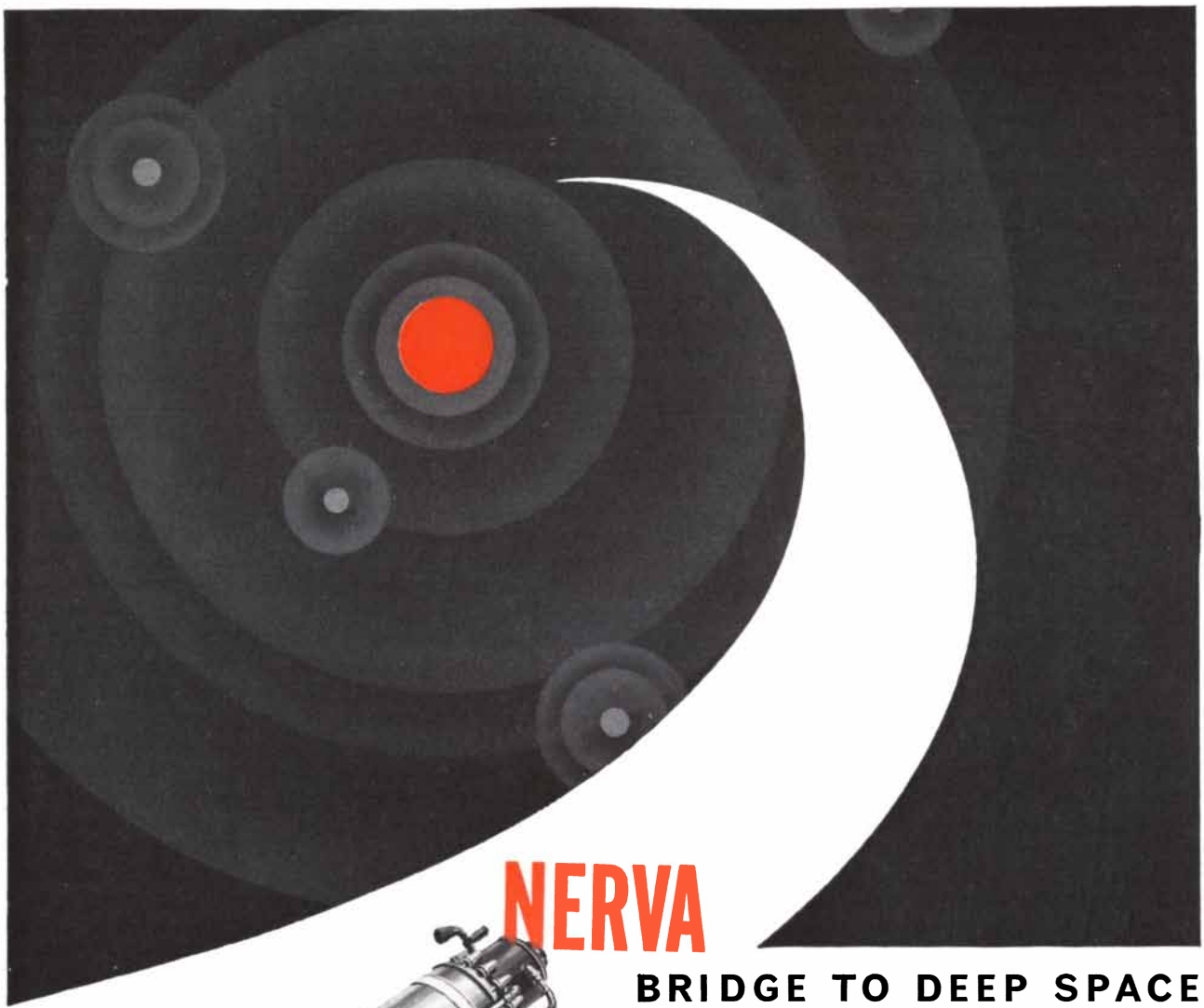
carried out on a New York City rooftop, with the horizon moon seen framed between tall buildings. The high value of the ratio for the normal illusion supports the idea that a framing effect can enhance the size of the horizon moon, as many city dwellers have speculated.

The apparent-distance theory was by now supported by a considerable body of experimental evidence, but it remained to be shown that no other factors are involved in the illusion. Two that have been frequently proposed are color and brightness. Often the horizon moon



TERRAIN'S IMPORTANCE was confirmed by using mirrors to reverse the positions of the horizon and zenith moons. By looking up into a mirror (*above*) the observer saw the horizon terrain and its moon overhead. Looking into another mirror (*below*) he saw a patch of zenith sky and its moon, but in a horizontal direction. The illusion was thereupon reversed: the overhead moon appeared 1.34 times larger than the one seen straight ahead.





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Nuclear **E**ngine for **R**ocket **V**ehicle **A**pplication—the key to future exploration of outer space, at ranges far beyond the reach of even the most sophisticated conventional propulsion system. NERVA is part of the ROVER program, which calls for deep space probes powered by a nuclear upper stage, using the liquid-rocket-powered Saturn as booster. Aerojet is responsible for overall NERVA design and research and development of components, and the Astronuclear Division of Westinghouse Electric for the nuclear reactor, which is based upon the Kiwi-B reactor work conducted at the Atomic Energy Commission's Los Alamos Scientific Laboratory. The Space Nuclear Propulsion Office, jointly operated by AEC/NASA, has overall responsibility for the NERVA program.

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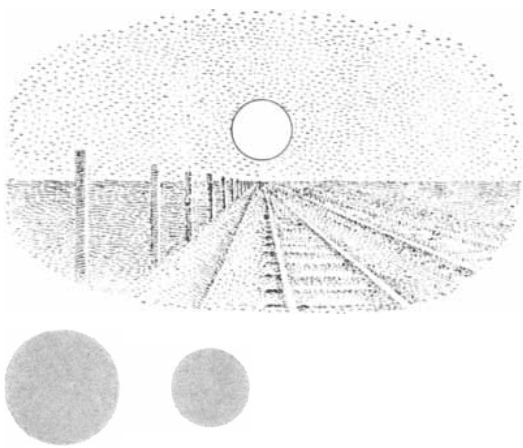
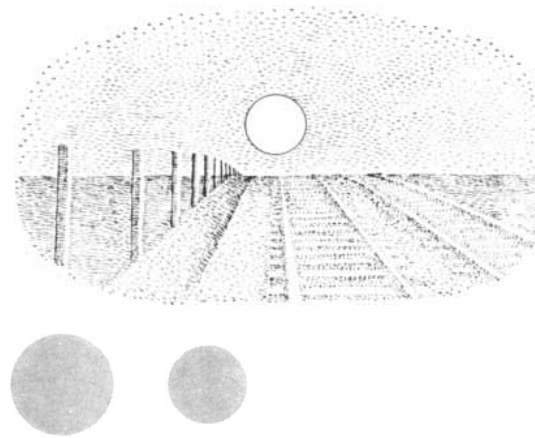
is much redder than the zenith moon because of the selective scattering by the atmosphere of the shorter wavelengths of light. Many people have suggested that the color difference produces a difference in apparent size. We tried putting a minus-blue filter in front of our artificial horizon moon and found that the resulting reddening had no effect on the illusion.

The Irish metaphysician George Berkeley, among others, attributed the illusion to the dimness of the full horizon moon in the twilight sky compared with the brighter zenith moon in the dark night sky. Again we duplicated the conditions in our apparatus. Neither decreasing the relative brightness of the artificial horizon moon nor increasing the contrast of the zenith moon against its background had any measurable effect on this illusion.

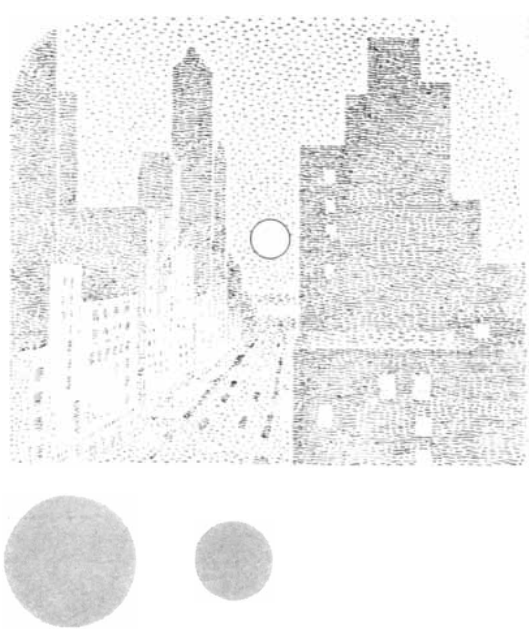
In sum, we have demonstrated that the moon illusion depends on the presence of terrain and specifically on the distance effect of the terrain. Eye elevation, color and apparent brightness evidently have nothing to do with the phenomenon.

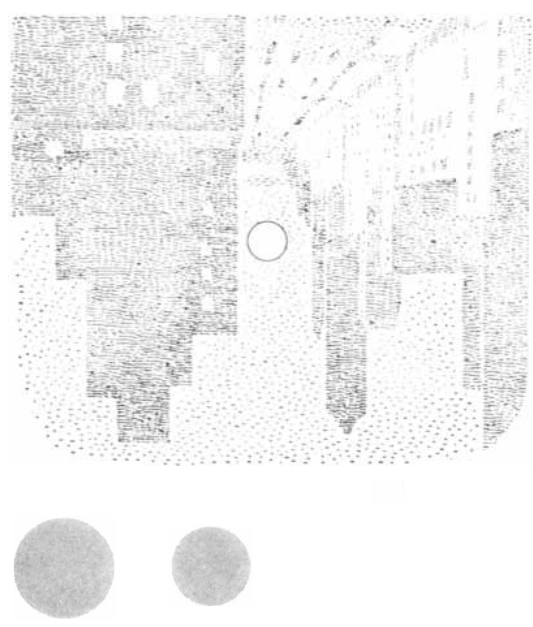
The theory we have been defending should not be confused with a deceptively similar explanation that has often been ventured. The horizon moon, it is said, can be compared with objects adjacent to its image along the terrain. If the moon is seen next to a distant house and if its image is about the same size as the house, then it appears as large as a house; since the house is quite large, the





EFFECT OF DISTANCE was tested more directly by comparing two horizon moons with a zenith moon. One horizon moon was placed where the visible horizon was far off (*left*); the other was over a nearby horizon (*right*). The illusion varied significantly with distance. (The railroad tracks, added here to emphasize the difference in distance, were not actually in the experimental scene.)





IMPRESSION OF DISTANCE is known to be lessened by inversion of a scene. Two horizon moons were compared with a zenith moon. In one case the horizon moon was seen normally between tall buildings; in the other case the skyline was inverted by a prism. The moon illusion was significantly smaller in the case of the inverted skyline, confirming the importance of distance as a factor.

Highly sophisticated space research instrument.

No ordinary household mouse this. He's Perognathus longimembris, the Little Pocket Mouse from the southwest desert.

He drinks no water at all. One of the smallest mammals in the world, he weighs in at only 6 to 10 grams fully grown. And he'll hibernate or estivate at the slightest provocation. He simply goes to sleep when it gets too cold or too hot, or food runs short.

We have big plans for these little animals at Northrop Space Laboratories. Nature could scarcely have designed an instrument more ideally adapted to investigate the long-term effects of space radiation and weightlessness.

A box just 6″ by 6″ by 10″ could hold 100 hibernating pocket mice—enough to comprise a reliable sample—and everything needed to keep them alive in space for several weeks. Such a package could be put into orbit quite easily, left there as long as necessary, and recovered for study with the mice still quietly sleeping.

This is just one of the many projects we have in work at Northrop Space Laboratories. Others cover such fields as plasma and nuclear physics, planetary physics and chemistry, materials and structures research, and space systems engineering as well as the manifold aspects of life support systems for space environments.

We have much to learn about the hazards of prolonged exposure to space conditions before we can afford to risk men on such long term projects as moon exploration or manned space stations. The Little Pocket Mouse may well give us a reliable and inexpensive short cut to much of this knowledge. **NORTHROP**

moon must be large. This explanation is incorrect because the illusion can be obtained over water or desert, where there are no familiar terrestrial objects for comparison. The apparent-distance theory, on the other hand, stresses the impression of distance created by the terrain considered merely as a plane extending outward from the observer—a distance impression that in turn affects the moon's apparent size according to well-understood relationships.

Eighteen hundred years after Ptolemy we have tested his hypothesis and provided evidence that it is correct. Oddly enough, there is no part of our technique that could not have been carried out centuries ago. But experimentation in psychology is a fairly recent development. So too is the theory of size perception, in which apparent distance is now understood to play a basic role.

VIEWING ZENITH MOON, an observer looks up through the half-silvered mirror, which combines the reflected image of the infinitely distant moon with the background sky. In the actual experiment the subject places his eye almost directly against the glass plate.

HORIZON MOON'S SIZE is adjusted by the experimenter until the observer says it is the same as that of the zenith moon. The ratio between the two sizes measures the illusion.

Studies of the Visual Processes Underlying Color Perception

Precise psycho-physical measurement techniques appear to clarify conflicting theories on the color receptor system of the human eye, possibly confirming an additive four-component receptor system as underlying color and brightness perception.

Scientists have been trying to understand how the eye sees color and to duplicate this process ever since the time of Sir Isaac Newton, who proposed that there were as many neural processes as there were discriminable colors. Thomas Young in 1801 recognized that if three primary colors, when mixed in different proportions, can be made to match any color of the spectrum, then a system of three independent receptors would be adequate. Von Helmholtz amplified the Young theory by suggesting that the brightness of colors was the sum of the responses of the three classes of color receptors. This has been termed an "additive" theory.

An alternate theory is the "opponents" theory proposed by Hering and based largely on psycho-physical data. He proposed that two antagonistic (or opposed) pairs of receptor mechanisms provide "color aspect" of color vision. These pairs are blue-yellow and red-green. Brightness in this theory is independent of the color mechanism but is dependent on a third black-white process.

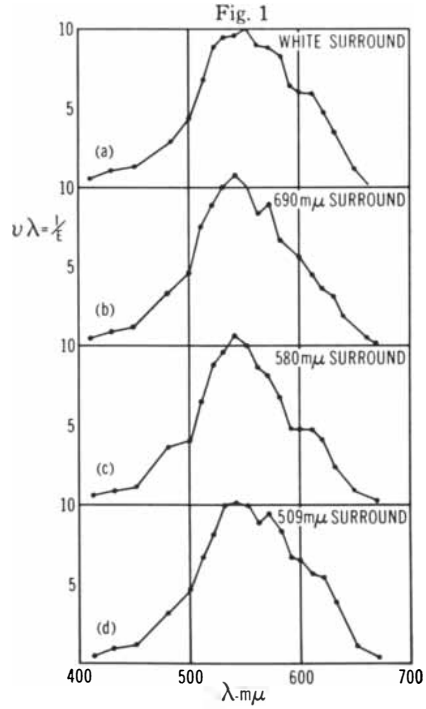
The conflict in theories is sharpest on two empirical questions: (1) Is yellow the combined response of the red and green mechanisms (additive) or does it have an independent response mechanism (opponents)? (2) Is brightness the summed response of the color receptors or an independent mechanism?

Honeywell psychologists are using a very sensitive technique utilizing psycho-physical responses of human subjects. By refining techniques of chromatic adaptation in combination with threshold measurement they have succeeded in isolating microstructure in the human foveal spectral sensitivity curve.

There now appears to be evidence that there are sensitivity peaks corresponding to red, yellow, green and perhaps blue. By adapting the eye to very narrow wave bands in the red, yellow and green parts of the spectrum it is possible to reduce these sensitivity peaks selectively supporting an additive theory but with at least four components.

In the Honeywell experiments, a seated subject fixates a small circle in a large surround field which carries the adaptive light. After adapting the eye to the surround field the subject fixates the small center circle where a narrow band stimulus from the various bands of the spectrum is flashed. The threshold energy for detecting this flash is measured. Measurements indicate (see fig. 1-a) that when the eye is neutrally adapted, there is a main peak in the green at 550mμ and sub maxima at 570mμ (yellow) and at 600mμ through 690mμ in the red.

Fig. 1



THRESHOLD ENERGY REQUIRED TO DETECT COLOR STIMULI

When the eye is adapted to red (fig. 1-b) the red shoulder or sub maximum at 600mμ to 690mμ is greatly reduced.

When adapting the eye to yellow (fig. 1-c) the 570mμ peak is almost eliminated.

Using a green adaptation (fig. 1-d) the main peak at 550mμ appears somewhat reduced.

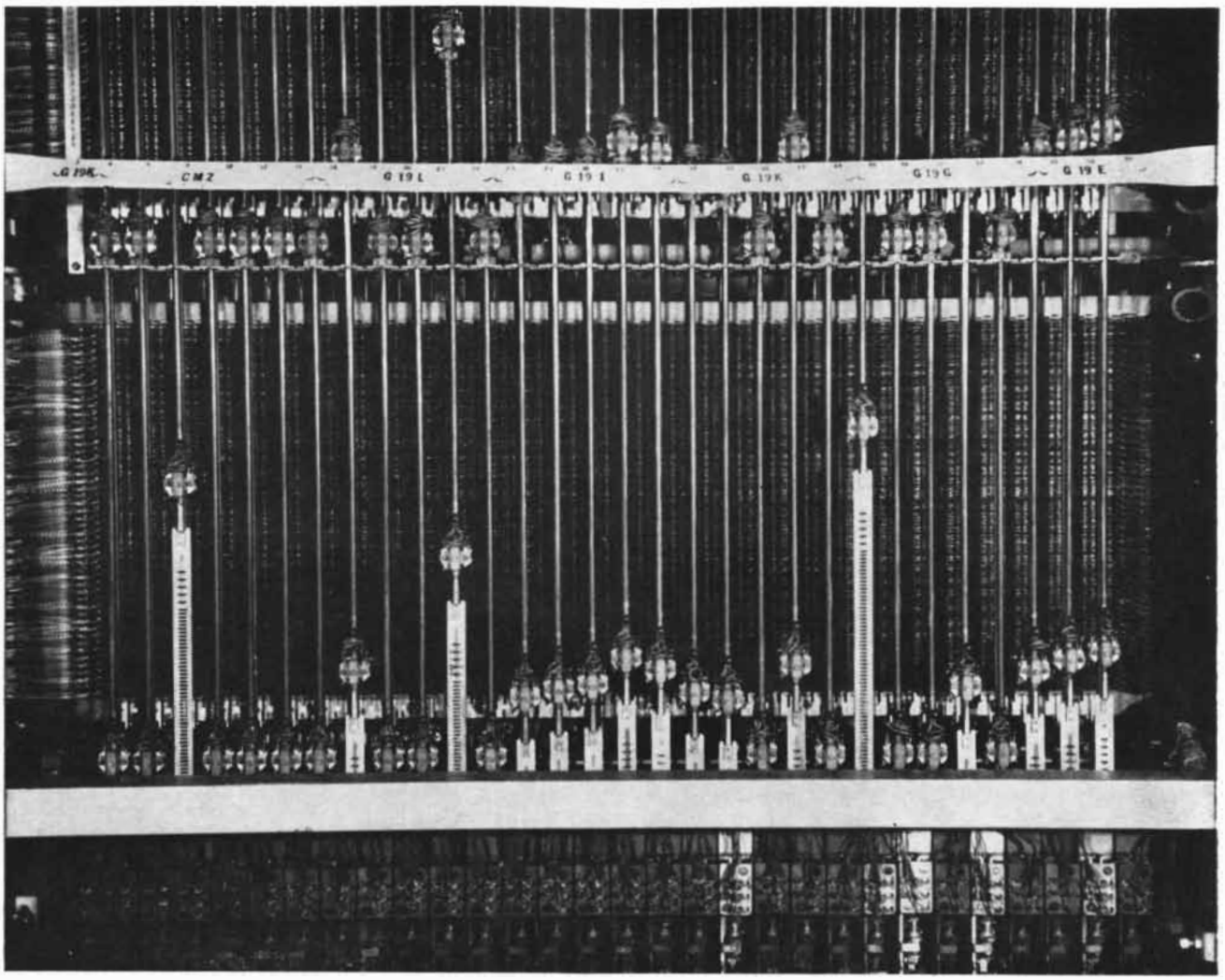
It is important to note that in each case the adjacent shoulder is unaffected.

These techniques demonstrate that spectral sensitivity may be a composite of several underlying chromatic mechanisms which above 500mμ have three independent components with peak sensitivities to green, yellow and red light.

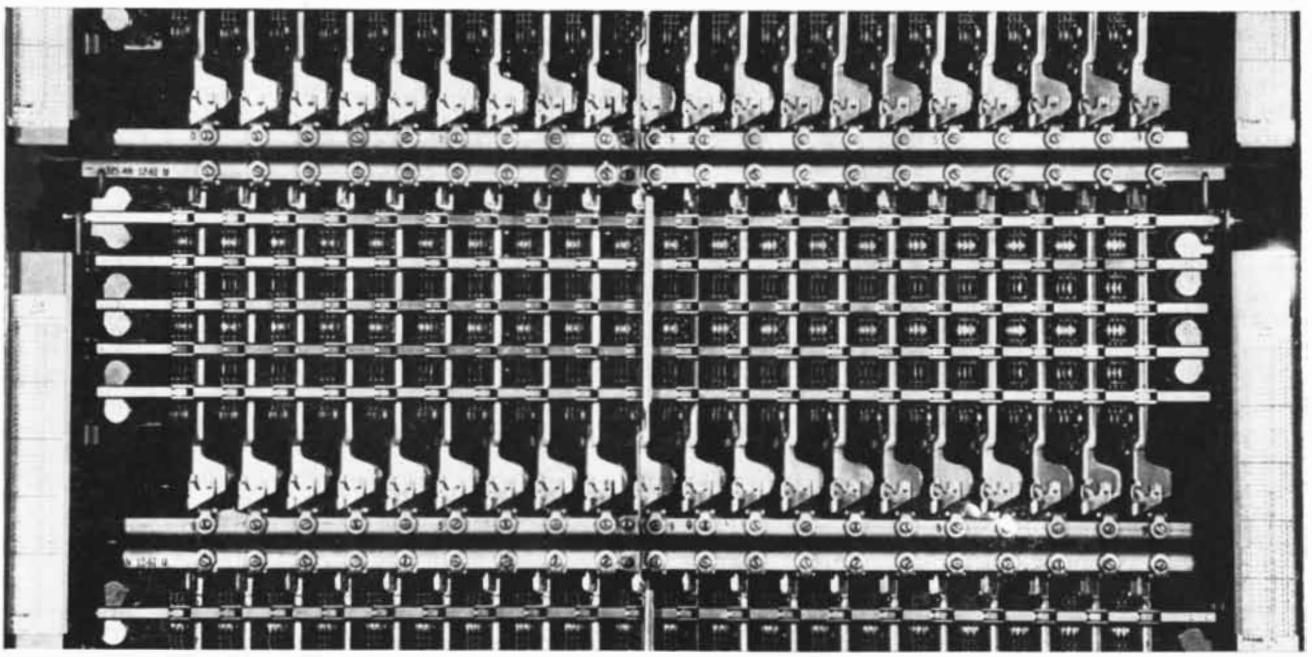
Further work is underway at Honeywell's Research Center to relate these findings to brightness perception and to explore more intensely the nature of the yellow response mechanism. Of obvious interest and concern to the medical and human factors field, a deeper understanding will also make possible significant advances in the technology of color measurement leading to mechanical simulation of color reception.

If you are engaged in scientific work in color perception and wish to know more about Honeywell's research in this area, you are invited to correspond with Dr. Harry Sperling, Honeywell Research Center, Hopkins, Minnesota.

If you are interested in a career at Honeywell's Research Center and hold an advanced degree you are invited to write Dr. John Dempsey, Director of Research at this same address.



THIRTY PANEL SWITCHES lined up side by side constitute the panel bank seen here. The vertical selector rods carry contact arms over the columns of contacts to the rear. The selector rods in raised positions are in the process of completing calls.



CROSSBAR SWITCH is the most recent development in electromechanical telephone switching. A typical crossbar switch is an array of 200 contact mechanisms (*see top illustration on page 139*); these are arranged in 20 vertical columns each having 10 contacts.

TELEPHONE SWITCHING

The operation of the network linking the 75 million telephones in the U.S. requires fast and efficient switching. Present electromechanical switching systems may soon be replaced by even faster electronic ones

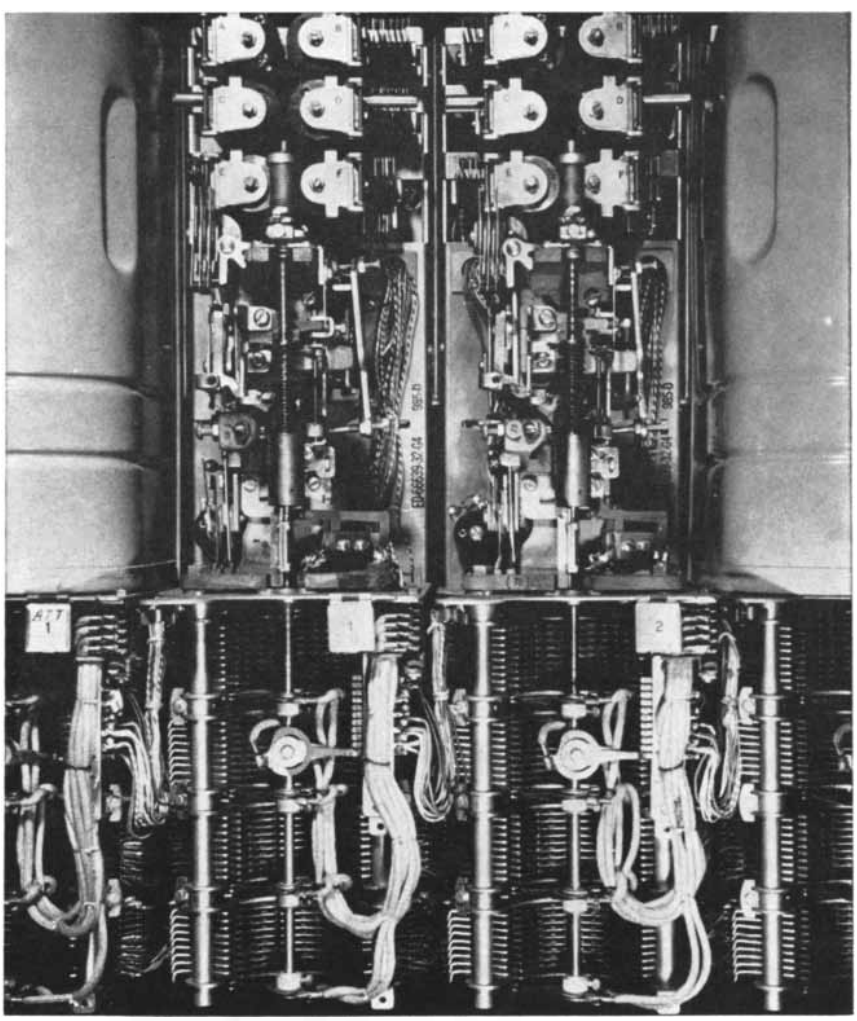
by H. S. Feder and A. E. Spencer

Right now you can pick up your telephone and make connection with any of the more than 75 million other telephones in the U.S. On the average 20,000 people throughout the country will have begun calls by the time you have read this far. By dialing a few numbers each caller will set up, in a matter of seconds, a unique pathway to another telephone. The path may be a mile or 3,000 miles long, and creating it can involve the operation of thousands of individual switches. When the call is finished, the path will be dismantled almost instantaneously and its parts will be ready to form new connections.

Even to people in the business, when they stop to think about it, the capability of the modern telephone switching system is fantastic. Built on one simple operation—the closing of a switch—these systems literally exceed the bounds of comprehension in their detail. Yet they operate controllably and predictably. Moreover, substantial improvements in speed and flexibility are in prospect.

All this began soon after Alexander Graham Bell patented the telephone in 1876. The telegraph had already posed a problem of electrical switching, but the demands of the simple commercial networks then in existence were modest. The telephone was a different matter: it was an instrument everyone could use. At first few people other than Bell himself had the imagination to think of the telephone as a part of their everyday lives. The new device was sold in pairs, for private communication between a house and barn, say, or a home and a nearby place of business. The early advertisements even warned of a possible lack of privacy if the purchaser connected a third telephone to his system!

In 1877 an enterprising Boston firm arranged to make telephone connections among several banks during the day, using the same wires that formed burglar-alarm connections at night. It was not long before private owners began to want to talk with one another too. The first commercial telephone exchange was opened in New Haven, Conn., in 1878. It accommodated eight lines, interconnected with a series of eight-point switches made of screws and lengths of brass mounted on a board [*see illustration on next page*]. There was a push button on each instrument to signal for service but no way of telling the opera-



MODERN STROWGER SWITCH consists essentially of a set of contact arms and a semicircular bank of contacts (*bottom half of two switches seen here*) and a system of electromagnets and ratchet mechanisms (*top half*) that control the movement of the contact arms.

tor when a call was completed. He simply listened in from time to time and disconnected the line when he heard no voices.

Soon afterward such crude switches were replaced by boards containing sockets, or "jacks," each connected to a line. The operator had a supply of flexible wires or cords with plugs on both ends. He set up a connection by plugging the ends of a cord into the two jacks associated with the proper lines. Auxiliary circuits between each instrument and the switchboard provided the means to signal for service, ring the telephone being called and notify the operator when the call was completed.

Each switchboard commonly had a capacity of 50 lines, and several boards could be placed side by side to make larger exchanges. One operator could reach over three adjacent boards, thereby serving 150 customers. As the number of customers increased beyond this, more than three boards were needed. Accordingly many calls required the services of two operators and the use of very long cords to set up the necessary connection between different switchboards. It therefore became advantageous to establish permanent connections, called trunks, between nonadjacent boards.

The idea is straightforward, but "trunking" added a new dimension to telephone switching networks. Previously each position, or jack, on each board led to an individual telephone. There was only one route between any pair of instruments. Now, in addition to jacks representing separate telephones, the operator had a number of more generalized terminals leading to other switchboards. Each of these represented a potential connection to any of a large number of telephones. Moreover, with more than one trunk line connecting each pair of boards, there was a choice of routes. If the operator found that one trunk line was busy, he could try another.

Often, however, a single operator could not keep pace with all the calls coming through his position. Soon a "multiple" switchboard was developed to decrease the load on the operator. Each unit in a multiple board had a complete set of "terminating" connections, one to each telephone line. A second set of "originating" connections to the lines was divided among a number of units [*see bottom illustration on opposite page*]. Each operator now handled only a fraction of the incoming traffic, but he could complete a call to any number in the exchange. The basic idea is simple enough, but a great deal of ingenuity went into the design of auxiliary circuits to keep all operators informed as to the status of all lines.

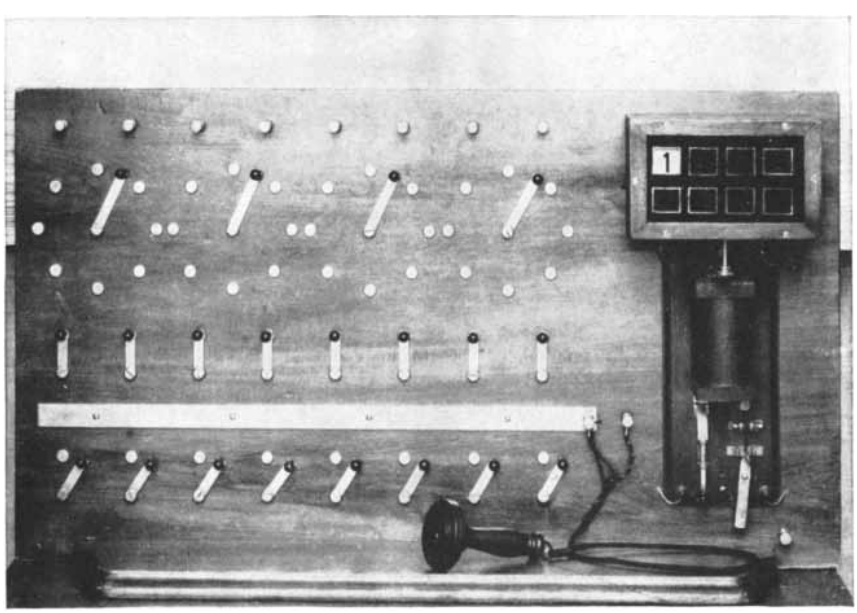
Notice that in referring to operators we have been saying "he." In the early days operators were usually boys or young men. They did not work out well. The youths talked back to customers, shouted, whittled the woodwork on the switchboards and in general created a state of bedlam. The substitution of young women was a complete success. The ladies were quiet, courteous and attentive; they showed more aptitude for the work and remained civil even under considerable provocation.

Once it got started, the telephone network grew at a rapid pace, and engineers began to think of ways to set up connections mechanically. One person who interested himself in the problem was not a telephone man at all but a Kansas City undertaker named Almon B. Strowger. In 1889 Strowger invented a rotary stepping switch that forms the basis for much of the telephone switching equipment in service today.

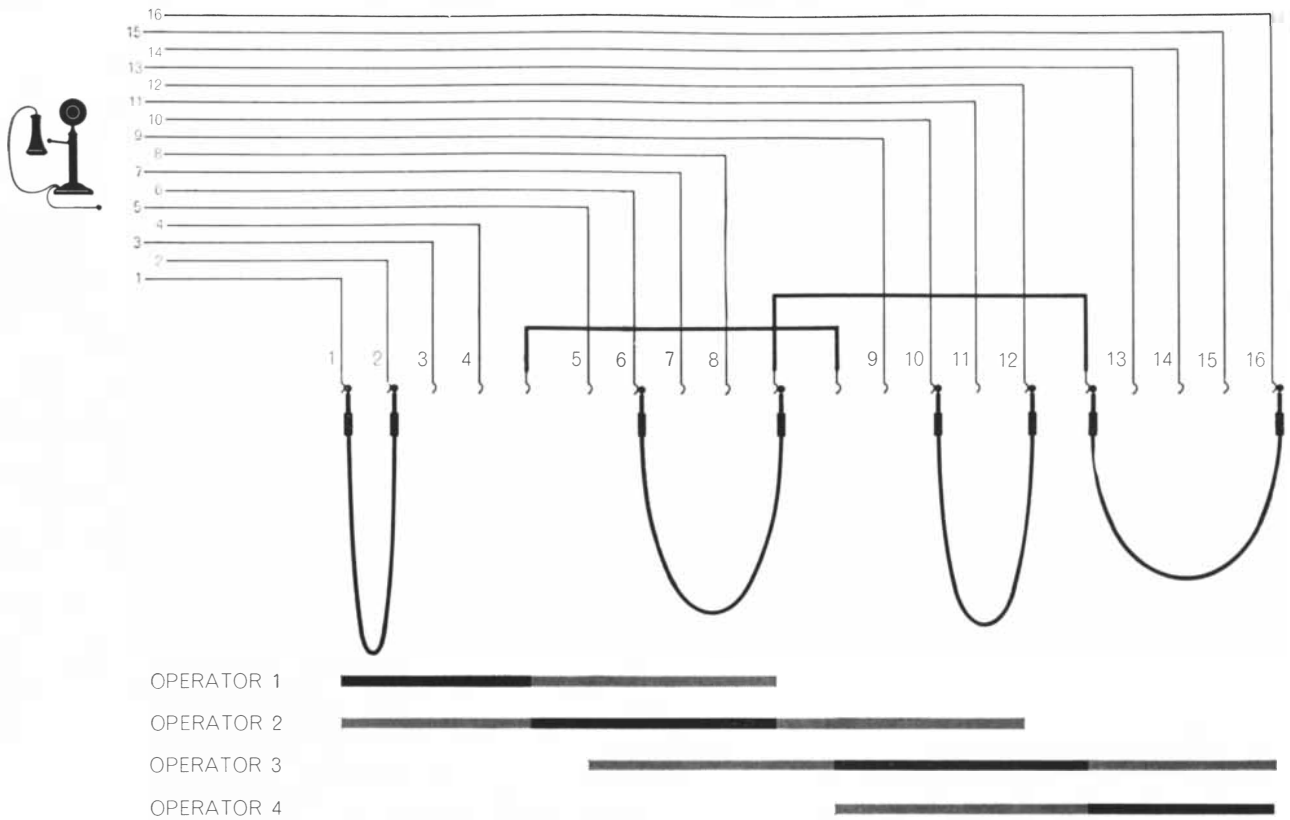
A story, which ought to be true although it may not be, is told of the invention. It seems that many of Strowger's undertaking clients reported getting a wrong number when they telephoned him, and not just any number but the number of a competitor, who proceeded to offer his own services to the callers. By what seemed more than coincidence, the competitor's wife was a telephone operator at the local exchange. Strowger went to the root of the problem: eliminate the operator.

Obviously a man of action, he set about designing a mechanical switch using a collar box and some straight pins for his model. He stuck 10 pins in a row on the inside of the round collar box, with their heads protruding toward the center. Then he pivoted a central arm so that it would make contact with each pin in turn as it rotated. He reasoned that if a group of switches such as this could be made to step from one contact to the next under the control of buttons at the telephone, each customer could set up his own calls. Strowger received a patent on the device in 1891, and it was first installed in La Porte, Ind., the following year.

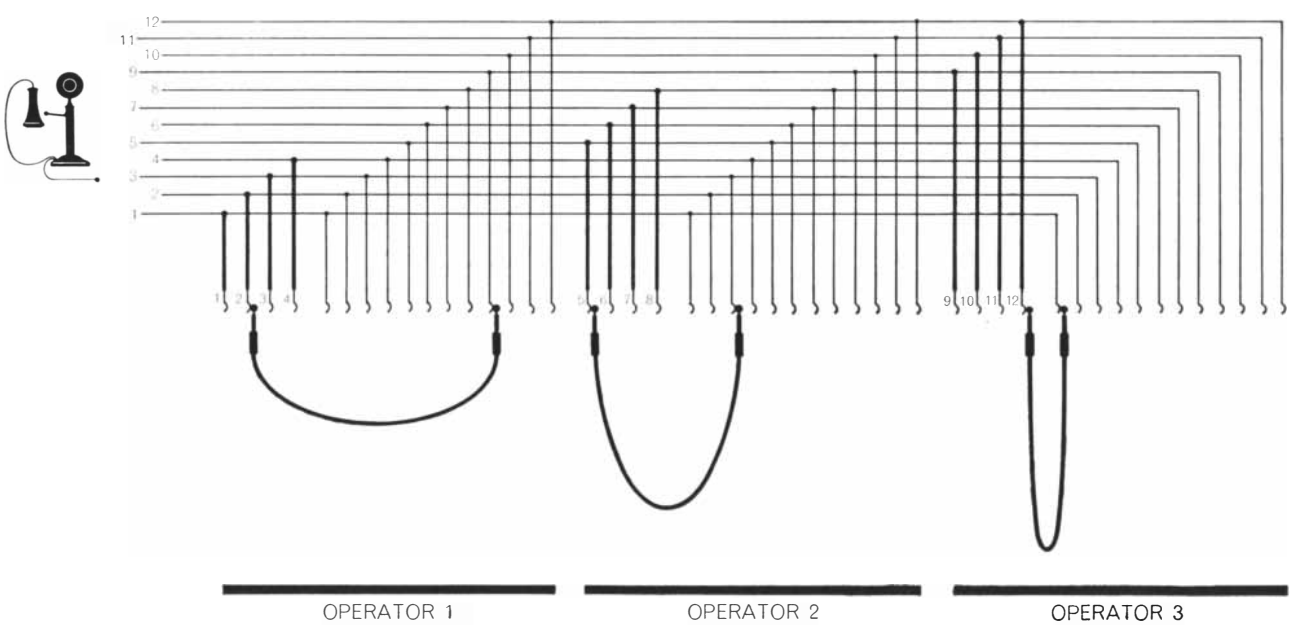
An improved version of the Strowger switch that is still in use today consists of an array of 10 rows of 10 sets of contacts, each row arranged in an arc of a circle as in the collar-box model. Two simple motions of the contact arm—one vertical, to find a selected row, the other rotary, to find a selected contact in that row—can connect it to any one of 100 lines. The switch is driven by electromagnets and ratchet mechanisms; each time one electromagnet is pulsed, the



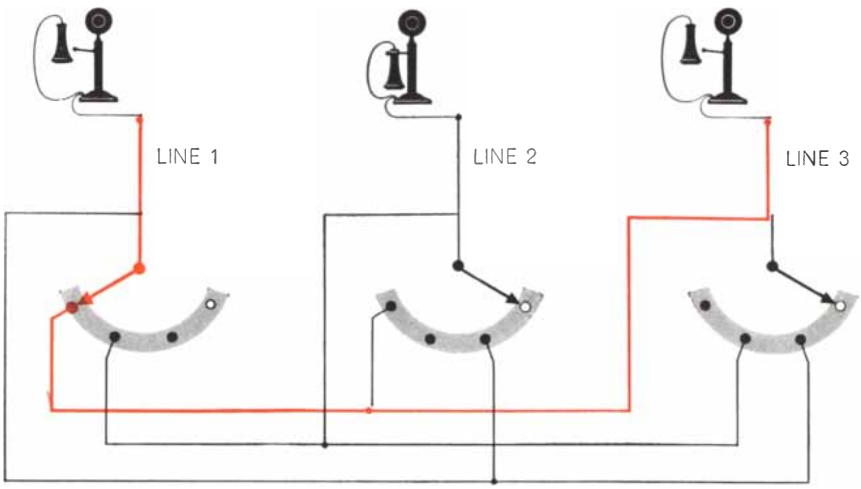
FIRST COMMERCIAL SWITCHBOARD (here represented by a model) was designed for eight telephones. Each of the telephones was equipped with a single push button for signaling the operator, who would then make a connection by setting switches to proper contacts.



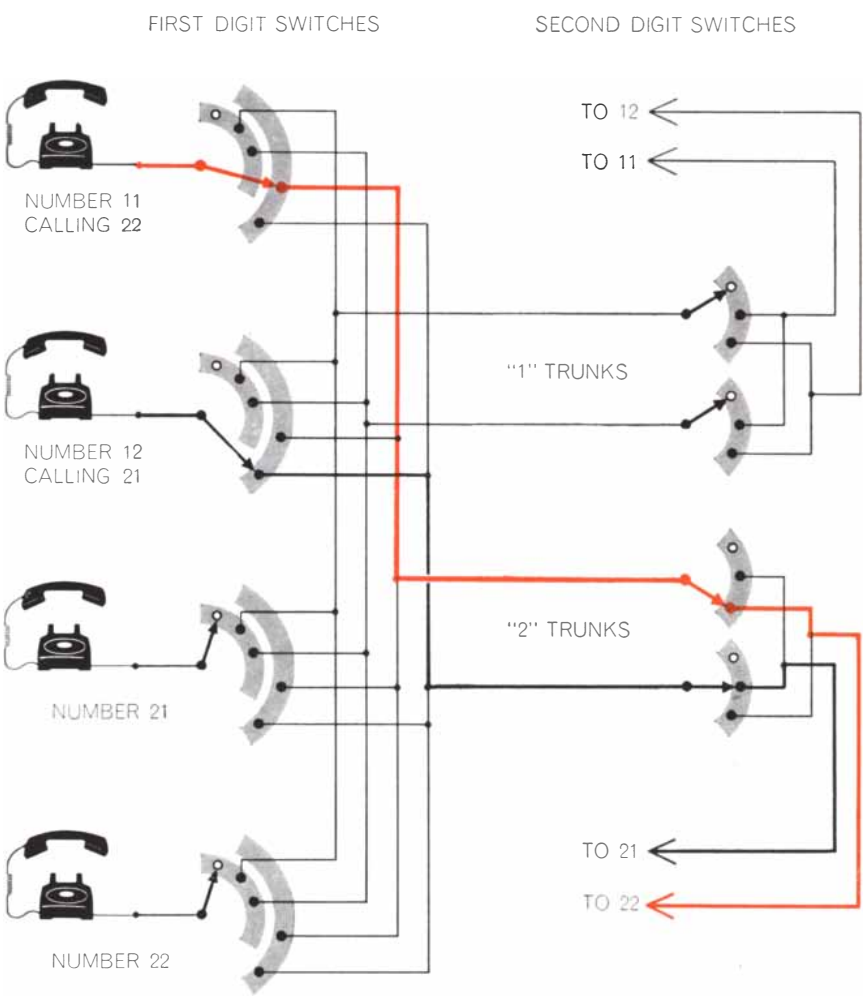
NONMULTIPLE SWITCHBOARD enabled operators to connect two lines in the same unit or in adjacent units. Thus Operator 2 could complete calls for Line 1 through Line 12. But a call on Line 6 for Line 16 required use of the trunk line (*heavy black line*) to Operator 4, who then completed the call. Operator 1 could reach Operator 4 by connecting directly with the same trunk line.



MULTIPLE SWITCHBOARD provides each operator with a limited number of "originating" connections (*vertical heavy black lines*) and a complete set of "terminating" connections. Thus Operator 1 can complete a call on Line 2 for Line 9 by making a direct connection. A nonmultiple switchboard (*see illustration at top of page*) would have required the use of a trunk line to Operator 3.



STEP-BY-STEP SWITCHING that set up a connection (*color*) between two phones was based on the early Strowger switch (*see illustration at left on opposite page*). When a subscriber dialed 3 on the first telephone, the Strowger switch associated with that line advanced three steps from the idle position and came to rest on the contact of the third telephone.



"HUNTING" available routes for two calls is illustrated. Dialing the first digit of 22 on Number 11 raises the contact arm to the contact bank leading to the "2" trunks; the arm hunts out the first nonbusy contact. Dialing the second digit then connects the call to Number 22. When 21 is dialed on Number 12, the first trunk line is busy and the arm hunts out the next nonbusy trunk. The dialing of the second digit connects the call to Number 21.

arm moves one row vertically, each time a second electromagnet is pulsed, the arm rotates one position horizontally. A third electromagnet releases the arm, letting it return to its starting position by spring action and gravity.

In the first systems employing the Strowger switch the telephones had no dials but small boxes with three push buttons, one for each electromagnet. Each instrument was connected to the arm of its own switch. Each contact in that switch was connected to one of 100 telephones. Repeated operation of the push buttons caused the arm to step along from row to row and from contact to contact so that the customer could set up a direct connection to any of 99 others. This arrangement, technically known as a step-by-step system, was popularly known as the "girl-less, cussless telephone."

In a self-contained network of 100 telephones step-by-step switching allowed each customer to do exactly what an operator would have done in setting up a call. How could the principle be applied to a system involving trunks? How could the customer know which of various routes to a given destination were available and which were busy? The answer to these questions constituted a giant forward stride: The switching network itself was designed to participate in the selection of a route.

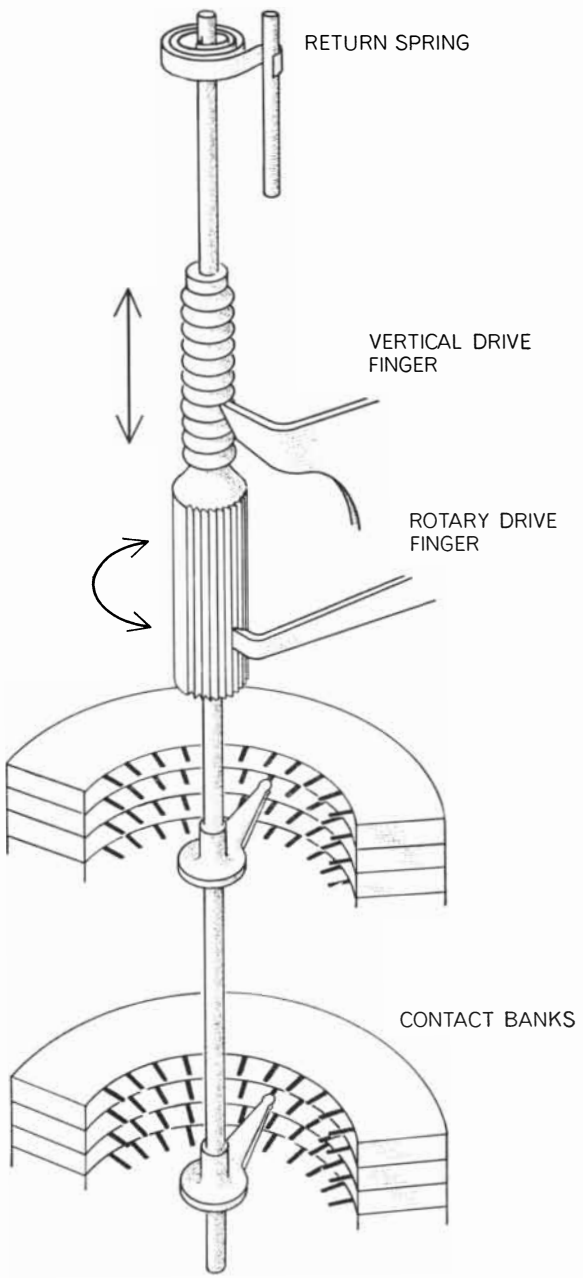
Under the new system each telephone originating a call was connected to the pivoting arm of a switch. The successive banks of contacts of that first switch, known as a selector, no longer led to individual telephones but to groups of trunks. In other words, the lowest 10 contacts were connected to 10 trunks running to one group of switches, the next row provided 10 routes to a second group, and so on. By dialing one digit (dials had quickly replaced push buttons) the customer selected a particular row of contacts, as before. When the arm reached the row, it proceeded to "hunt" across it automatically: it stepped from one contact to the next until it found one that was not busy, then stopped there. This action was made possible by coupling two similar contact arms on the hunting switch so that they moved together. Each of the arms had an associated bank of contacts. The first bank was used for the desired connection. Each contact in the duplicate bank carried a signal indicating whether its corresponding member in the original bank was busy or idle. If the signal showed busy, a pulse was delivered automatical-

ly to the second electromagnet mentioned earlier, thus causing the switch to step horizontally along the row. When a contact carrying the idle signal was reached, no further pulse was delivered and the switch rested there.

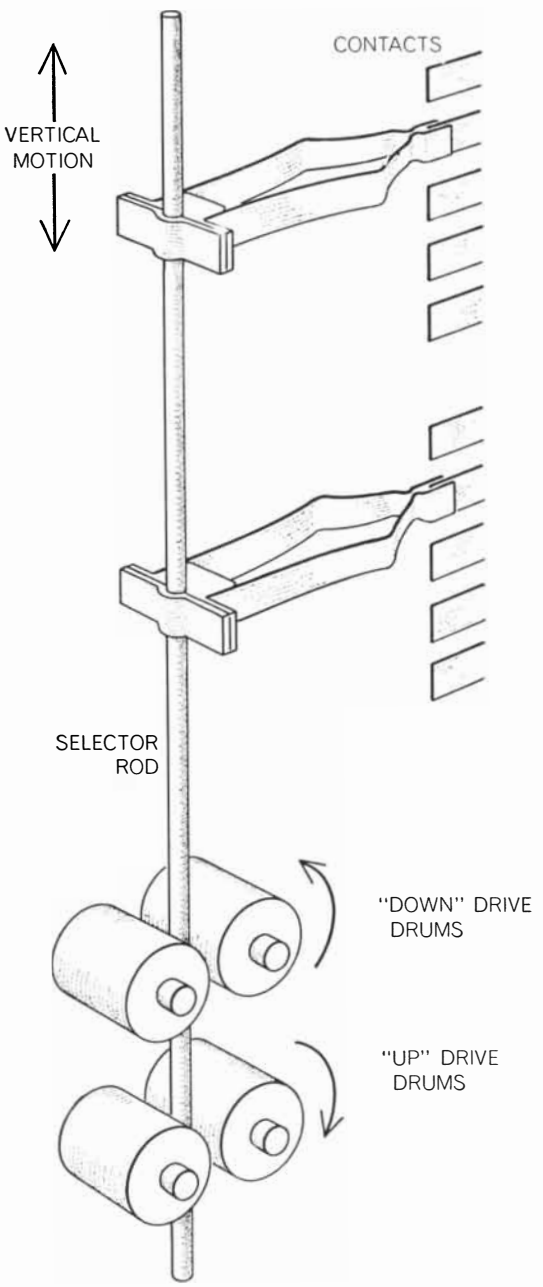
The customer now had a trunk line to the group of switches serving the number he was calling. At the end of the trunk was another switch leading to the individual telephones. Further dialing pulses operated that switch—both vertically and horizontally—to make the desired connection. The entire procedure was still largely under the control of the person dialing, but hunting increased the efficiency of operation and made possible larger systems of 1,000 lines or more.

The hunting concept was also applied to reduce the number of switches required in a system. Formerly each telephone was connected directly to an individual selector switch. A new arrangement introduced a "line finder" switch that hunted over a group of lines, finding one that was requesting service. Through the line-finder switch that line would then be connected to one of a group of selector switches. In this way switches no longer had to be supplied on a per-line basis; they were provided in smaller quantities appropriate to the traffic.

In addition to improving the efficiency of switches and decreasing their number, engineers extended the trunking idea to more and more complex branching networks with several stages of in-



ORIGINAL STROWGER SWITCH made possible systems of 100 telephones each. Vertical and rotary motion of the contact arms in step-by-step fashion connected one telephone with any of 99 others.



PANEL SWITCH has several flat banks of contacts with as many as 500 terminals in a column. Any terminal can be reached by contact fingers of a selector rod controlled by motor-driven drums.

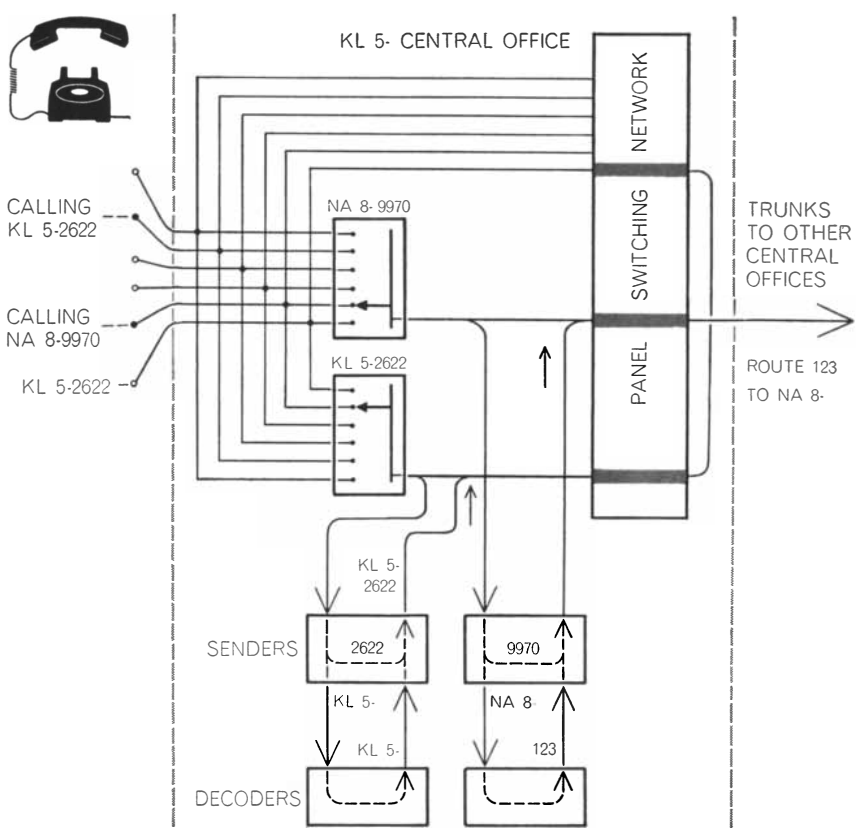
termediate selector switches. As the branching increased, the number of separate pulsing signals necessary to operate all the switches grew. Eventually numbers were standardized with three-digit codes (two of which were commonly labeled by letters) for central offices and four-digit numbers providing access to as many as 10,000 telephones in each office.

These advances in technique solved the major problems and made large switching systems serving many thousands of lines economically feasible. Step-by-step systems employing the Strowger switch are still used in many central offices, usually the smaller ones. The arrangement allows little flexibility in the assigning of telephone numbers, because the numbers must correspond to the location of particular terminals on the switches. In addition, the switches in the early step-by-step systems we have described are directly controlled by the dialer; in a sense he operates them by hand. As a result the entire assemblage is geared to the manual speed of the person dialing a number. Yet even these fairly rudimentary switches can work a good deal faster than that, and more advanced devices operate literally millions of times faster. The amount of equipment tied up in completing a single call under direct control is inherently capable of handling hundreds of calls in the same length of time.

Furthermore, Strowger switches provided access to one of only 100 output terminals. Increasing the number of possible connections per switch would reduce the number of stages through which a call had to be routed and would also allow hunting over larger trunk groups. The next switch to be developed, the panel switch, has 500 contacts arranged in a single vertical column and contact fingers that move up and down along them. Unlike the moving arms in Strowger switches, the fingers are not driven a step at a time by ratchets but move smoothly on motor-driven shafts controlled by clutches [*see illustration at right on preceding page*]. Therefore these switches are not controlled directly by dial pulses, as are the Strowger switches. To control the panel switches and to speed up system operation, a new element, called a "sender," is introduced. The sender records the incoming dialed number and then uses it to control the panel switches at a much higher speed.

Used with the sender is a decoder. The function of this decoder is to convert the decimal numbers received from the dial to the nondecimal system required by the switches. In addition the decoder provides flexibility in rearranging trunk connections. Panel switches, in combination with sender-decoders, became standard equipment for larger installations. Although they are no longer being installed, many are still in service in New York, Chicago and other big cities.

Panel switches are much more efficient than their predecessors, but they too have drawbacks, mostly connected with the long and frequent excursions of their contact arms. The excursions take time and wear out the clutches and other moving parts. Continual "fingering" of contacts causes electrical noise, particularly since the contacts tend to collect dust and dirt. For this reason the panel devices have now been displaced by the "crossbar" switch, which represents the last word in electromechanical switching.



PANEL SWITCHING SYSTEM described in the text removes the switching process from the dialer's direct control by interposing "senders" and "decoders" between the dial and switching systems. The call's route is set up automatically and thus much more quickly.

The crossbar consists of a grid or matrix of 10 horizontal and 10 vertical wires, with one group slightly in front of the other so that they do not touch. At each intersection is a movable contact. As many as 10 of them can be closed at one time to connect any of the horizontal wires to any of the vertical wires, providing 10 separate paths through the grid. The contacts are ingenious combinations of springs and levers that open or close in response to the combined rotary motion of one of five horizontal bars and linear motion of one of 10 vertical bars. Only 20 electromagnets are required to control the 100 contacts: two magnets for each rotating bar (one for each direction of rotation) and one magnet for each bar moving linearly. The action of these switches involves small, rapid mechanical motions and is adapted to straightforward selection schemes for closing the contacts. Crossbar systems offer advantages beyond those inherent in the switch itself. The trend toward separation of switching and control functions, which began with the introduction of senders and decoders, has been carried all the way. In modern crossbar systems the network switches have nothing to do with hunting or path selection. Control is centralized in a group of circuits called

markers because they mark a path through the network of crossbar switches. The arrangement is very flexible and makes more decisions in less time than earlier systems could. In addition it offers many new services.

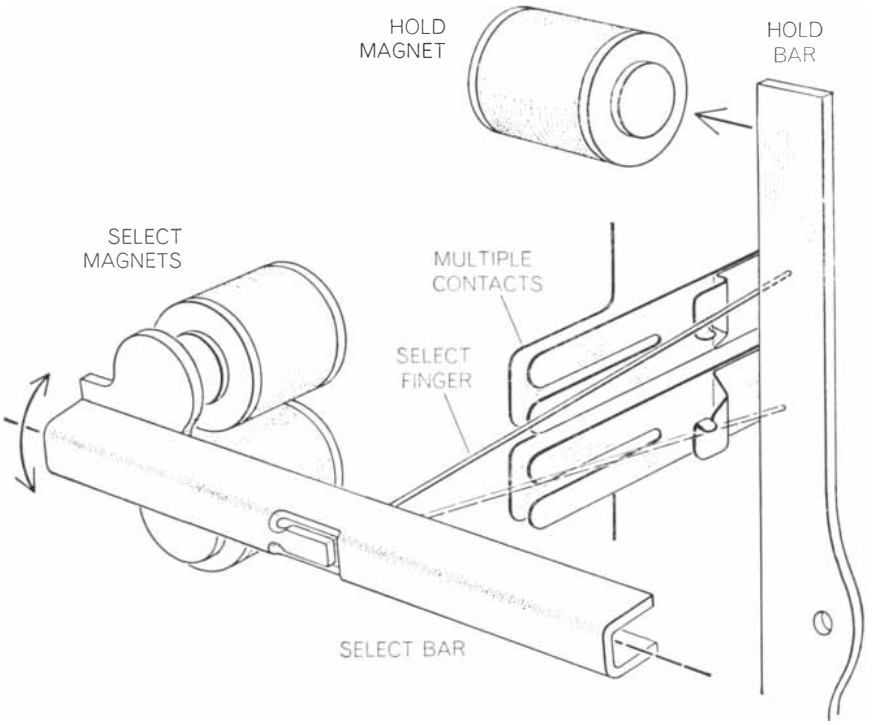
One of these is "alternate routing." If the marker finds that all the trunks going directly to a particular central office are busy, it can select an alternate route via another nearby office, which in turn picks out an idle trunk to the desired destination. The system also makes a second trial if an attempt to set up a call is thwarted. When one part of the network is busy or has failed, it will try another. A third valuable feature is the ability of the system to detect failures within its own equipment and report them on punched cards. This greatly simplifies the task of trouble-shooting the complex circuits.

In the crossbar system electromechanical switching has gone about as far as it can go. The major advances of the future lie in electronic circuits, which appear to offer even greater flexibility and still higher speed. They should make possible a reduction in the size and cost of switching systems in addition to providing more versatile service.

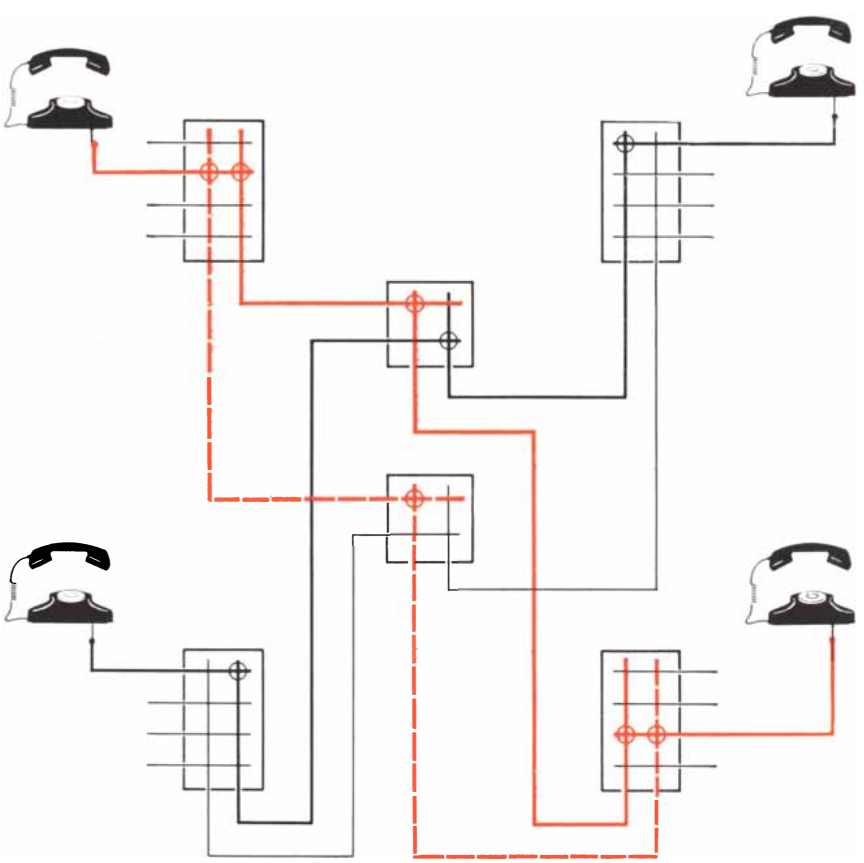
The basic unit for electronic switching is the transistor. It is a simple on-off device: a signal applied to a control electrode opens or closes the circuit between two other electrodes. A transistor is therefore equivalent to a mechanical switch with only a single contact. To enable transistors to compete with today's fast-acting multiple contact switch it is necessary to exploit to the full their high speed. Mechanical relays switch in thousandths of a second, transistors in millionths of a second (microseconds) or less. By capitalizing on the 1,000-to-1 advantage it is possible to build a single electronic unit that replaces several markers and other items of control equipment in crossbar systems.

Electronic switching has also clarified the role played by logic and memory. Obviously the earliest control systems could store information and carry out logical operations, but the fact that they did so was somewhat obscured by the mechanical detail. In electronic systems these functions stand out clearly.

Controlling any switching system, no matter how complex, in reality involves nothing more than the making of a large number of simple logical decisions. For example, suppose that the control is informed by the appropriate monitoring circuit that a particular telephone is off



CROSSBAR SWITCH CONTACT MECHANISM operates by the combined motion of a "select bar" and a "hold bar." The motion of the hold bar closes the contact only when the "select finger" has been placed in either of two positions by the movement of the select bar.



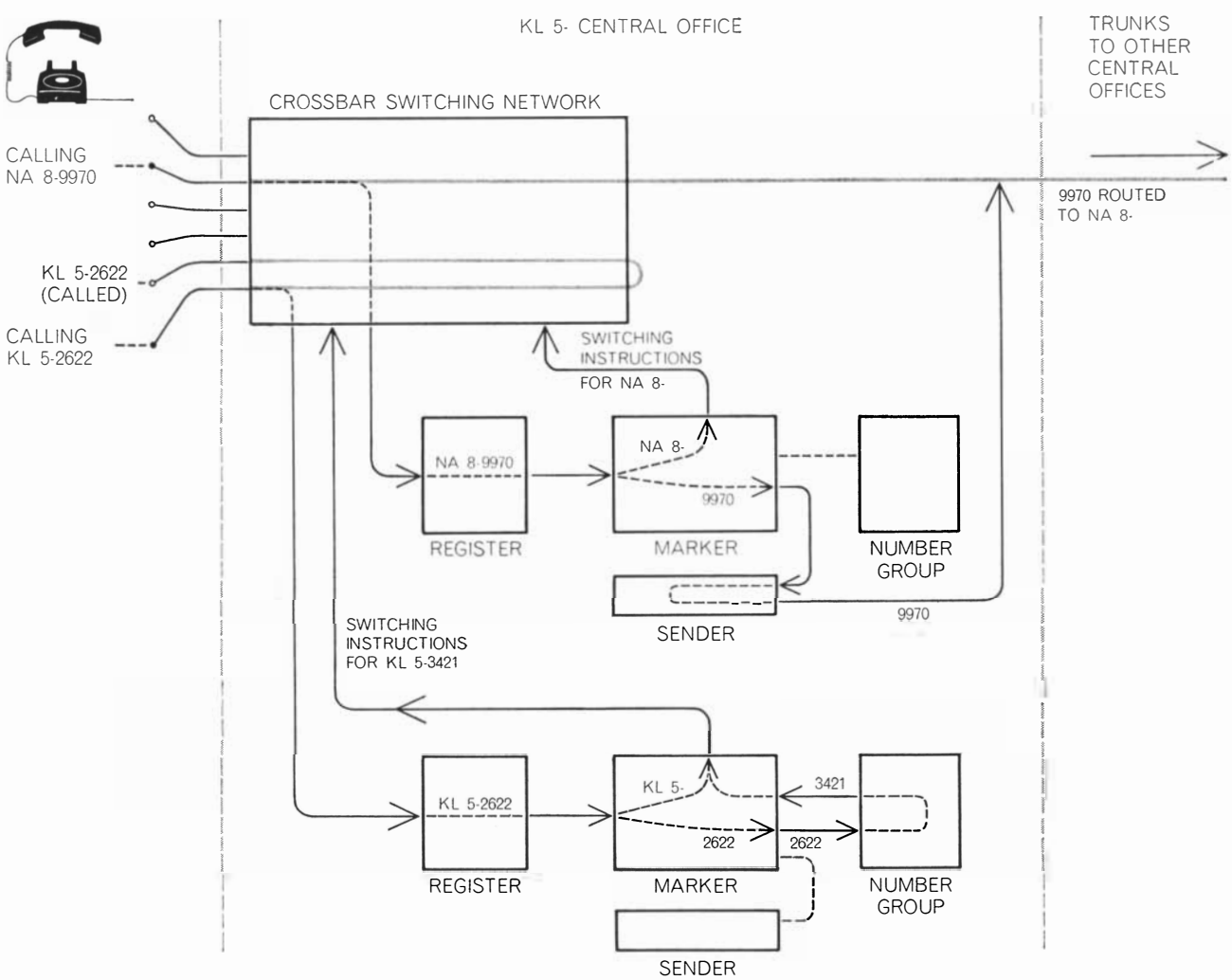
CROSSBAR SWITCHING SYSTEM uses space division to route telephone calls. Two typical paths, in color and in black, are spatially separated, although they appear to cross at some points. The broken line in color represents an alternative path for one of the calls.

the hook. What action should be taken? In order to decide, the control circuit first determines whether the telephone is in a talking connection or is connected to a dial tone. In either case "off hook" is a proper line condition and no action is required. If neither situation exists, the line has just gone off hook and is requesting service. The control device then arranges to supply dial tone to the telephone. Similarly, the decisions of the control in response to any other condition can be spelled out in terms of the present state of the call and new information received from hook and dial.

There are two approaches to the problem of building logic into control systems. One might be called wired logic. Each logical operation is clearly defined and a circuit is designed to do the specific job. As an illustration of simple wired logic circuits, consider a light controlled by a pair of switches. If the switches are wired in parallel, the light goes on when either one *or* the other is snapped. The circuit embodies a logical "or" function. If the switches are wired in series, the operation of the first switch *and* the second switch is required to turn on the light—a logical "and" function. Elementary "or" and "and" units can be combined in large circuits capable of deciding complicated logical questions.

Wired logic circuits make virtually all decisions in electromechanical switching systems, and they do an excellent job. They can be built to take advantage of the many contacts that are available in relay and other mechanical switches. But each circuit is tailor-made for a single operation; to make a change usually requires extensive reworking and rewiring. Furthermore, if electronic logic elements are used, the circuits often become quite expensive.

The second type of control, called a stored program, consists essentially of a special-purpose computer with two memories. One is a semipermanent memory in which are stored the processing routines for setting up calls. The procedures are "written" not in copper wire and solder, as in wired logic, but in the form of magnetic patterns on plug-in cards. Changing one of the logical procedures is then accomplished simply by



CROSSBAR CENTRAL OFFICE employs registers, markers and senders. For a call within the central office, the register receives the originating dial pulses (*KL 5–2622*), stores the information and passes it on to the marker. The marker sends the last four digits to the number group (an electronic "telephone directory"), getting back a code number; it uses the new information (*KL 5–3421*) to select a path through the switching network and then closes the proper switches to complete the call. For a call outside the central office (*NA 8–9970*) the sender routes the last four digits to the appropriate office along a path selected by the marker.

substituting a new card. The second memory stores short-term information such as the present state of various calls. It may be thought of as an electronic scratch-pad.

As our earlier examples have shown, the processing of a telephone call can be analyzed into a number of discrete situations, each calling for a logical decision as to the next step. A telephone off hook constitutes one situation; two telephones connected for talking, a second situation; one instrument put back on hook, a third, and so on. Each such situation—and there are hundreds—may be assigned a number. The semipermanent plug-in card memory lists each situation number, together with the different actions that may be required, depending on the additional information coming in from the customers by way of hook and dial.

This information is recorded in the scratch-pad memory as it is received. Also listed on the scratch-pad are the states of the switches in the network. The content of the short-term memory continually changes to reflect the progress of the calls the system is working on.

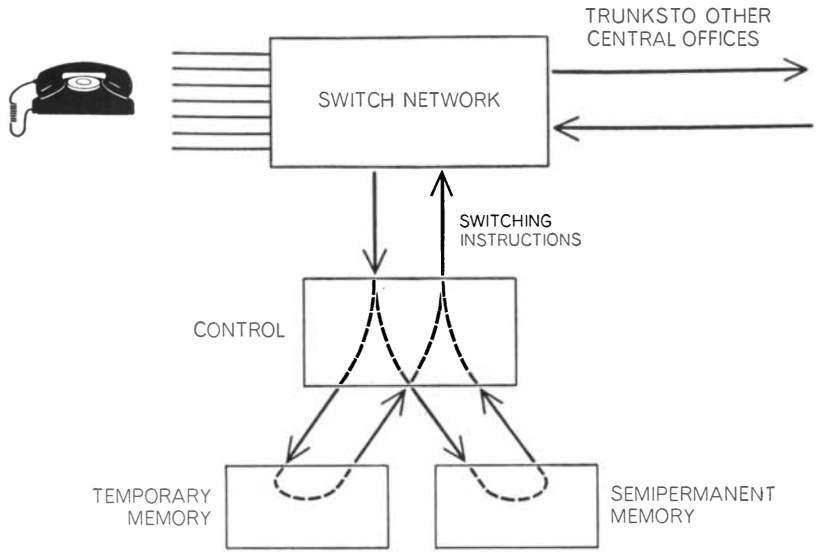
In oversimplified terms, the processing of a call goes something like this: A customer takes his phone off hook to start the call. Assume this is labeled Situation No. 1. Space is now assigned on the scratch-pad for the call, and the calling telephone number and Situation No. 1 are written in this space. The scratch-pad memory is electronically interrogated at frequent intervals. At the next interrogation Situation No. 1 is read out and checked with the program stored in the semipermanent memory. The instructions found there are to determine whether the telephone is answering a call or originating one. The information can be obtained by referring to the scratch-pad memory. In the present example the scratch-pad will show that the off-hook telephone is not connected to another telephone or to dial tone; in other words, that this is a call origination. Accordingly the program will instruct the network to connect the telephone to an originating register that supplies dial tone. After this has been done the scratch-pad is revised to list the call as being in Situation No. 2.

As each dialed digit is received, it is recorded in the scratch-pad memory. The digits can then be read out to enable the stored program to choose a path through the network. As each call is acted on, the scratch-pad notations are changed to read Situation No. 3, No. 4, No. 5 and so on as appropriate. The scratch-pad has a space for each call in process and the information in the various spaces is examined sequentially. The sequence is so rapid, however, that from a customer's point of view calls are handled side by side, so to speak, and not one after the other.

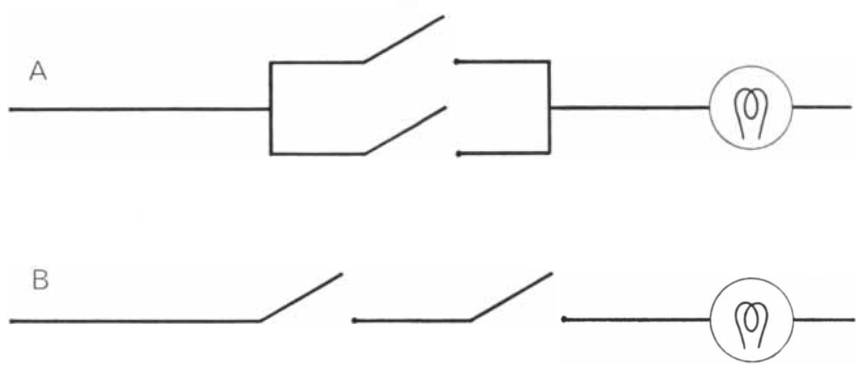
A stored program control has the advantage of great flexibility. Only the size of the semipermanent memory limits the new routines that can be introduced on plug-in cards. Services that were not even thought of when the system was designed can easily be installed as the need becomes clear.

Recently an electronic telephone switching system was tried out in Morris, Ill. It used a stored-program electronic control. One of the new services it demonstrated allowed customers to reroute incoming calls to other numbers. People visiting friends for the evening could arrange to have their calls transferred to their host's telephone by dialing a special code. The transfer was just as easily discontinued by dialing another code. A second feature replaced the usual seven-digit dial code with a two-digit code for numbers frequently called. These are merely samples of the many new services that electronic switching systems will make possible.

The Morris experiment demonstrated beyond question the technical feasibility as well as the great versatility of electronic systems. There is, however, still a great deal of activity in the field of telephone switching. One area in which



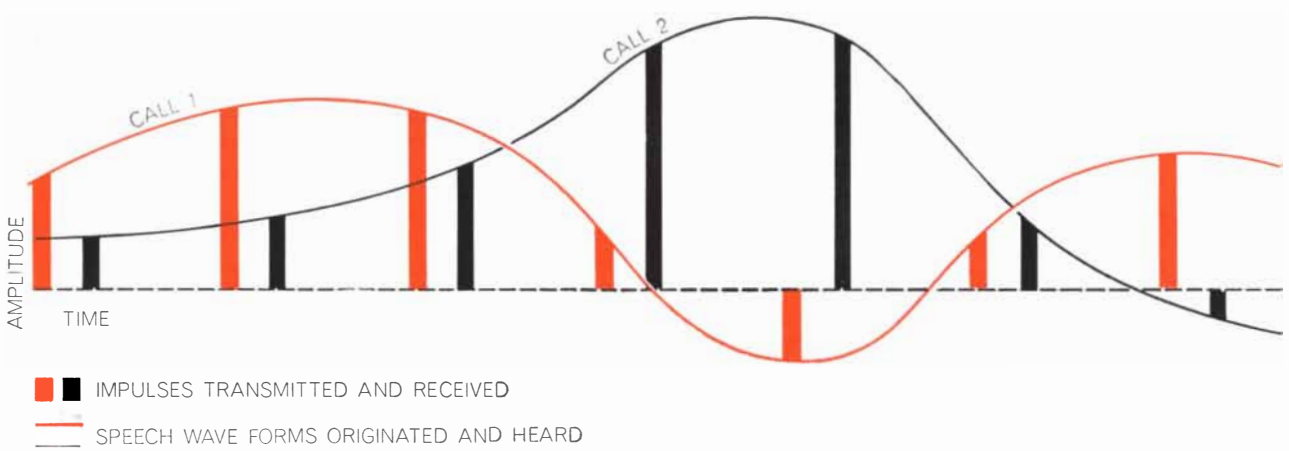
ELECTRONIC SWITCHING SYSTEM is simplified here. The temporary memory stores dial pulses. Using this and processing information stored in the semipermanent memory, the control circuit selects a path through the switch network and closes the proper switches.



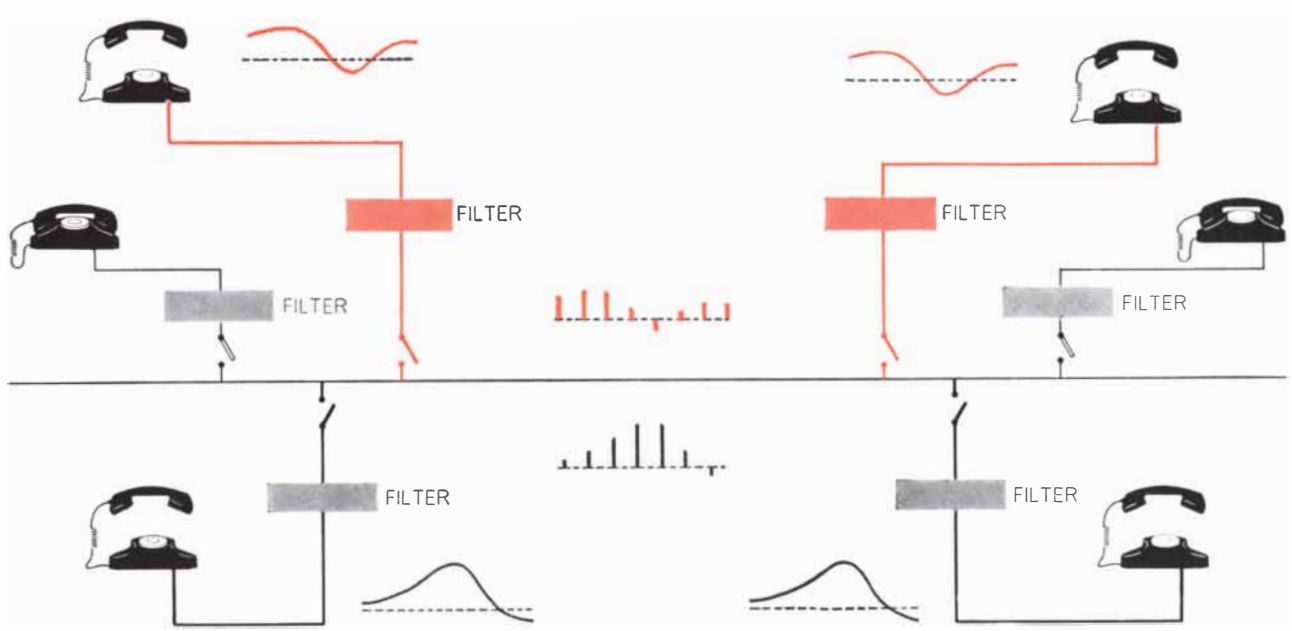
SIMPLE LOGIC CIRCUITS are illustrated by a light controlled by switches wired in parallel (*A*) and in series (*B*). *A* represents a logical "or" function (closing one switch *or* the other turns the light on); *B*, an "and" function (the first *and* second switch must close).

there is intensive study has to do with a different type of switching network altogether—one that only the great speed of the transistor has made possible.

All the switching networks we have discussed so far have had one property in common: the pathways that exist at any one time are physically separate. At no place do two calls travel the same route simultaneously. For that reason such systems are said to have space-division networks. The new approach, now being studied at the Bell Telephone Laboratories and elsewhere, is known as time division. Calls travel over the same path at the same time, separated from one another in time. This is how the scheme works: When a connection is established between a pair of telephones via the common path, the two switches leading into and out of this path do not stay closed all the time. Instead they open and close continually at a rapid rate, being closed only a small fraction of the time, typically two microseconds in every 100. Therefore they send through the common path not the complete electrical wave coming from the transmitting telephone but a series of short pulses that are samples of that wave [*see upper illustration below*]. Each pair of switches, for each pair of connected telephones, works the same way, but their times of closing are displaced with respect to one another so that the sampling is done in rotation and signals from all the calls are separated in time. The approximate capacity of the common path equals the time between closures of any pair of switches divided by the time for which each pair



SAMPLES OF SOUND (impulses transmitted and received) are transmitted or received in a time-division telephone system. Although only two telephone calls have been represented, a common path is theoretically capable of carrying many simultaneous calls.



TIME-DIVISION SWITCHING NETWORK works on the repetitive and simultaneous opening and closing of selected pairs of switches. When the switches are open, a filter stores the energy from the sending telephone and, when they are closed, transmits this energy to the receiving filter. This filter converts the pulses into a smoothed-out wave and feeds it into the receiving telephone.

remains closed. In the present example 100 would be divided by two, giving 50 simultaneous calls.

Although the switches for each connection are closed perhaps only 2 per cent of the time, the signal reaching the receiving phone is complete and essentially undistorted. In fact, theoretically it is transmitted without any loss of information whatever. The reconstitution of the complete wave, surprising as it may seem, is analogous to the effect we see whenever we go to a movie. The picture is a series of still "samples" of motion; the eye smooths over the intervals between stills and restores the motion.

In time-division telephone switching networks the smoothing action is accomplished by electrical filters. There is one between each telephone and its switch. While the sending switch is open, the filter stores the energy coming from the telephone. When the two switches are closed, this energy is transmitted via a pulse to the receiving filter, which is identical with the sending device and caused to be in resonance with it. The "resonant transfer" provides theoretically lossless transmission. (In practice there is a small loss.) The receiving filter in turn converts the incoming pulses to a smoothed-out wave, which it feeds into the receiving telephone.

The system can be designed to meet any required fidelity; that is, the final wave can be made as nearly identical with the original as is desired. To obtain adequate fidelity the frequency at which the switches close—the sampling rate—must be somewhat more than twice the highest frequency transmitted. If the highest transmitted frequency is 3,500 cycles per second, a usual figure in telephone work, the sampling frequency should be something more than 7,000 cycles per second. In practice it is usually set at 8,000 cycles or more.

Time-division switching offers the main advantage of requiring fewer switches than space-division schemes for systems of equal capacity. The advantage is partially offset by the need for two filters, as well as some other additional components, for each pair of sampling switches.

There is no question that both time-division and space-division electronic switching networks are technically feasible. Both schemes must be considered strong contenders, and each may find its own area of usefulness. Although the cost and reliability of electronic switching systems are still being investigated, there is little doubt that the great benefits they offer will soon be realized.

MATHEMATICAL GAMES

Fiction about life in two dimensions

by Martin Gardner

Satire often takes the form of fantasy in which human customs and institutions are caricatured by a race of nonhuman creatures or a society or world with its own peculiar standards or physical laws. Twice there have been notable attempts to base such satire on a society of two-dimensional creatures moving about on a plane. Neither attempt can be called a literary masterpiece, but from a mathematical point of view both are curious and entertaining.

Flatland (first published in 1884 and now, happily, available as a Dover paperback) is the earlier and better known of the two. It was written by Edwin Abbott Abbott, a London clergyman and school headmaster who wrote many scholarly books. The title page of the first edition bears the pseudonym of A. Square. The book's narrator is a square in the literal sense. He possesses a single eye at one of his four corners. (How he managed, without feet, to move over the surface of Flatland and how he managed, without arms, to write his book are left unexplained.)

Abbott's Flatland is a surface something like a map, over which the Flatlanders glide. They have luminous edges and an infinitesimal height along the vertical co-ordinate, or third dimension, but they are completely unaware of their height and have no power to visualize it. Society is rigidly stratified. At the lowest level are the women: simple straight lines with an eye at one end, like a needle. There is a visible glow from a woman's eye but none from her other end, so that she can make herself invisible simply by turning her back. If a male Flatlander inadvertently collides with a lady's sharp posterior, the encounter can be fatal. To avoid such mishaps, women are required by law to keep themselves visible at all times by executing a kind of perpetual twist step. Among ladies married to men of high rank this is a "rhythmical" and "well-modulated undulation." Lower-class females try to imitate it but seldom achieve anything better than "a mere monotonous swing, like the ticking of a pendulum."

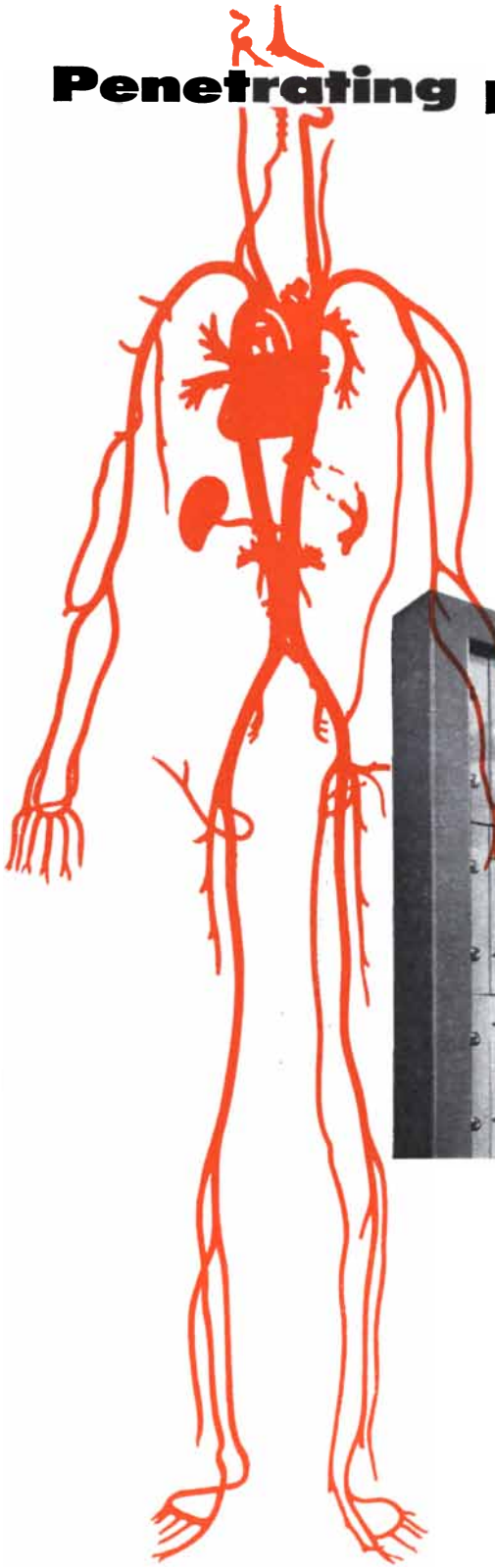
Soldiers and workmen of Flatland are isosceles triangles with extremely short bases and sharp points. Equilateral triangles constitute the middle class. Professional men are squares and pentagons. The upper classes start as hexagons, and the number of their sides increases with their rank on the social ladder until their figures are indistinguishable from circles. The circles, who top the hierarchy, are the administrators and priests of Flatland.

In a dream the square narrator visits Lineland, a one-dimensional world, where he fails to convince the king of the reality of two-dimensional space. In turn the square receives a visitor from Spaceland—a sphere who initiates him into the mysteries of three-space by lifting him above Flatland so that he can look down into the interior of his pentagonal house. When he returns to Flatland, the square tries to preach the gospel of three-space, but he is thought mad; he is arrested for his views and is in prison as the tale ends.

The sphere had entered Flatland by moving slowly through the plane until his cross section reached a plane figure of maximum area. It is easy to see that this section is a circle with a radius equal to the radius of the sphere. Suppose that instead of a sphere a cube had entered Flatland. What is the maximum area of a plane cross section that a cube of unit side could attain? The cube can, of course, tip his body at any angle as he crosses the plane. This is a pretty little problem, first posed by C. Stanley Ogilvy in *The American Mathematical Monthly* and answered in his forthcoming book, *Tomorrow's Math: Unsolved Problems for the Amateur* (to be issued this fall by the Oxford University Press). The answer will appear in this department next month.

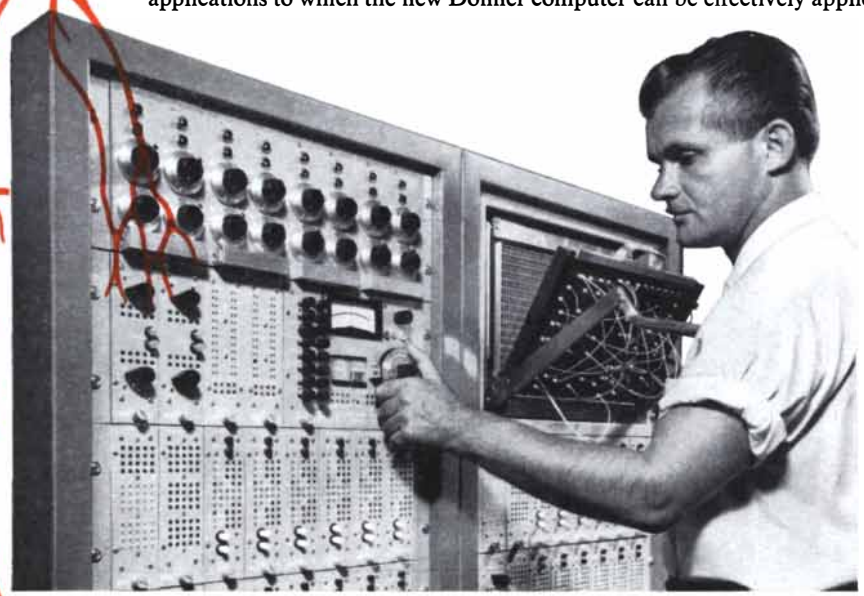
A much more ambitious work of two-dimensional fiction than Abbott's—a full-blown 181-page novel, in fact—was

Penetrating physiological frontiers with the new Donner analog computer



A new general purpose analog computer to simulate and compute even the most complex physiological problems is the latest development of Systron-Donner.

A powerful research tool for building dynamic models of physical systems, the capability of the Donner 3200 computer ranges from problems in aero-space to simulation of physiological processes in bio-medical research. Problems relating to such complex processes as determining the metabolism in compartmental systems, mechanical properties of arteries, regulation in the cardiopulmonary system, action potentials in neural elements and muscles—illustrate a typical group of bio-medical applications to which the new Donner computer can be effectively applied.



Equipment flexibility and usefulness—unmatched by any comparable system—are the essential characteristics which allow the Donner 3200 to solve a wide variety of complex problems. The 3200 Analog Computers can be obtained in systems requiring only 4 or as many as 100 amplifiers. With Donner, you need only acquire the system that fits your present needs, yet be assured that the basic 3200 system can be expanded merely by inserting additional computing modules when the need for greater computational capacity arises. Thus, your initial 3200 computer installation can be limited to a nominal investment. Cost depends on type and amount of equipment. Typical complete 3200 systems (including linear and non-linear computing equipment) average only $500 per amplifier channel.

Systron-Donner would be pleased to provide you with a bibliography of bio-medical computer applications and a brochure describing the Donner 3200 Analog Computer. Please direct inquiries to David Taskett.

SYSTRON-DONNER
Corporation

CONCORD, CALIFORNIA

Can satellites cut communications costs?

Within a few months, National Aeronautics and Space Administration plans to launch the first Hughes Syncom communications satellite into orbit. Hughes engineers foresee that this Syncom can be the prototype for an advanced *synchronous* satellite system which could significantly reduce intercontinental communications costs.

A synchronous satellite is one which orbits the earth at an altitude of 22,300 miles. At this altitude it can be made stationary over an assigned latitude—traveling one revolution with the earth each day.

From this position the satellite would "see" 40% of the earth's surface. And it could serve as a "switchboard in space"—relaying signals between ground stations as far as 10,000 miles apart.

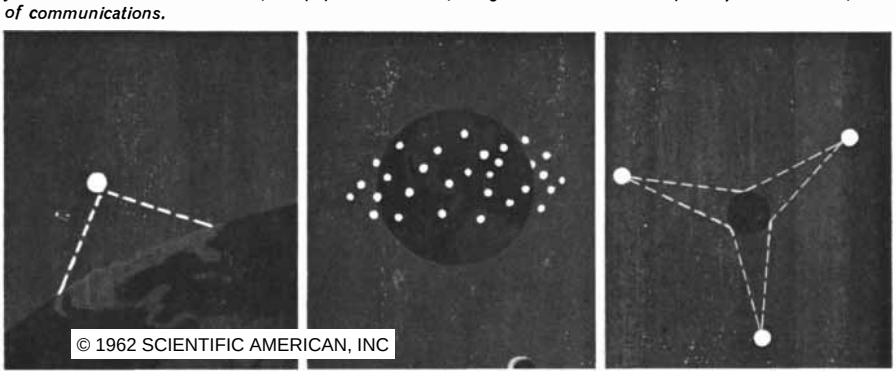
The Hughes communications system would require just three such satellites spaced around the earth (see fig. 3 below). They could bring intercontinental telephone, TV, telegraph and radiophoto service to *every* inhabited place on our globe.

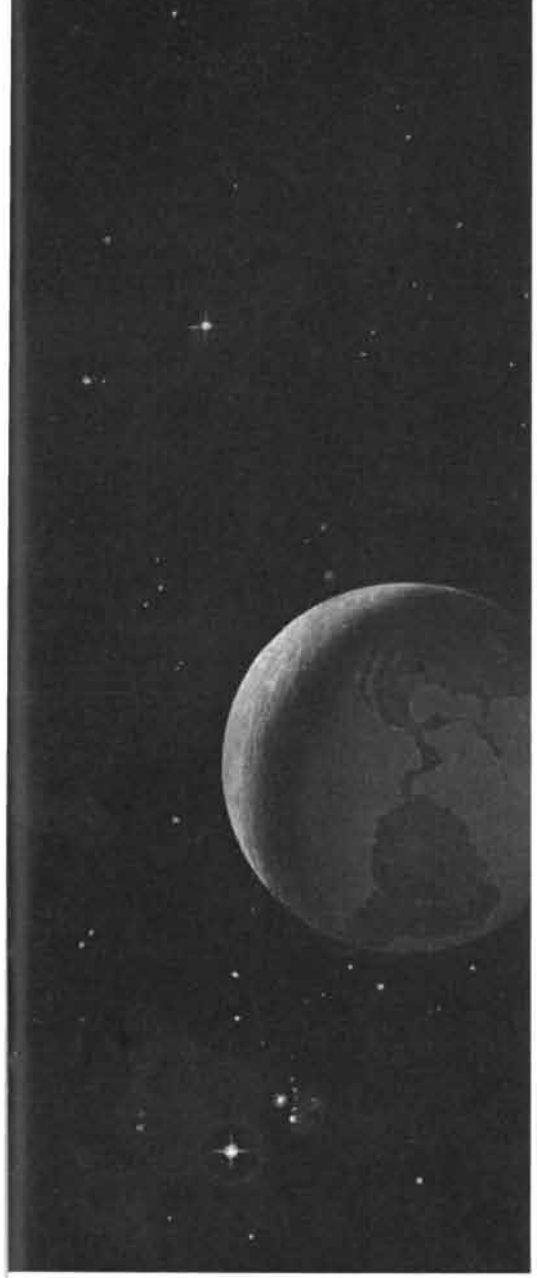
Equally important, the Hughes concept would accomplish this with greater simplicity and economy. For example, with just three satellites to put into orbit, fewer boost rockets would be expended—and valuable launch pad time would be saved.

Compared to other proposals, the Hughes system would require much less expensive ground stations. And because each satellite in the Hughes system would remain stationary over a point on earth, each could continuously communicate with many sta-

Three concepts of satellite communications

(1) Passive reflector satellite *— NASA'S Echo balloon helped prove signals could be "bounced" from one point on earth to another.* ***(2) Low altitude active satellites*** *would move in random orbits. Estimates indicate approximately 50 such satellites, together with complex ground stations, would be required to adequately cover the globe.* ***(3) A stationary high-altitude synchronous system*** *will require just three satellites to serve all of the populated areas of the globe with low cost telephone, TV and other forms of communications.*





tions. This permits a feature called "multiple access," where as many as 100 countries can be interconnected in whatever combinations the telephone demand requires at any time. In fact, one operational synchronous satellite over the Atlantic Ocean could handle the intercontinental service between 90% of the world's phones—1,200 conversations simultaneously!

Initially designed as a Hughes-sponsored project and built under contract to NASA's Goddard Space Flight Center, the Syncom I satellite system may inaugurate the most practical use of space so far visualized. It could reduce communications costs while permitting people throughout the world, even in less developed countries, to share in a communications system built by free men in the cause of greater world understanding.

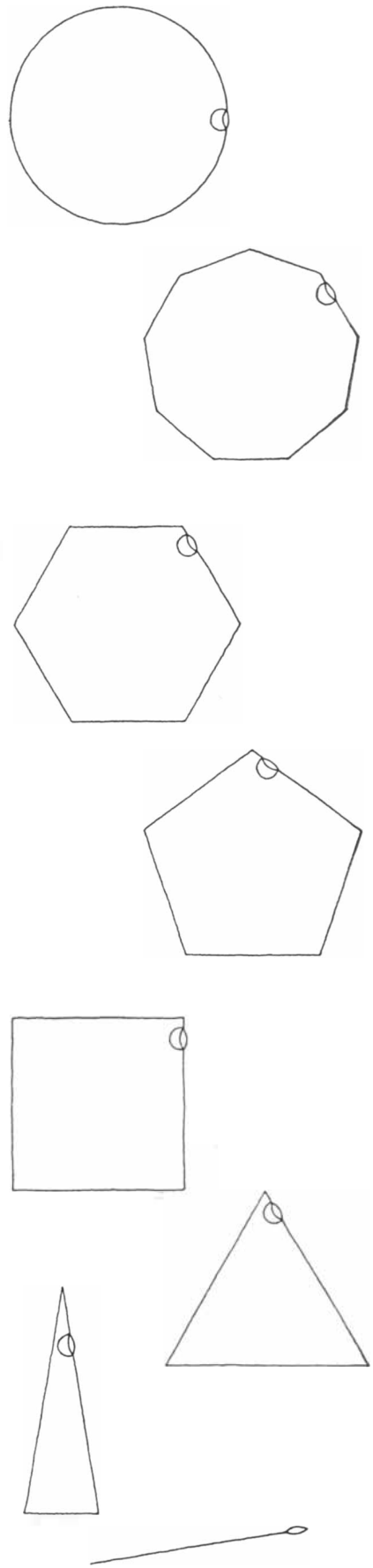
Charles Howard Hinton's *An Episode of Flatland*, published in London in 1907. Hinton was the son of James Hinton, a prominent London ear surgeon who was a friend of George Eliot's and the author of many widely read books. Young Charles studied mathematics at Oxford, married Mary Boole (one of the five daughters of George Boole, the logician) and settled in the U.S. He taught mathematics at Princeton University and at the University of Minnesota. When he died in 1907, he was an examiner in the U.S. Patent Office.

A long obituary in the New York *Sun* was written by Gelett Burgess of purple-cow fame, who recalled that Hinton had invented an automatic baseball pitcher. It shot balls with charges of gunpowder and could be adjusted to produce a pitch of any desired speed or curve. The Princeton team practiced with it for a while, but after a few accidents the batters were afraid to face it.

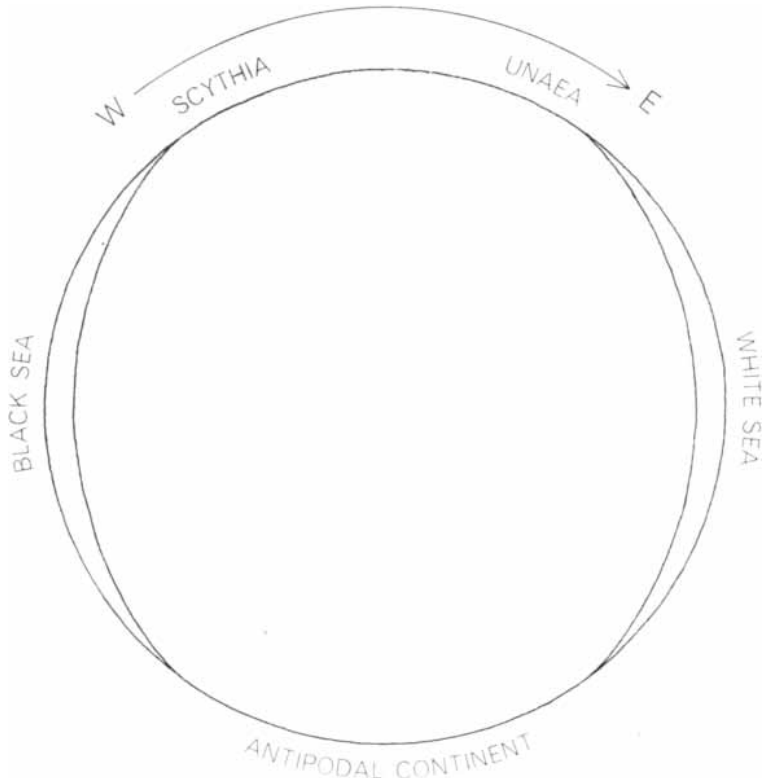
Hinton was best known as the author of books and articles on the fourth dimension. He developed a method of building models of four-space structures (in three-space cross sections), using hundreds of small cubes, labeled and colored in a manner detailed in his two most important books, *The Fourth Dimension* and *A New Era of Thought*. By working with these cubes for many years, Hinton maintained, he actually learned to think in four dimensions. He taught the method to his sister-in-law Alicia Boole when she was 18. Although the girl had no formal schooling in mathematics, she soon developed a remarkable grasp of four-space geometry and later made significant discoveries in the field. The wife of Hinton's son Sebastian is Carmelita Chase Hinton, founder and retired head of the Putney School in Vermont.

In constructing his Flatland, which he called Astria, Hinton took a more ingenious approach than Abbott. Instead of allowing his creatures to wander at will over the surface of a plane, he stood them upright, so to speak, on the rim of an enormous circle. If you place coins of various sizes on a table and slide them about, you will find it easy to imagine a flat sun around which flat circular planets orbit. Gravity behaves as it does in our space, except that on the plane its force naturally varies inversely with the distance instead of with the square of the distance.

The planet Astria is depicted on the next page. The direction (indicated by the arrow) in which it rotates is called east, the opposite direction west. There are no north and south, only up and down. The



One-eyed Flatlanders, in order of social rank



Charles Hinton's two-dimensional planet, Astria

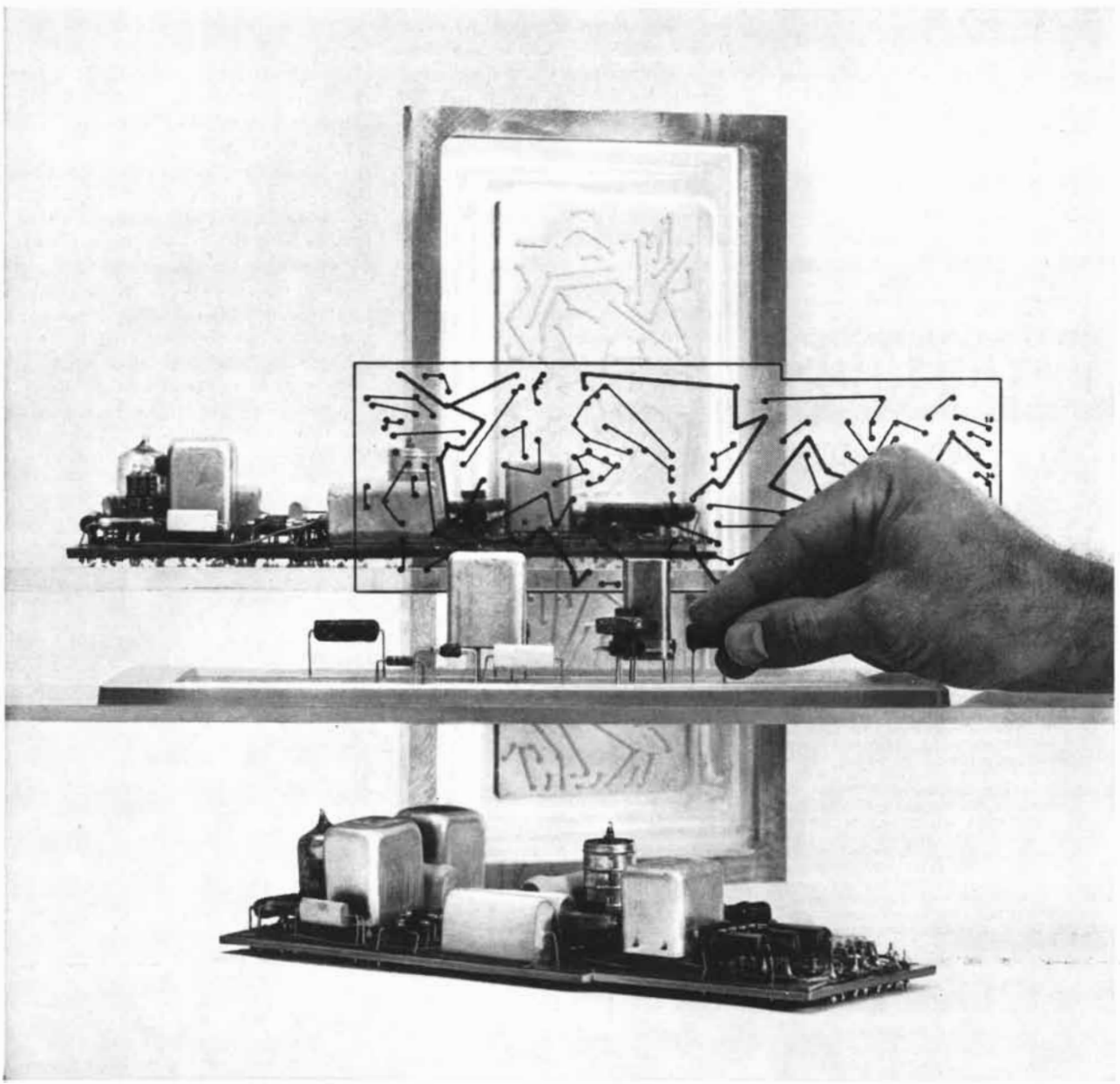
Astrians' bodies have a complex structure, but to avoid going into anatomical details Hinton represents them schematically as right triangles in the manner shown on page 150. Like Abbott's Flatlanders, the Astrians have only one eye. (Apparently neither writer considered the possibility of introducing two-dimensional vision involving a pair of eyes each with a one-dimensional retina.) Unlike the Flatlanders, they have arms and legs. To pass each other, two Astrians must of course go under or over each other, as would two acrobats on a tightrope. All male Astrians are born facing east, all females facing west. They keep this orientation until they die because there obviously is no way for an Astrian to "turn over" to become his mirror image. To see behind him an Astrian must bend backward, stand on his head or use a mirror. The mirror method is the most convenient; for this reason Astrian houses and buildings are well supplied with mirrors. To kiss his son a father must hold the boy upside down.

The inhabited region of Astria was originally divided between the civilized Unaeans in the east and the barbarian Scythians in the west. The Scythians had one great advantage in warfare: their male warriors could strike the Unaeans from behind, whereas the Unaeans could retaliate only by the awkward method of hitting backward. As a result the Scythians drove the Unaeans eastward until they were squeezed into a narrow territory bordering the White Sea.

The Unaeans were saved from extinction by the rise of science. Their astronomers, observing eclipses and other phenomena, became convinced of the roundness of their planet. A study of tides in the White Sea enabled them to deduce the existence of an antipodal continent. A select band of Unaeans sailed over the White Sea and crossed the new continent in a 100-year march during which each tree along the route had to be climbed over or cut down. Sons and daughters who survived the ordeal then built new ships to cross the Black Sea. The Scythians, taken by surprise, were quickly overwhelmed because now it was the Unaean men who could attack from the rear! World government was established; an era of peace had begun. All this is background history to set the stage for the novel.

I will spare the reader the details of the book's melodramatic two-dimensional plot. It is in the tradition of early socialist fantasies, attacking plutocracy in the name of an altruistically planned society. There is a rather flat love affair involving Laura Cartright, beautiful daughter of the rich, powerful Secretary of State, and Harold Wall, her handsome (in a plane sort of way) proletarian

PROCESSES. Progress in communications products depends not alone on new designs but on finding better ways to make them. In the Bell System, that's Western Electric's job. Case in point: amplas (apparatus mounted in plastic)—a new way of mounting electronic components by embedding their leads in a plastic panel. In the amplas process, the component leads are inserted in a transparent mold of rubber-like consistency (with pattern visible beneath). A liquid epoxy resin is then poured around the leads. After heat treating and cooling, the flexible pattern is peeled away from the hardened epoxy resin panel. The component leads, which extend through the panel, are then wired and mass soldered. With amplas, machining operations and hardware needed with printed wiring boards can often be eliminated. Amplas is representative of the many unique process developments by which Western Electric engineers have achieved low-cost manufacture of high-quality products. **WESTERN ELECTRIC**



suitor. Central to the plot is an ominous note of doom: The close approach of Ardaea, another planet, is expected to change Astria's orbit to an ellipse so eccentric that the climate will become alternately too hot and too cold to support life. The government begins a vast shelter program, excavating deep subterranean chambers and stocking them with provisions for the survival of the upper class.

The dreaded fate is averted by the mathematical theories of Laura's uncle, Hugh Miller, an eccentric old bachelor who lives on Lone Mountain. Miller (a thinly disguised Hinton) is the only man on the planet who believes in a third dimension. He has convinced himself that all objects have a slight thickness along a third co-ordinate; that they slide about over the smooth surface of what he calls the "alongside being." By working with models he has been able to awaken in himself a sense of three-space forms. He has come to understand that he is actually a three-space man directing a corporeal two-space body.

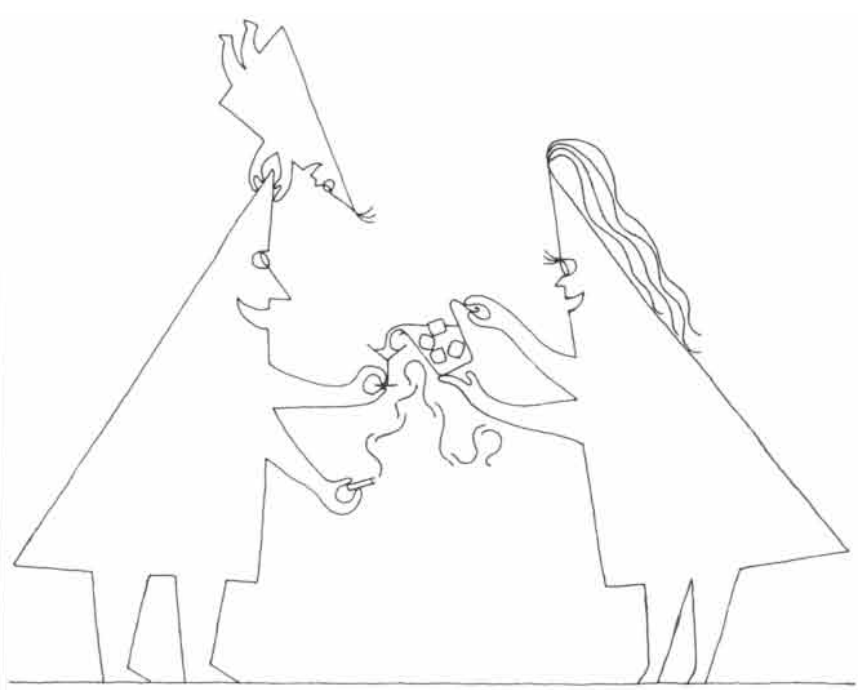
"Existence itself stretches illimitable, profound, on both sides of that alongside being," Miller says in an eloquent address to the leaders of Astria. "Realize this... and never again will you gaze into the blue arch of the sky without an added sense of mystery. However far in those never-ending depths you cast your vision, it does but glide alongside an existence stretching profound in a direction you know not of.

"And knowing this, something of the old sense of the wonder of the heavens comes to us, for no longer do constellations fill all space with an endless repetition of sameness, but there is the possibility of a sudden and wonderful apprehension of beings, such as those of old time dreamed of, could we but ... know that which lies each side of all the visible."

If there were some mechanical means of touching or latching on to the surface of the "alongside being," it would be possible to alter Astria's course in such a way that it might escape the influence of the approaching planet. There is no such method. But since the true self is three-dimensional, it may possess such power. The old man proposes a mass effort at what J. B. Rhine calls psychokinesis, or PK—the power of thought to influence the motion of objects. The plan is carried out successfully. A concerted PK effort on the part of everybody alters Astria's orbit just enough to avert catastrophe. Science, armed with the new knowledge of three-space, begins a great leap forward.

It is amusing to speculate on two-dimensional physics and the kinds of simple mechanical devices that would be feasible in a flat world. Hinton points out elsewhere (in an essay on "A Plane World") that houses on Astria cannot simultaneously have more than one opening. When the front door is open, the windows and back door must be closed to keep the house from collapsing.

A tube or pipe of any kind is impossible: how could its sides be joined with-



Home life among the Astrians

From endless, unknown space, strange, exciting tales are brought to us through the medium of electronics. Who knows what tomorrow's space explorations will bring?

One thing is certain. RCA power tubes will help establish communications between spacecraft and Earth just as they did in the Mercury capsule and Pioneer V. And, as in the Tiros and Echo satellites, RCA Camera Tubes will take pictures to be transmitted back to Earth.

These are but a few examples of the many RCA power tubes, microwave devices, and imaging and sensing devices used in space exploration. They are and will continue to be among the indispensable components reporting to Earth from outer space.

For information on RCA electron tubes that can help your space programs, contact: Marketing Manager, Industrial Tube Products, RCA Electron Tube Division, Lancaster, Pennsylvania.

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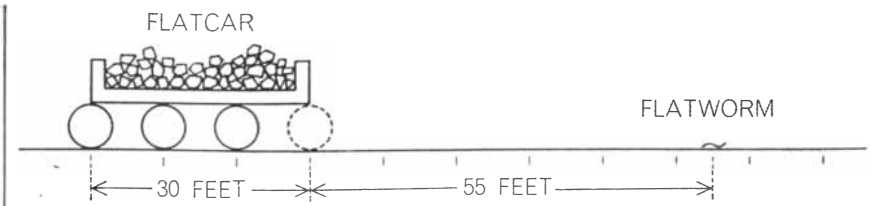


How many circles will roll over the flatworm?

out obstructing the passageway? Ropes cannot be knotted. (It has been rigorously proved that ropes can be knotted only in three-space, but surfaces can be knotted in five-space, solids in seven-space, and so on for all odd-order spaces.) Hooks, levers, couplings, tongs and pendulums can be used, as can wedges and inclined planes. Wheels with axles are out of the question. A crude gear transmission might be made possible by partially encasing each wheel in a curved rim. Methods can be worked out for rowing ships; airplanes would have to fly like birds by flapping wings. Flatfish should have little difficulty paddling through the water with properly shaped fins. Liquor could be kept in bottles and poured into glasses but no doubt would taste flat. Heavy objects can be transported by rolling them along on circles much as a three-space object can be rolled over cylinders.

This Astrian method of moving objects introduces a delightfully bewildering problem sent to me recently by Allan B. Calhamer, a reader in Billerica, Mass. The illustration above shows a loaded Astrian flatcar, 30 feet long, that is being moved along a straight track by means of three circles. The circles are at all times exactly 10 feet apart from center to center. As soon as the position shown is reached, the rear circle is picked up by an Astrian at the rear and tossed to a companion in front, who places it at the spot shown by the broken line. The flatcar is pushed forward over the three circles, which roll along the track, until the wheels are once again in the position shown. The back circle is tossed to the front as before and the procedure is repeated as often as necessary.

The flatcar is being moved off the page to the right. Exactly 55 feet in front of the point at which the dotted circle touches the track is a flatworm. Assuming that the worm does not move, how many circles will roll over it?

The reader is urged to try to solve the problem first in his head. Next, check your answer with pencil and paper; finally, compare it with the answer to be given in this department next month.

For those who would like to do a bit more homework, generalize for n equally spaced wheels. Surprisingly, it is not necessary to know the size of the wheels.

The answers to last month's solitaire problems:

Greek cross: 34–14, 54–34, 46–44–24, 14–34, 42–44, 34–54, 64–44.

Fireplace: 45–25, 37–35, 57–37, 34–36, 37–35, 25–45, 46–44–64, 56–54, 64–44.

Pyramid: 54–52, 73–53, 52–54–56–36, 34–32, 13–33, 32–34, 35–55, 43–45, 55–35, 24–44, 36–34–54, 64–44.

Lamp: 35–37–57, 55–35, 57–55, 51–53–33, 41–43–23, 31–33, 23–43, 65–45, 35–55, 43–45, 55–35, 25–45, 46–44.

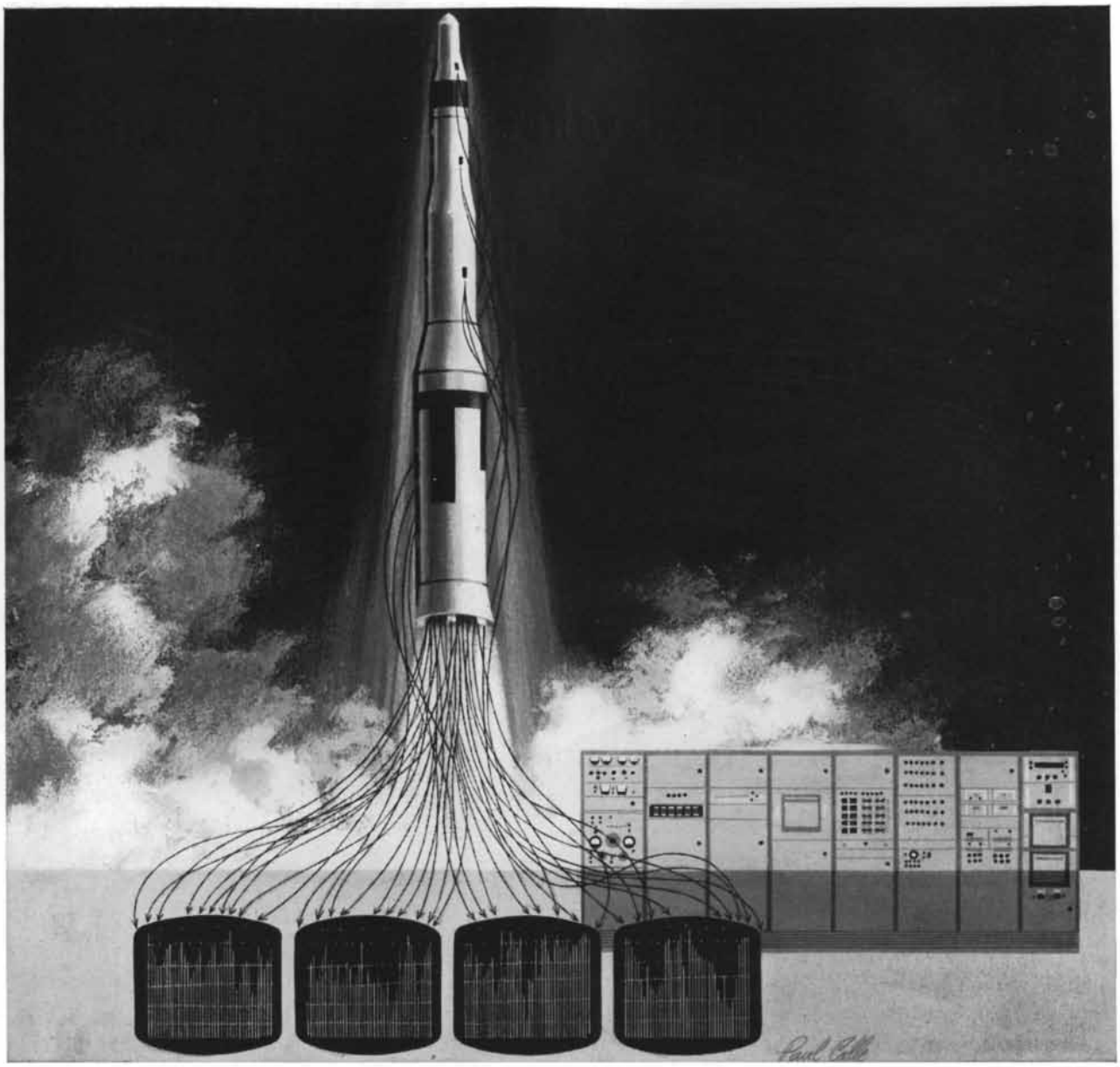
Inclined square: 53–51–31, 35–37–57, 33–13–15, 55–75–73, 15–35, 73–53, 57–55, 31–33. The pattern is now a smaller inclined square. Continue: 64–44, 34–32–52–54–34, 24–44. This leaves a Latin cross, the simple solution of which was explained last month.

Wall: 64–44, 34–54, 46–44, 14–34, 44–24, 42–44, 54–34–14. This solves the problem. By continuing to play it is easy to reduce the figure to four pieces on the corners of the central 3 by 3 square.

Square: 46–44, 25–45, 37–35, 34–36, 57–37–35, 45–25, 43–45, 64–44, 56–54, 44–64, 23–43, 31–33, 43–23, 63–43, 51–53, 43–63, 41–43. The finish is apparent: 15–35, 14–34, 13–33 on the left, and the corresponding moves on the right, 75–55, 74–54, 73–53. The puzzle is now solved. Four more jumps will leave counters on the corners (36, 65, 52, 23) of an inclined square—an unusually difficult pattern to achieve if one does not know earlier positions.

Pinwheel: 42–44, 23–43, 44–42, 24–44, 36–34, 44–24, 46–44, 65–45, 44–46, 64–44, 52–54, 44–64. The position now has fourfold symmetry. It is completed: 31–33, 51–31, 15–35, 13–15, 57–55, 37–57, 73–53, 75–73. The final figure is a stalemate.

The shortest stalemate, starting with a full board and a vacant center cell, is reached in these six moves: 46–44, 43–45, 41–43, 24–44, 54–34, 74–54.



AT RADIATION, CHALLENGE IS OPPORTUNITY

Example: Advanced data systems to speed Minuteman

Minuteman's *real* plume is a 352-channel trail of telemetry information for instant visual analysis by test crews. The high/low-level PCM multiplexing system — designed and produced by Radiation Incorporated — represents a major advance in data-handling techniques. It is packaged in *less than a cubic foot* of space, processes analog signals, and will yield maximum performance data from each test firing.

Radiation also developed checkout instrumentation to convert Minuteman's 352 telemetry channels into display form for real-time analysis by test crews. And, the company produced four complete ground data-processing facilities to monitor and record information from all digital telemetry and guidance equipment.

Radiation's scientists and engineers have entered the age of satellite instrumentation with competence in data acquisition and processing for aerospace and range instrumentation. Nimbus, Telstar and OAO will utilize Radiation's proven PCM techniques for long life operation as called for in space environments.

Become a part of this challenging space electronics program. We are currently seeking experienced engineers in the design and development of high-speed airborne and ground digital/analog data systems as either individual contributors or project engineers. Send us your resume or write for details. Director of Data Systems, Dept. SA-72, Radiation Incorporated, Melbourne, Fla. *Radiation is an equal opportunity employer.*

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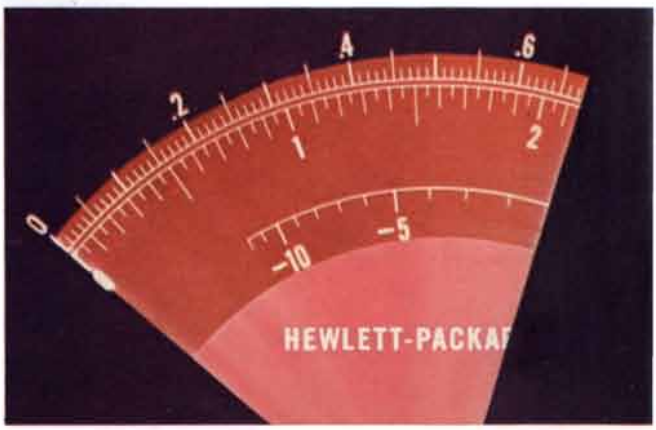


PROGRESS

IN SCIENTIFIC MEASUREMENT

is dependent on measuring tools of increasing accuracy. When today's scientist must compromise maximum measuring accuracy for the high cost of specialized measuring devices, technological progress is hampered or blocked.

Hewlett-Packard's continuing program of basic scientific research, coupled with increasingly sophisticated manufacturing techniques, provides science and industry with more accurate, more dependable measuring tools on a mass-production basis and at reasonable cost.

In precision electrical metering, the universally accepted d'Arsonval movement possesses an inherent flaw known as "tracking error."

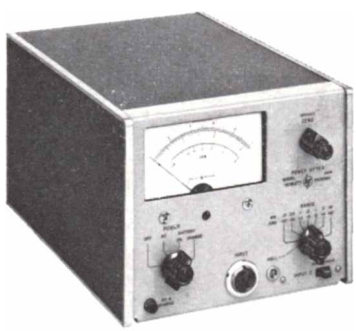
This flaw, a product of mechanical component inconsistencies, causes variation between actual electrical quantities and the meter deflection or indication. Industry practice has been to employ preprinted scales calibrated to the movement only at given points. While the meter then reads accurately at the points calibrated, indicating errors are present elsewhere on the scale.

The only previous alternative was tedious, expensive hand calibration of meter scales.

Now hp has developed a unique system which employs a blank scale and literally custom prints each meter scale to match precisely with the electrical quantities the instrument is measuring. The hp system, also, instantly detects and rejects faulty meter movements. The result is a thoroughly reliable meter which actually provides *better* than the 1% accuracy previously claimed for the ultimate in precision electronic test meters.

In ways such as this, Hewlett-Packard seeks constantly to advance the state of the art and improve over 400 hp measuring instruments. To assist in this work, and in the development of many new, high value instruments annually, hp is continually interested in ambitious engineers desiring a stable future and a continuing opportunity for creative endeavor.

hp means accuracy, dependable performance, realistic value, sales and service everywhere



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7441

THE AMATEUR SCIENTIST

How an electric field can modulate light by changing the refractivity of a crystal

Conducted by C. L. Stong

Someday technicians manning lunar outposts may keep in touch with the people back home over beams of modulated light. The fluorescence emitted by ruby and other crystals can be beamed with the necessary sharpness, and in theory it has substantially greater capacity than radio for carrying information. Signals transmitted optically can be detected by photoelectric cells. To harness light efficiently as a medium of communication, however, experimenters must first devise a practical apparatus for imposing multiple signals on light waves. Hans Jaffe and Joseph Stephany of the Clevite Corporation in Cleveland, Ohio, suggest that the desired modulator may be based on one of those "useless" laboratory curiosities handed down from the 19th century: the Pockels effect, which involves changes in the refractive properties of certain crystals when they are subjected to an electric field.

"The optics of crystals," writes Jaffe, "was a preferred subject of physicists during the first half of the last century and provided some of the most exciting and elegant experiments of the period. This interest grew during the second half of the century to include interactions in crystals among heat, light, elastic stress and electric fields. The development of quantum theory early in the present century diverted so much attention to other matters that crystal phenomena faded somewhat into the background. But the field continued to expand and to make increasing contributions to technology. Now a new generation of solid-state physicists is beginning to examine some long neglected phenomena of crystals.

"These phenomena include changes in the way in which light is propagated through certain crystals when an electric field is applied across the crystal lattice. This effect was first investigated intensively by F. Pockels at the University of Heidelberg during the 1890's. To find out whether the change in refraction is a primary effect or merely a photoelastic effect caused by piezoelectric strain, he investigated crystals of quartz, tourmaline, Rochelle salt and sodium chlorate and concluded that there is a primary effect. He observed a change in refraction even when all the deformation that normally results from piezoelectric strain was suppressed. But the effect on refraction barely reveals itself in most natural crystals.

"The period of World War II brought an active search for good piezoelectric materials for use as detectors of underwater sound, and one particularly attractive group was found: the phosphates of alkali metals, especially the ammonium and potassium dihydrogen phosphates. In the course of investigating these compounds I found that their crystals exhibited a pronounced Pockels effect. Of especial interest is the fact that the effect is observed in this class of crystals when both the light and the electric field parallel the optical axis of the crystal. This enables the experimenter to construct a light modulator from a thin crystal plate of large area without troublesome birefringence effects, provided that the light is kept nearly parallel to the optical axis.

"Last year I asked Joseph Stephany, then a summer assistant at the Clevite Corporation, to set up a demonstration modulator with a crystal of ammonium dihydrogen phosphate. In the course of this work he came on some interesting but not entirely expected resonance phenomena. His components were selected from materials that are readily and inexpensively available, so that amateurs can repeat the experiment."

"The Pockels effect," Stephany writes, "is usually demonstrated by sandwiching the crystal plate between two sheets of electrically conducting glass and inserting this assembly between a pair of crossed Polaroid filters. A beam of light that enters the crystal through one of the Polaroid sheets vibrates in a single direction, at right angles to the direction of vibration of light that can pass through the second filter, and the beam is therefore blocked. But the application of a direct-current potential of several thousand volts across the conducting glass alters the refraction of the crystal by a controllable amount, so that the incoming light is transmitted by the second Polaroid filter. An apparatus of this type, I knew, could be used to modulate a beam of light electrically. Full modulation by voice currents, however, would require an amplifier capable of supplying voice currents to the crystal at a potential of thousands of volts. Such amplifiers are not commonly available and they would be hazardous to use.

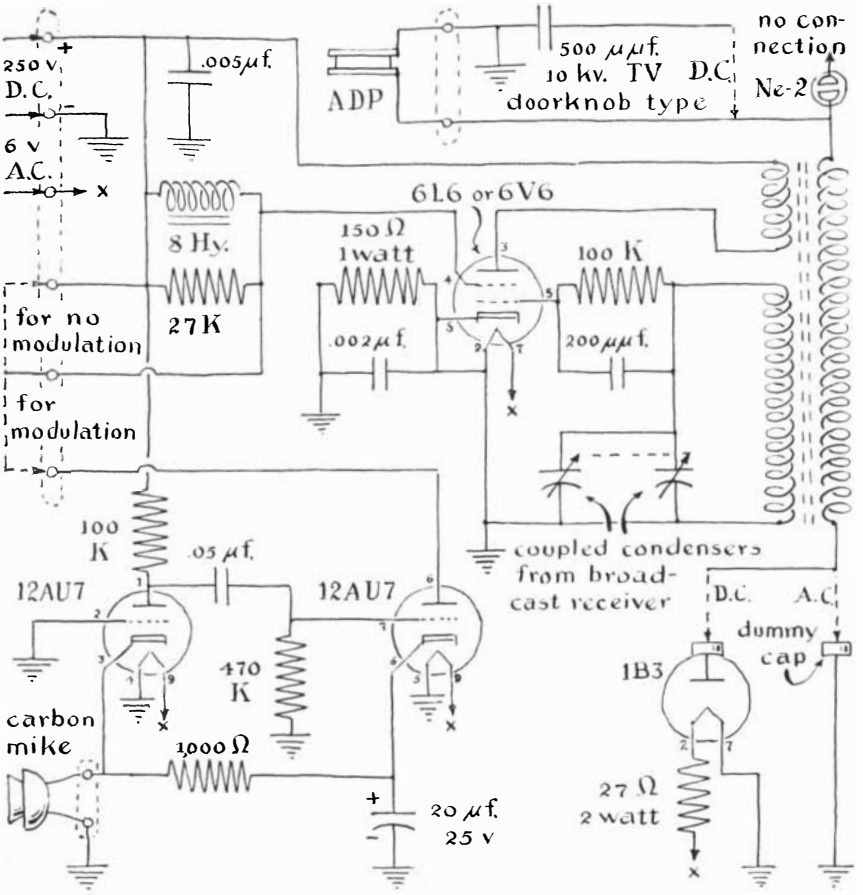
"I decided to resolve the difficulty by developing the high voltage at high frequency—to apply a conventional radio-frequency carrier to the crystal and modulate the carrier. High voltage at radio frequencies is relatively safe and is easy to generate with apparatus made of inexpensive parts. An adequate receiver is equally simple: a photoelectric cell connected to a radio set. A system that operates at radio frequency has the additional advantage of being immune to low-frequency noise such as 60-cycle flicker from fluorescent lamps, street lights and neon signs. The receiver would operate at twice the frequency of the voltage applied to the crystal and could therefore be tested close to the transmitter with a low probability of spurious electrical transmission between the two. In addition to constructing an apparatus based on this scheme I set up an optical bench so that the behavior of the crystal could be observed visually during modulation.

"All the electronic parts, with the exception of the photocell and special coils, were salvaged from an old television set and a small radio. Most were mounted on 6-by-14-inch breadboards and wired according to the accompanying schematic diagrams [*opposite page*]. The object is simply to excite the crystal

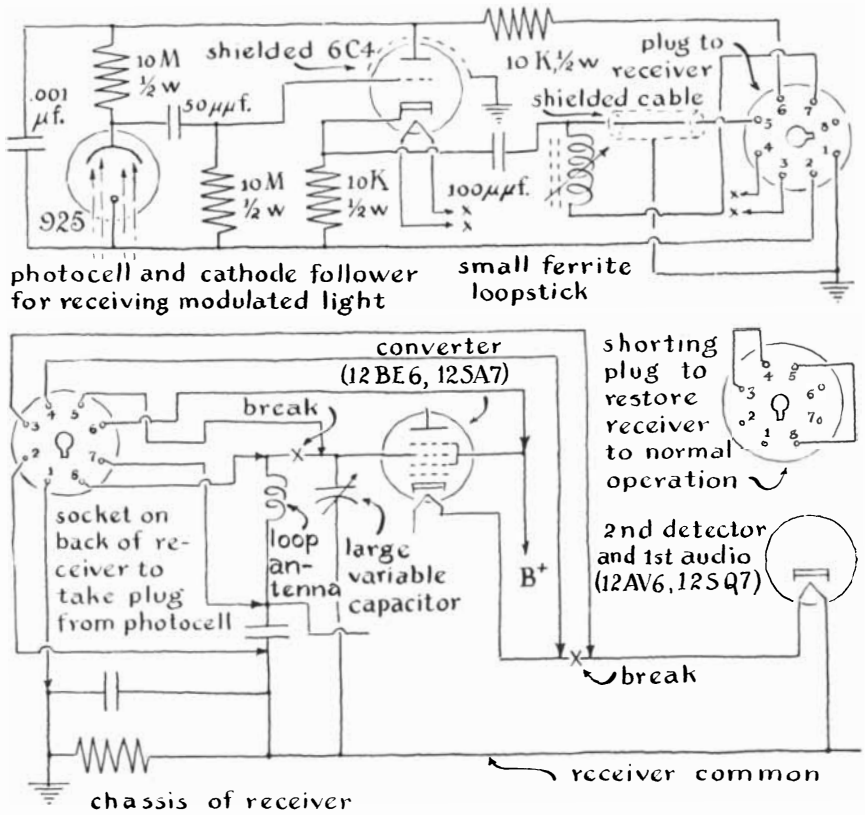
cell with output voltage from a conventional modulated oscillator of low power. The circuit details can be altered to accommodate materials at hand. Radio amateurs will encounter no difficulty in constructing this part of the apparatus; other experimenters may wish to call on a local radio ham for help.

"The two primary windings of the oscillator coil are wound on a cardboard tube approximately 1½ inches in diameter and 3¼ inches long, as shown in the accompanying drawing [*top of next page*]. I wound the secondary coil on a ferrite core 1/2 inch in diameter and 7½ inches long that was salvaged from a broadcast receiver. (An equivalent core is priced at 65 cents by the Lafayette Radio Corporation, No. MS-333.) All windings are No. 24 enameled copper magnet wire. The primary coils must be wound in the direction shown in the illustration, and the core should be wrapped with plastic electrical tape prior to winding. An ordinary filter choke or the primary of an audio-output transformer can be used as the choke for modulating the screen grid. Either a 6V6, 6L6 or 6DQ6 vacuum tube can be used for the oscillator. The voice signals are picked up by a carbon microphone. The output of the oscillator is shifted from direct current to high-frequency alternating current by moving the connector from the plate cap of the 1B3 tube to the dummy cap. The Ne-2 neon signal lamp lights when the doorknob capacitor is disconnected and is tied into the circuit by a single lead. The apparatus operates from direct-current sources of 250 volts at 70 milliamperes and 6.3 volts at two amperes. The incandescent lamp of the optical bench requires a separate source of 6.3 volts at three amperes.

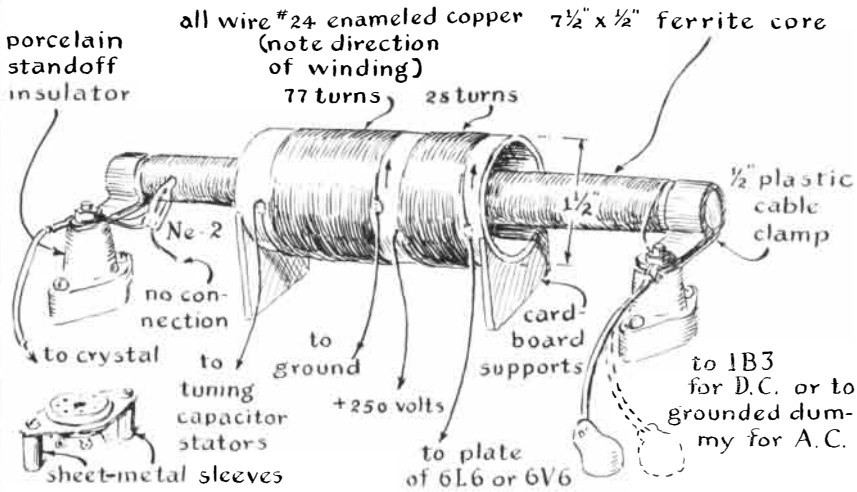
"The base of the optical bench is made of 3/4-inch lumber, three inches wide and three feet long, as shown in the accompanying illustration [*bottom of next page*]. Supports for the lenses and filters are cut from a tin can and are lined with plastic tape at points in contact with the glass to prevent scratches. Both lenses are 2½ inches in diameter and have a focal length of five inches. Mine were bought from the Edmund Scientific Company in Barrington, N.J. (catalogue No. 1166). The lamp of the optical bench is a six-to-eight-volt automobile parking bulb mounted so that the axis of the filament is aligned with the axis of the optical train. The photocell is a conventional No. 925 and can be ordered through dealers in radio supplies. Crystal blanks of ammonium dihydrogen



Schematic diagram of modulated oscillator



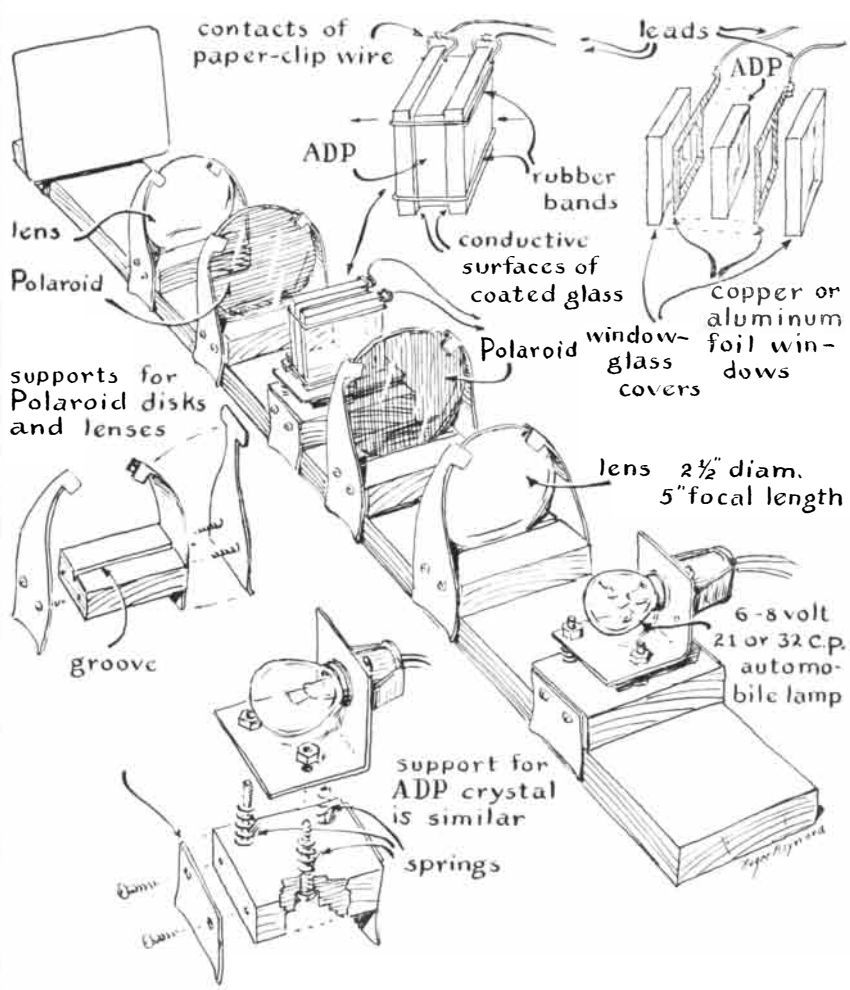
Schematic diagram of photocell pickup and converter for receiver



Details of oscillator coil assembly

phosphate are available from the Electronic Research Division of the Clevite Corporation (540 East 105 Street, Cleveland 8, Ohio) and from the Electro-Ceramics Company (2645 South Second West, Salt Lake City, Utah). These crystals are not identified by code number; if readers refer to this article when ordering, the supplier will select the proper item.

"The crystal must be cut, ground, polished and mounted between glass plates. My crystal plate was cut from a whole crystal and when finished meas-



Details of optical bench assembly

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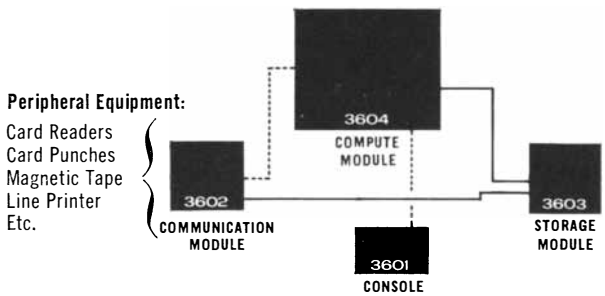
The chart below shows the modular design of the 3600 . . . consisting of three physically separate but highly integrated elements called modules.



These modules provide:

- High-speed data communication via bi-directional data channels which may be expanded in modules up to 32 bi-directional data channels.
- High-speed magnetic core storage containing 32,768 48-bit words, expandable in modules of 32,768 words up to a total of 262,144 48-bit words.
- High-speed computation, the heart of the 3600 system, providing true double precision floating point arithmetic (25 decimal digits) as well as conventional fixed point arithmetic (11 decimal digits). All arithmetic operations are in the parallel binary mode.

HIGH-SPEED OPERATIONS

The high-speed magnetic core memory of the 3600 allows an information access of less than 1 millionth of a second with a total memory cycle time of 1.5 millionths of a second. In addition, there are special circuits in the 3600 employing tunnel diodes that operate at 4 billionths of a second. In summary, high-speed functions in the 3600 include:

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- Single precision floating point add or subtract in 4 microseconds (250,000 per second)
- Single precision floating point multiply in 1-6 microseconds (167,000 per second)
- Double precision floating point multiply or divide in 2-26 microseconds (38,500 per second).

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An integrated software system designed for use with the 3600 will be oriented around a Master Control System (MCS) . . . which allows programming systems to be independent of particular system configurations as well as of types and numbers of peripheral equipment. Some of the important programming systems operating under the MCS will include

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- COBOL
- Monitor System
- COMPASS
- 1604 Compatibility Package

For further information on the Control Data 3600, call the Control Data representative in your area, or write for Publication No. B-4B-62.

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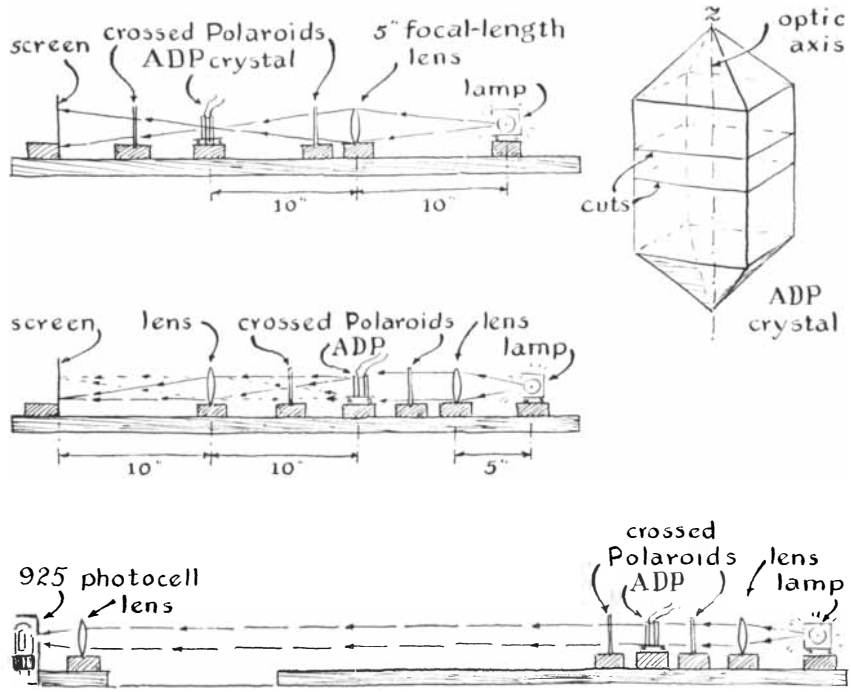
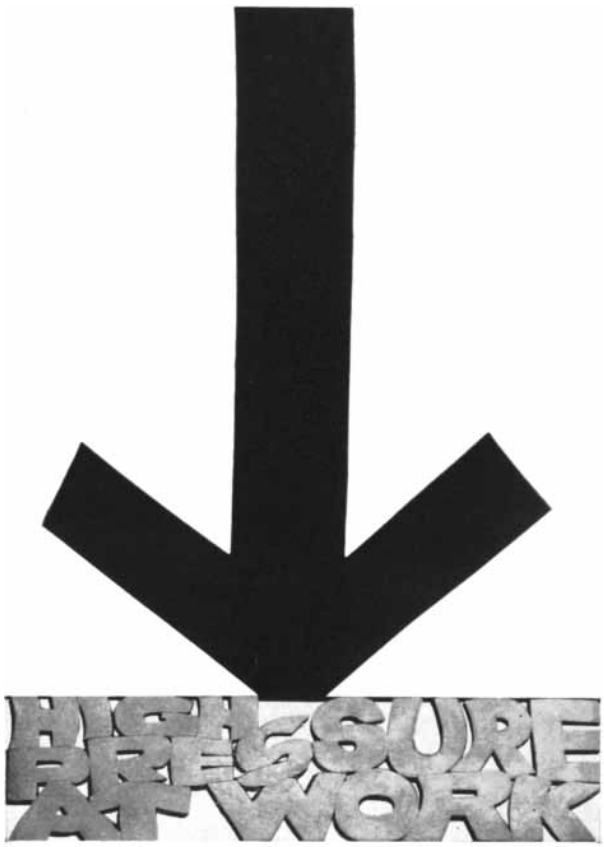


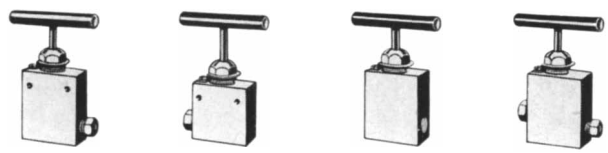
Schematic diagrams of optical bench setups and ADP crystal

ured 1½ inches square and 1/4 inch thick, with the major faces of the plate perpendicular to the optical axis of the prism [*see diagram at top right in illustration above*]. The orientation of the side faces is not important, but they usually parallel the natural faces of the prism. Incidentally, those who would like to try their hand at an art of another sort may enjoy growing their own crystals. An excellent outline of the process is given in *Crystals and Crystal Growing*, by Alan Holden and Phylis Singer, Science Study Series S7, Anchor Books, Doubleday & Company, Inc.

"Plates of ammonium dihydrogen phosphate must be handled with care. They dissolve in water, crack when subjected to abrupt changes in temperature and break easily when dropped. In the course of the experiment observations will be made of certain patterns of vibration, so the plate must be ground as closely as possible to a perfect square. This is not difficult if the experimenter works with care. First, a piece of grade 00 sandpaper (or a finer grit if available) is fastened to a flat surface such as a breadboard. A teaspoonful of kerosene is poured in the center of the sandpaper for lubrication. The plate is then placed face down on the sandpaper and ground with a light pressure and a circular motion. Add kerosene as necessary to keep the work wet and move the plate to fresh portions of the sandpaper to prevent small chips from scratching the ground face. Lift the plate after two minutes of grinding, wipe it thoroughly with soft facial tissue and examine it. The plate, as bought, may have been coated with a film of aluminum. This must be ground off. Continue grinding until the surface is flat, has no deep scratches and appears white and translucent like ground glass. Then grind the opposite face. Use plenty of kerosene and shift to areas of fresh abrasive as the pores of the sandpaper fill up. Measure the thickness from time to time with calipers and vary the pressure exerted during grinding to keep the faces flat and parallel. Finally, grind the edges. Check this part of the work with an accurate try square. The major faces of the finished plate should be flat and the edges should be at right angles to the major faces.

"The ground plate is now cleaned and polished by holding it in a stream of tap water for about 10 seconds. The water will dissolve a thin layer from all surfaces, leaving a polished surface. The crystal becomes slippery when wet and the edges must be gripped with care. Change your grip every two seconds or so to prevent the formation of finger impressions around the edges. I usually shift the plate from hand to hand. Be sure not to touch the major faces during this operation. After the 10-second rinse shake off the excess water and wipe all surfaces gently with facial tissue until





HOW TO BUY A VALVE TO WORK AT HIGH PRESSURES

Buying valves to work at high pressures calls for a certain amount of experience and understanding of the unusual effects of high pressure at work. Here are some of the facts you should know:

TWO-PIECE STEMS. Select one that does not rotate against the seat when closing and which is designed for no backlash. Also look to avoid corrosion by making sure the stem is made from a material consistent with the body.

COINED VALVE SEATS. Hardening of the seat after machining is vital, because fluids under high pressure and temperature conditions seek out flaws as leak points.

MATERIAL QUALITY CONTROL. The valve should be made from material which has been carefully chosen. Rigid quality control, which includes chemical and physical analysis, should be part of the manufacturer's standard procedure.

HYDROSTATIC PRE-TESTING. There's no room for guesswork when tons of pressure bear down. Hydrostatic pre-testing must be 100 per cent—the only absolute assurance of function possible.

EVEN SPOT GAS-TESTING! Fluid viscosity is a major factor in valving. Under high pressures certain gases will move through all but the soundest valves. You should look for a substantial spot check with gas in the manufacturer's specs to make sure you're protected under virtually any service conditions.

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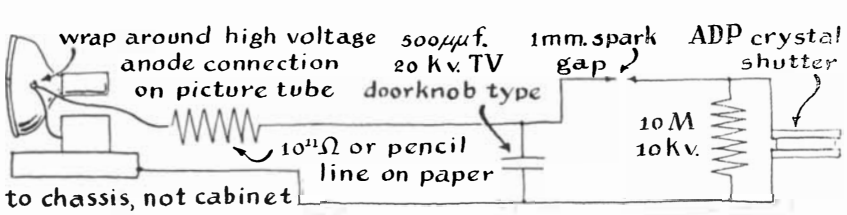
they are dry. Shift your grip as the plate is wiped, as you did during the rinsing operation. Objects a foot away can be seen clearly through a properly finished plate. If the dry crystal is placed between crossed Polaroid filters and held up to the light, a dark cross with concentric colored rings should be visible.

"The polished plate is next mounted between two sheets of electrically conductive glass. The glass should be somewhat larger than the plate, say about two inches square. Manufacturers of this material include the Corning Glass Works and the Pittsburgh Plate Glass Company. Small amounts can be ordered through local dealers in laboratory supplies. Place a few drops of pure mineral oil on the major faces of the plate and press a glass on top of each face so that the oil spreads to the edges without bubbles. Then bind the stack together at the edges with rubber bands. Electrical connection to the glass is made by paper clips to which leads are soldered. Distant objects should appear clear and undistorted when viewed through the completed stack. A similar unit can be made without conductive glass by framing the major faces of the plate with aluminum or copper foil, but although this arrangement will respond to high-frequency voltage it cannot be used for experiments with direct current.

"To observe the Pockels effect align the lamp, a lens, a Polaroid filter, the crystal assembly, another Polaroid filter and a screen of white cardboard in sequence on the optical bench as shown in the top diagram at left in the accompanying illustration [*page 160*]. Light the lamp and adjust the position of the lens until a light spot of minimum diameter is focused on the Polaroid filter nearest the lamp. Then rotate the other filter until a minimum amount of light is transmitted. A cross and a pattern of concentric circles should appear on the screen. Finally, rotate both filters together until the arms of the cross are horizontal and vertical, as in the accompanying photograph [*upper illustration on page 164*]. Switch on the oscillator and adjust the tuning capacitor for maximum direct-current output. The application of this potential to the electrically conductive glass plates will change the uniaxial interference pattern on the screen to the biaxial pattern shown in the second photograph [*lower illustration on page 164*].

"The crystal assembly can now be used as an ultrahigh-speed shutter, one capable of opening and closing in a few millionths of a second. To demonstrate shutter action switch off the direct current, remove one Polaroid filter, insert a second lens between the crystal and screen and adjust it until the image of the crystal appears on the screen. Replace the Polaroid filter and move the lens that is between the lamp and the crystal toward the crystal until the cross and colored circles appear on the screen. Continue moving the lens toward the crystal and simultaneously adjust the position of the crystal assembly as may be necessary to keep the expanding image of the cross centered on the screen. A position will be found at which the full screen is uniformly dark. This represents the 'closed' position of the Pockels shutter [*see middle diagram at left in the illustration on page 160*]. The screen will brighten when direct current is applied to the crystal assembly. One can adapt the shutter for high-speed photography by constructing a circuit that will apply a short pulse of high voltage to the crystal assembly. The high voltage can be obtained from a television receiver and might be pulsed by an arrangement similar to that shown by the accompanying schematic diagram [*below*]. I have not tried this particular scheme, but it should work nicely. The experimenter should observe the usual safety precautions when working with high voltage. Light is not fully blocked by the crystal in the 'closed'-shutter condition—the transmission amounts to about one part in 500. It is therefore advisable to synchronize the action of the crystal with a camera shutter.

"Modulator action is demonstrated by switching the oscillator for alternating-



Circuit for generating short pulse of high voltage

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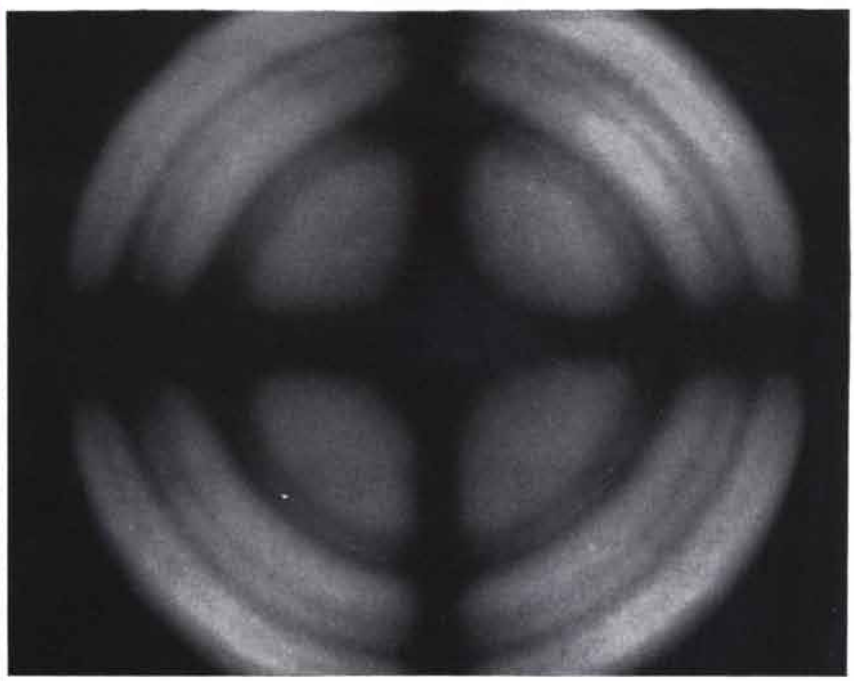
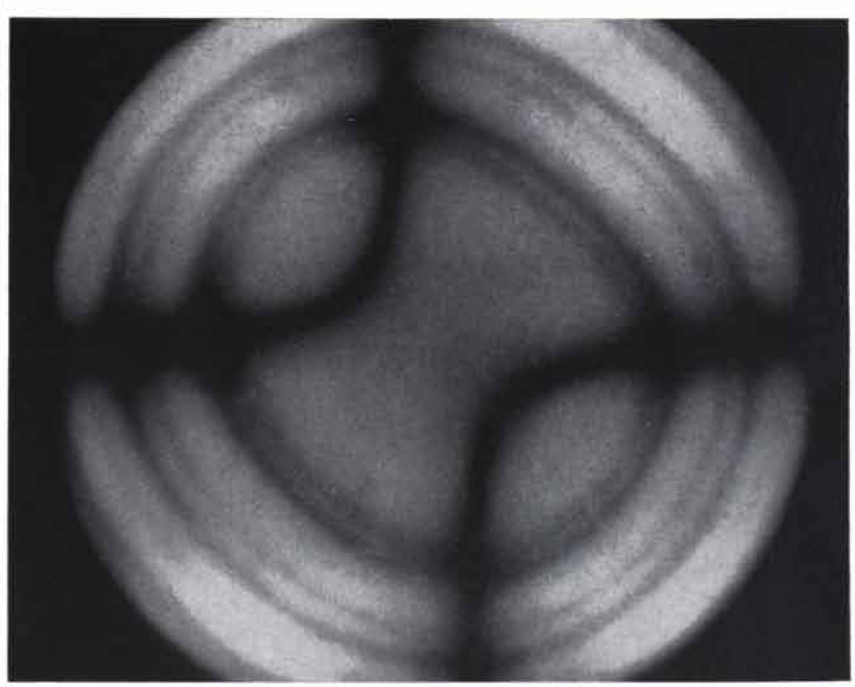
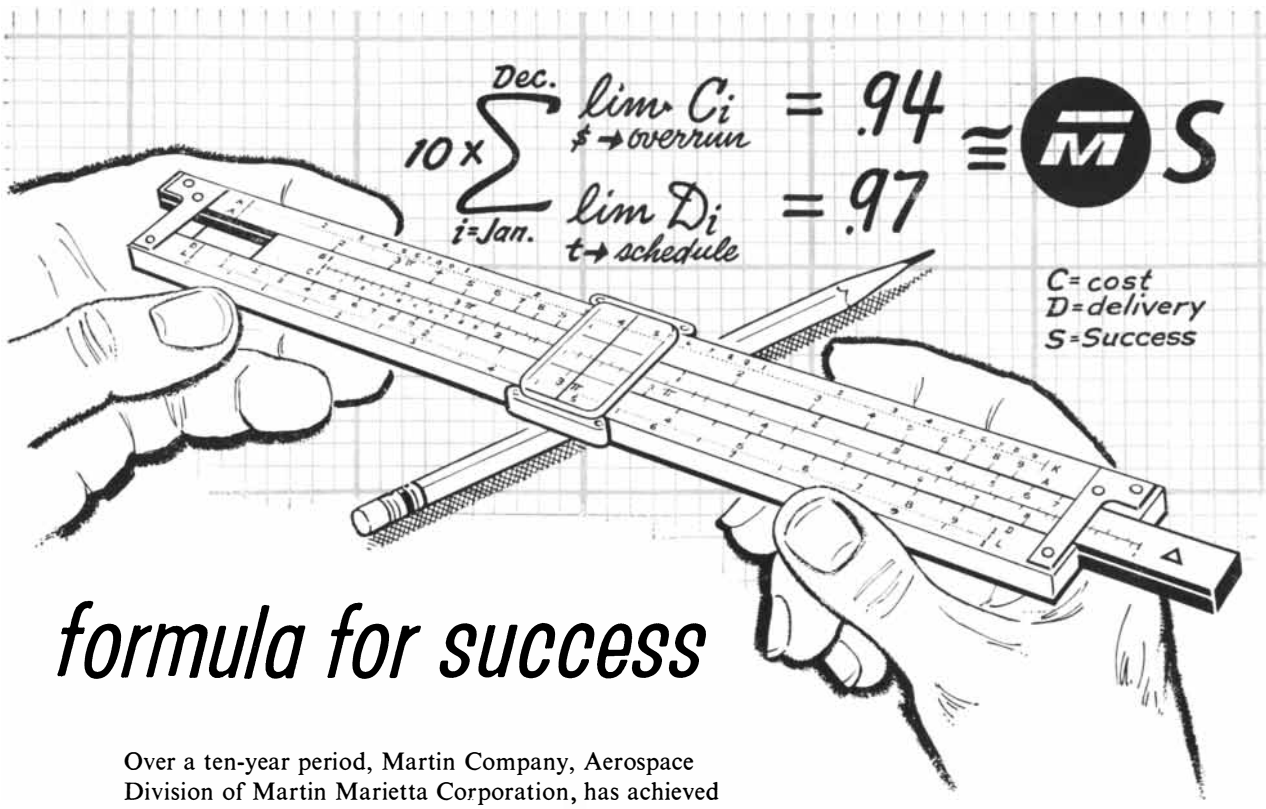
current output. The screen should be dark until current is applied. Switch on the oscillator and rotate the tuning capacitor slowly through its full range. At certain frequencies a grid pattern will appear on the screen, and it may shift or flip depending on the characteristics of the apparatus, as shown in the accompanying photograph [*page 166*]. The flipping effect is induced by the tendency of the oscillator to lock into the resonant frequency of the crystal—the natural period at which the crystal would vibrate mechanically if struck a sharp blow—and higher harmonics of that frequency. The patterns of vibration are analogous to those of a Chladni plate.

"Next, replace the screen with the photocell and switch on the radio receiver. Maintain the grid pattern. Then adjust the lens nearest the photocell





Uniaxial pattern of ADP crystal (top) becomes biaxial when electric field is applied (bottom)



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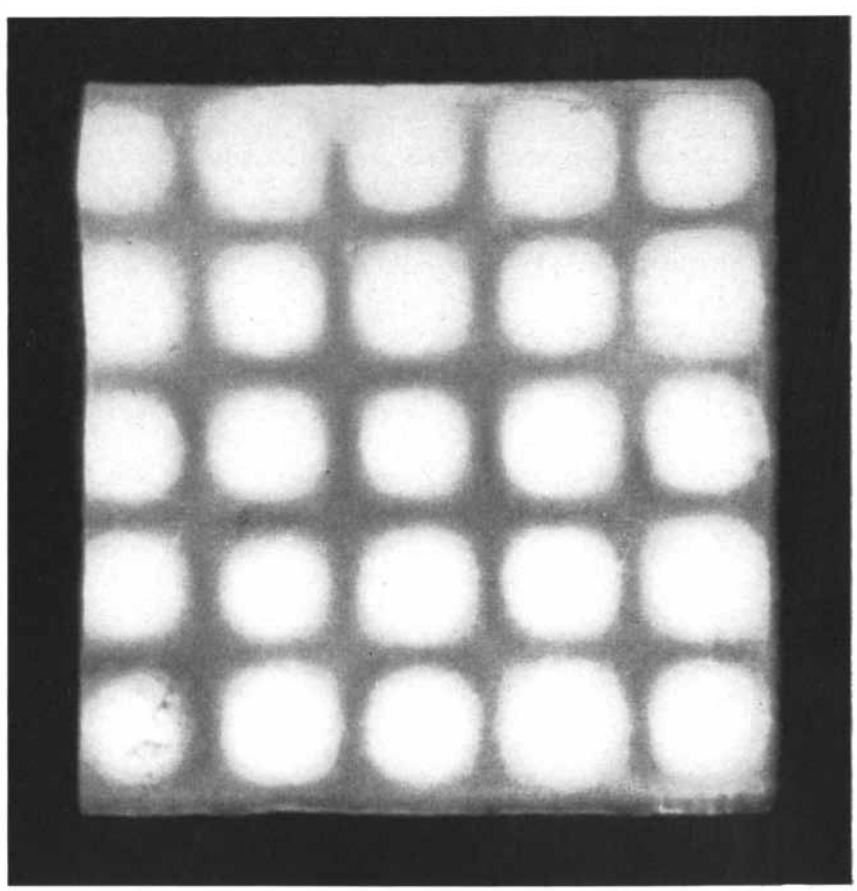
until the image fills the window of the cell [*see bottom diagram in illustration on page 160*]. Do not adjust for a sharp pattern because the bright spots in the pattern may paralyze local areas of the photocell. Tune the receiver until a frying sound is heard, which indicates a signal from the oscillator. If no response is heard, adjust the oscillator to another grid pattern and try again. Select the pattern and oscillator setting that produce the strongest signal. Spurious signals can be transmitted directly from the oscillator to the nearby receiver, so test for a valid signal by interrupting the light beam. The frying sound should stop when an opaque object is placed in the beam. Connect the carbon microphone and speak. You are talking over a light beam on a subcarrier channel. By coupling other modulating circuits to the crystal assembly and connecting companion radio receivers to the photocell it would be possible to transmit additional voice signals simultaneously over the same beam, each actuating its own loudspeaker.

"How far can one talk over this system? The distance is limited primarily by the intensity of the light and the amount that the beam spreads. With the automobile lamp bulb as a source we communicated over a distance of 100 feet. The filament is not a point surface and so the beam cannot be focused sharply. We substituted a concentrated arc lamp for the incandescent lamp bulb and conversed easily over a distance of 300 feet, the limit of our available space. The beam from the transmitter must fall on the photocell, and in setting up the apparatus for long-distance transmission we found that it is not easy to draw a perfect bead on the target.

"This apparatus was assembled as an introductory demonstration of how a crystal can modulate light. It has been suggested that a system based on the modulation of reflected sunlight should be effective over distances up to about 10 million miles [see "Kerr Cell Modulator for Space Communications," by Ronald G. Taylor; *Electrical Design News*, September, 1961]. An optical radar has also been proposed. An optical-maser beam modulated by an ADP crystal should locate objects more accurately and at appreciably greater distances than conventional microwave radars are capable of doing."



Fundamental resonance pattern of ADP crystal

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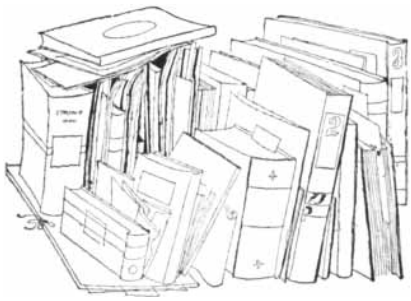


BOOKS

A playwright's account of man and his origins

by Marshall D. Sahlins

AFRICAN GENESIS, by Robert Ardrey. Atheneum Publishers ($6.95).

Robert Ardrey is a playwright, here turned author of a book about human nature. *African Genesis* is his great tragedy. The villain is man; the genre is naturalism. Ardrey conducts, as he puts it, a personal investigation into the animal nature and origins of man. As in much naturalistic fiction, this character, man, shows no development while on stage: his behavior has been set down by events beyond memory, in the main by genes implanted well before the opening curtain. So Ardrey takes us back to the social life of subhuman primates and other vertebrates, most notably birds, and to the South African "man-ape" fossils discovered by the anatomist-paleontologist Raymond A. Dart and his co-workers. Dart, according to Ardrey "a genius," is the tragic hero. His flaw has been a propensity to argue the case of a predatory African genesis in obscure scientific journals, and then not always to the point. That is where Ardrey comes in (to borrow from another playwright): to give order that these bodies high on a stage be placed to the view, to speak to the yet unknowing world how these things came about. So do we hear of carnal, bloody and unnatural acts; of accidental judgments, casual slaughters, of deaths put on by cunning and forced cause. All this does Ardrey truly deliver.

An unfair play? Well, Ardrey makes it very difficult for an anthropological critic to enter the lists against him. He believes he has discovered not only the true nature of man but also an "unwitting combine" of professors-that-be who refuse to acknowledge the evidences of this true nature. The true nature is made up of certain "cultural instincts" developed in the course of animal evolution and transmitted in the human line; they are bad instincts and they account for the great troubles of our world. The combine, intellectually committed to the "romantic fallacy" that man is basically noble, unique among animals and governed not so much by his animal nature as by his cultural circumstances, arrogantly pays no heed. Hence Ardrey makes out his discovery to be a revolutionary doctrine, and with great flourish and considerable flair he lets fly many barbs in the general direction of the "phalanx of modern thought" and the "censorship of scientific orthodoxy."

He's against the interests. His theory is sensible, yet the fuddy-duddy scientists won't see it. Immediately Ardrey is the underdog. Moreover, by the mere act of approving the book anyone can demonstrate that he is the intellectual equal, indeed the superior, of the ivory-tower boys. Then there are some minor attractions that will appeal to certain fringe types. Karl Marx is an enemy of the revolution, an incurable romantic with dreams of abolishing private property and class tyranny. It is indeed a motley assortment of powers that have entered into an unholy alliance to exorcise the haunting specter of man's animal ancestry: Rousseau and Jefferson, Freud and Marx, the British Museum (why does its great library not contain a copy of C. R. Carpenter's monograph on the gibbon?), the namby-pamby anthropologists and their committed publics; the whole troop of howling monkeys that is man refuses to look into the river of time and see the reflection of its own hideous visage.

Now, who wants to be accused of being a counterrevolutionary? What is more to the point, who *is* a counterrevolutionary? Ardrey maneuvers his critics onto false ground; they must joust from mounts mired in quicksand. Intellectual conservatism is contrary to the spirit of any science, not least to the spirit of anthropology. The bitter arguments are over who has the better revolutionary program. Every field has its fuddy-duddies and its muddle classes, but a science only rarely, and then only temporarily, vests its interests in them. So let the issue be joined in fact, knowledge and logic, and may the judges bear a wary eye for other sorts of hit. Ardrey's book has life, it has style (imagine, a book on fossil man written in English rather than in anthropology!), and it took neither little work nor little courage to write it. But I think it is wrong.

History, circumstance, culture—these in Ardrey's view have been more effects than causes of the human condition, more the acting out of a prehuman legacy of instincts and drives. The biological imperatives outweigh reason or learning over the long run. They can reappear after long periods of suppression, and they apparently have become immune to selection, since they can be carried again and again to irrational, self-destroying lengths.

From the dim vistas of a vertebrate past comes, first of all, man's territorial instinct, an urge to gain and defend a piece of ground. By a loose bit of translation the territorial instinct is equated to a historically specific form of property, private property; thus bourgeois proprietary inclinations with regard to capital goods become human-animal nature. This upshot is not unusual. Ignoring the million years in historical development of cultural forms, Ardrey typically takes as *human* the conditions he finds at hand, reads them into vertebrate sociology and so accounts biologically for *human* behavior. This is probably convincing to those sufficiently disturbed by the world as they know it and operating on a similar ignorance of cultural evolution and cultural variation. The plausibility of Ardrey's thesis, as we shall see, depends as much on ignorance of mankind as it does on knowledge of animal-kind.

The territorial instinct, Ardrey believes, becomes manifest in defense of social as well as individual property. Man is a social animal: society is his means of defense. He is therefore compelled to suppress aggressive individual drives on occasion in the interest of social cohesion. He develops, as have other social animals, a sort of primal morality

of amicability toward members of his own group, which is coupled with hostility toward other groups. The amity of the in-group is a love born of hate: it rests on and sustains collective territorial defense, and it multiplies hostility by the factor of society. At the social level, then, the territorial instinct is the root of such familiar human behavior as xenophobia, war, rampant nationalism and the Hungarian revolution; at the individual level it is the root of crime and a general reluctance to love one's neighbors.

Man also inherits a long-standing compulsion to dominate his fellows and to compete aggressively for status. Out of this come the status-seekers and "the roasting flesh of Jews." A certain "play of instinct" is possible, in which territorial urges add impetus to dominance urges. If in a misguided historical moment such as the Bolshevik revolution private property is abolished, the frustrated territorial compulsion—now actually a vague competitiveness—releases its energies in the dominance struggle, with results that make the English industrial revolution look like a picnic on the Thames. Drunkenness, suicide, mental breakdown and abortion are the price of socialism in Scandinavia.

Ardrey is not pleased with man—especially women. The male instincts at least are social. The male is the defender of the horde, of its territory, of its fallen. Even dominance—the sheer struggle of it—breeds order. Women only breed children. Otherwise they are complete anarchists. Note that they are the ones truly preoccupied with sex, which can be mighty disruptive, and order means nothing to them alongside the competitive struggle to latch on to the best-fixed male. Female neuroses are the product of our unnatural attempt to give women social roles, the vote, masculine jobs. They haven't the instincts for it. Can't clean up the mess that's inside.

We come to the jewel in man's crown of instincts: murder. The human line distinguished itself from other primates by forsaking the arboreal life in favor of a bipedal, ground-living adaptation that, coupled with the adoption of a carnivorous diet and a necessary reliance on weapons, produced the killer ape. Cain! We are Cain's children, born with weapons in our hands. The small man-ape *Australopithecus africanus* is our ancestor. Dart has shown him to be an unparalleled predator, truly nasty, brutish and short. So we are cursed with an "irrational, self-destroying, inexorable pursuit of death for death's sake." All human history has had one supreme objective: the perfection of the weapon.

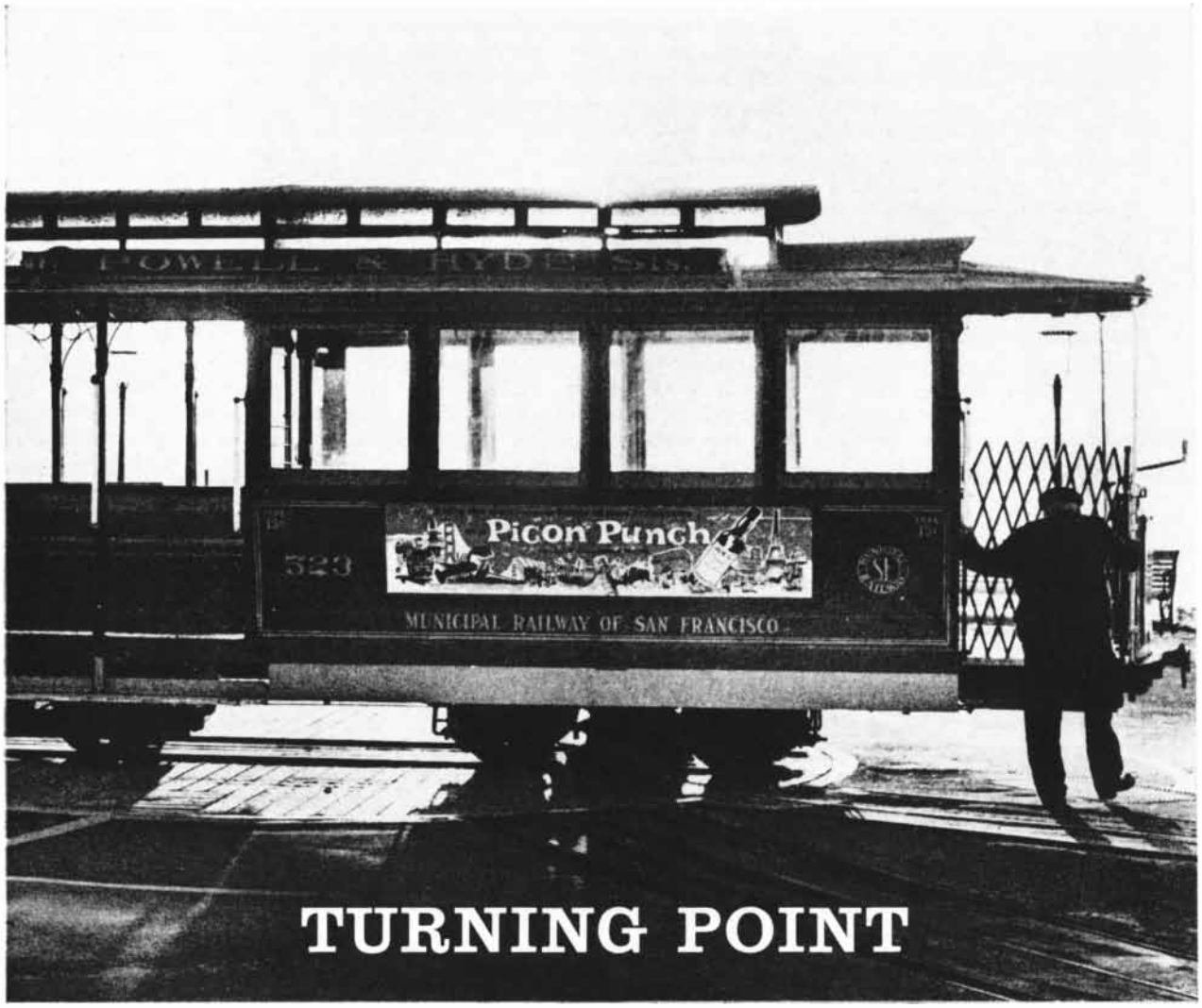
Ardrey's thesis is completely foolproof, which is the main trouble with it. The instincts are each vague enough to accommodate a sizable multitude of sins. Territory is property—individual or collective, landed or monetary. In fact, the drive to acquire territory is just about any attempt to acquire wealth. In any human society where some goods are socially valued above others (which is to say any human society) the obvious likelihood is that the "territorial instinct" can be discovered. A similar exercise can be performed with dominance and the rest of the animal legacy. In such a procedure it is important *not* to recognize cultural variations in proprietary interest, political form or what have you, and *not* to attempt to account for these variations. It is better to ignore them, because the variations suggest a *tertium quid* lurking in the background of the animal-nature–human-behavior relation, a third term—custom, circumstance or culture—that constrains the former and orders the latter. To invite contemplation of cultural variation is to open the door to the larger part of the romantic fallacy.

Moreover, to give his theory ironclad invulnerability Ardrey can manipulate the instincts *ad hoc:* all his pieces are queens. If you abolish private property, you haven't abolished the territorial impulse, you have simply channeled it elsewhere. In Ardrey's view man, like other higher mammals, has instincts somewhat weaker than those of lower species, instincts more susceptible to suppression by reason or learned response; hence the development of a primal morality. On the other hand, the frail voice of reason and the timid gesture of the learned response are as nothing against the deep command of instinct. The instincts sooner or later prevail, sooner or later are touched off, "like a desert river [vanished] season after season, then in a flick of a thunderstorm come ripping and raging out of the inscrutable earth." So when we are good to our neighbors, it is the amity of the in-group; when we are bad—well, what did you expect? When there is peace, the heart of the predator inside us is stilled; when there is war, it is raging out. Ardrey can explain everything and its opposite. With this technique nothing need remain a mystery, except perhaps the tenacity of such an unanimal-like idea as the romantic fallacy.

It becomes impossible to imagine conditions under which Ardrey's theory would fail to stand up. The vagueness of the instincts and their *ad hoc* play guarantees that the thesis will always hold true. There's the rub. If the failure of the theory cannot be conceived, the theory cannot be tested. It is therefore not a hypothesis. It belongs in an altogether different realm of proposition, one that has always been assigned a lower status by the scientific quest: truth. Ardrey's theory is simply the truth, the revolutionary truth.

A truth is characteristically immune to a test of evidence. Ardrey's explanations of apparent empirical contradictions demonstrate the power of his thesis in this regard. Let us take the gorilla, an admittedly exceptional case. The gorilla is just about our nearest living relation, yet a recent authoritative study of these animals in the wild indicates that they lack territoriality as well as displays of intertroop hostility. Ardrey's explanation is that the gorilla is at the end of his evolutionary tether and, somehow knowing it, has given up the ghost. Ardrey's long and eloquent argument to this effect is artful as prose but as biology must rank as grotesque. I compress and paraphrase it: Pity the poor gorilla, a dying species, an evolutionary failure in the twilight of his existence. Committed to a forest that has disappeared from under him, he came out of the trees and became a stem eater. His oversized body, his tree swinger's chest and arms are a mass of architectural incongruities about as meaningful to his present existence as an atticful of memories to a bankrupt nobleman. Doomed by ancient crises beyond control of memory, he knows it, knows it in the balance of instincts that govern his behavior. Vital instincts lose their hold. Primate compulsions fade like color from the skin of the dying. By day he seldom copulates and by night he fouls his own nest.

L. S. B. Leakey and his wife recently discovered at Olduvai Gorge in Tanganyika an early hominid, *Zinjanthropus,* which resembles the larger variety of *Australopithecus* called *Paranthropus. Zinjanthropus* was found with pebble tools of the sort that gave rise to the whole Stone Age archaeological sequence. He was not a confirmed predator-carnivore; he probably hunted only small game. *Zinjanthropus* appears to have developed later than the small australopithecine (Cain) presumed by Dart to have been a predator using weapons of bone and elevated by Ardrey to the dignity of an ancestral deity. That much we know. How does Ardrey handle *Zinjanthropus?* Abel. A kind of freak, a side branch. Backward, inoffensive lumbering ape man with the chewing structure



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of a vegetarian ape. How could *he* have been man's ancestor? He was slain by Cain, who took his stones away from him. This brings to mind the following sloka, which, as you have not heard it, I shall now proceed to relate:

There was a young man named
Zinjanthropus,
Who never became *Pithecanthropus.*
By his small cousin Cain
He was dastardly slain,
And that is what saved my hypothopus.

Now we must consider the great omission: ethnology. Ardrey presents us with a view of human nature that does not make relevant the accumulated anthropological evidence of man's behavior. Except for the roasting flesh of Jews, the Hungarian revolution and other events of that nature and of our time, the human condition, or rather conditions, are perfunctorily dismissed. As noted before, the omission is all the more serious because it is difficult to reconcile the facts of cultural variation with any theory of instincts (indeed, anthropologists have had fair success explaining cultural variation without recourse to instinct), and the further one travels down the scale of primitiveness, the greater the obstacles to Ardrey's theory. In such critical matters as territorial exclusiveness, private property and intergroup relations, the simpler peoples depart considerably from the supposedly immutable animal legacy.

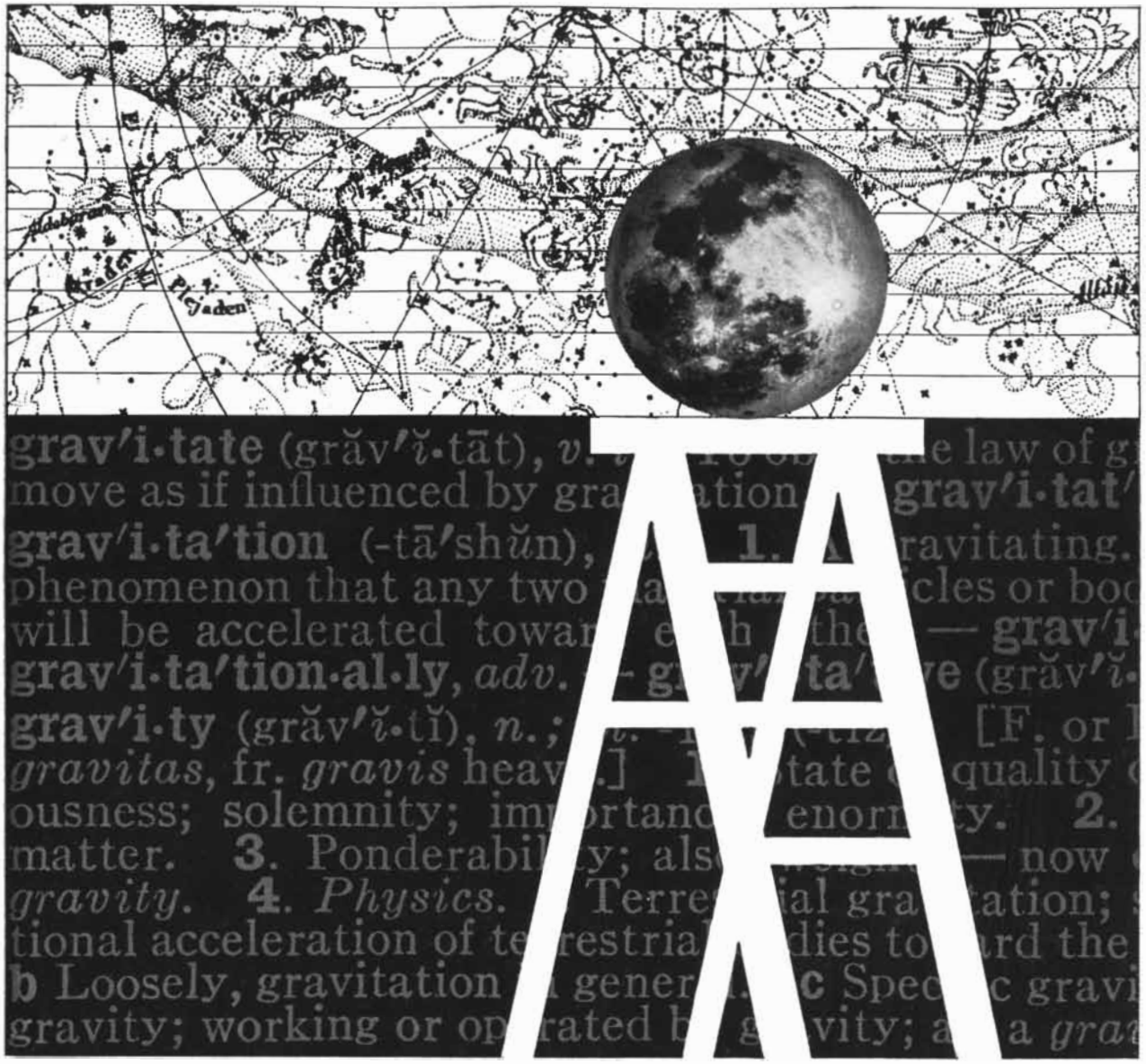
Ardrey recognizes this, but he banishes the evidence from primitive cultures in the same sort of way he disposes of the gorilla and *Zinjanthropus,* with a tale that struts and frets but signifies nothing. The Eskimos should be an ideal case. They rank among the world's greatest and most courageous hunters, and raw meat is the national dish. Here is the killer ape in sealskin clothing. But for all that the Eskimos are too nice in too many ways, and Ardrey chucks them out along with the whole mélange of tribal peoples. They are all too timid, somehow not *real* men, although how a descendant of Cain could so betray his heritage is not revealed. Ardrey writes:

"The Eskimo ... Yahgans ... African Bushmen ... these and other peoples in tropical hideaways of central New Guinea, of Malaya, of Borneo, all [reveal] natures much the same—gentle, shy, extremely timid and entirely nonaggressive. [This overstatement is based on the work of Sir Grafton Elliot Smith.] ... The conclusion that the shy, timid, amiable, non-aggressive nature of pristine man has been revealed by the character of these people is a logical sequitur simply to a false premise. What has been revealed is nothing more than that people living where nobody else wants to live may quite possibly suffer from nonaggressive dispositions. Who disputes with the Eskimo his blubber, his long night, his home built of ice cubes? No one. By adapting himself to a way of life superbly unattractive to Sioux or Apache, a shy creature has insured his survival in perfect confidence that he will escape the notice of all but romantic anthropologists.... All that has been actually demonstrated by this loosely disciplined but immensely popular raid into the outposts of man's nature has been that timid people tend to live at unfashionable addresses." Ardrey, incidentally, would have had problems even with the Sioux or the Apaches. The Sioux had their own blubber: they cried when they met people, early observers report, in order to manifest the lively joy that they felt at meeting them. The transformation between 1650 and 1800 of the partly horticultural Sioux of Minnesota, who could not bear to torture prisoners, to the horse-riding, buffalo-hunting scourge of the northeastern Great Plains would be instructive to debate. Was it just the release of an instinct, or was it a response to invasions from the north and east and to the advance of the European fur trade? Instinct or history, compulsion or cultural process?

The variation in the human condition from society to society and from one historical epoch to another is an intellectual message that cannot be shut off. The meaning is simple, the implications for the study of mankind enormous and complex: custom and the forces of its development tamper with the lives of men. Human nature is one thing, the human behavior of any particular society quite another. In each society human nature has been laid hold of, shaped out of obvious recognition—governed. It is natural to eat, but why eat, as Englishmen do, tea and crumpets at five in the afternoon or, as Americans may do, ravioli and lemon Coke at six? Man may very well be bad by nature. (Incidentally, it is doubtful if *any* anthropologist believes him to be innately good; many probably figure him to be inherently bad, by our standards. All would agree that he has a flexible and large capacity for good and bad, if only because he alone can assign the words "good" and "bad" to any kind of action.) Suppose all men do fight and do enjoy pointing a gun; it remains unanswered what governs the historic moment, the episode that is war, and what tells man in which direction to aim the gun. Man may have an urge to possess, but no human society would long survive that did not define, constrain and satisfy that compulsion on its own terms. The urges are repressed, twisted this way and that, sublimated, until in the end man lives in spite of, not because of, his innermost self. It is not up to the instinct how, or even if, it shall be satisfied. Man can war on the playing fields of Eton, hunt with a paintbrush in the dim recess of a cave, dominate, as primitives often do, by being nicer to others than to oneself.

All sorts of facile ironies on Ardrey's book suggest themselves: he underestimates his player, the play's the thing, and so on and on. The most revealing is that Ardrey's human drama is too stereotyped. The play is an inevitable tragedy from the moment, long before the opening curtain, that one takes his seat and has thrust upon him the lurid playbill. Not only does man respond flexibly to different cultural conditions, but also culture itself has shown unrecounted flexibility. The modern nation is not the mere counterpart of the primate horde, a simple territorial in-group characterized by an everlasting hostility toward the outside. It is not even the primitive tribe on a larger scale. It is a kind of standing miracle, an evolutionary smash hit that broke up the million-year run of tribal and archaic-state history. It went on record as a denial of the tribe, a denial that the ethnic tie is stronger than American citizenship, that the King of France was the King of Franks, that the stranger was not the fellow. To be sure, the nation did not abolish strife; it only concentrated it. But if men can live peacefully within the nation after a million years of tribal mistrust, who can say we have reached the limits of the human conception? After all, once the definition of man was a tribal identity: Navaho means "people," Eskimos call themselves "the men." Today everyone will recognize that he is a member of a planetary race. Man has discovered humanity. Even the ultimate weapon—which does it ultimately strengthen: the fibers of the nation or the fibers of the world, the idea of a chosen people or the realization that we are all in it together?

Behind all this is the final irony. Man is unique, because he has the unique capacity to make the world a stage. He names things, calls things good and bad, acts accordingly and is satisfied with himself accordingly. He takes the raw stuff of nature, human nature and mother nature, and transforms it into a new kind of reality, into systems of name-ideas, into cultures: hydroelectric power, God, brother, incest, fair price, 30 dol-



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lars or 30 days, no-good rat, love, evil. It is a new sort of reality, a different kind of design for social survival, one subject to historical circumstance and capable of varying the human response.

I'll take the good old-fashioned muckraker. I like this anecdote of Lincoln Steffens' (a great revolutionary hero, Steffens; incomparable urban paleontologist digging in an australopithecine underworld of organized crime, organized power, organized murder): "I always like to put the story," he writes, "Wundt's assistant Külpe told us after a visit to the neighboring University of Jena to see the aged philosopher Erdmann, whose history of philosophy, in some ten volumes, we had all read and studied. They had a warm, friendly talk, the old scholar and the young scientist, all about the old philosophers and their systems. But when Külpe tried to draw him out on Wundt and the newer school, Erdmann shook his head, declaring that he could not understand the modern men. 'In my day,' he explained, 'we used to ask the everlasting question: What is man? And you—nowadays you answer it, saying, He *was* an ape.'"

Short Reviews

THE CORRESPONDENCE OF ISAAC NEWTON: Vol. III, 1688–1694, edited by H. W. Turnbull. Cambridge University Press ($25). The present volume of this magnificent edition of Newton's correspondence, the last prepared by the late H. W. Turnbull, covers the period from December, 1688, to August, 1694. The contents, in general, are not so weighty as those of Vol. II, which reproduced the celebrated exchange of letters between Newton and Leibniz, but there is no lack of interesting and important material. In January, 1689, Newton was elected one of the representatives of the University of Cambridge in the Convention Parliament, and the letters that begin this volume show how seriously he took his responsibilities and how much time he devoted to them. The last letter in the book informs Robert Barton that "I have sent you & my sister [Hannah] a barrel of Oysters, wch I suppose at their first coming it may be a novelty with you." The 148 letters and papers make a varied fare.

There are letters to and from Huygens relating to the *Principia;* three exciting manuscripts dating from the 1660's and 1670's (and hitherto unpublished, except for part of one) recording Newton's early thoughts and calculations relating to motion and gravitation; correspondence between Newton and Leibniz on problems of the calculus; exchanges with the ponderous Bentley, Master of Trinity College, Cambridge, pertaining to the *Principia* and Bentley's sermons; memorandums and manuscripts by the Scottish mathematician David Gregory; letters to John Locke on theological matters; sundry missives that throw light on Newton's character, his delusions of persecution and his period of severe dejection; and a delightful interchange with Samuel Pepys that shows Newton in his best light—kindly, patient and brilliantly clear—as he explains to Pepys, who had no knowledge of mathematics, the solution to a question put to him by a certain Mr. Smith. The question was this: A has in a box six dice, with which he is to throw a six; B has in another box 12 dice, with which he is to throw two sixes; C has in another box 18 dice, with which he is to throw three sixes. Query: "Whether B & C have not as easy a Taske as A, at even luck?" Newton labored for days working out the answer, and he painstakingly demonstrated that A's chances of throwing one six with six dice were greater than B's chances of throwing two sixes with twelve dice and, in turn, that B's chances were greater than C's.

Among the diversions is a letter to Locke in which Newton says: "I once made upon my self with ye hazzard of my eyes. The manner was this. I looked a very little while upon ye sun in a looking glass wth my right eye & then turned my eyes into a dark corner of my chamber & winked to observe the impression made & the circles of colours wch encompassed it & how they decayed by degrees & at last vanished." There is a letter from the sycophantic, pretentious Swiss mathematician Nicholas Fatio de Duillier inviting Newton to become his partner in an alchemical patent-drug racket. One exchange starts with an apologetic, somewhat frantic note from Newton to Locke containing the famous line: "Being of opinion that you endeavoured to embroil me wth woemen & by other means I was so much affected with it as that when one told me you were sickly & would not live I answered twere better if you were dead. I desire you to forgive me this uncharitableness." Locke's reply states "that I am more ready to forgive you than you can be to desire it & I do it soe freely & fully yt I wish for noe thing more than the opportunities to convince you yt I truly love & esteem you & yt I have still the same goodwill for you as if noe thing of this had happened." And there is a report to Nathaniel Hawes, treasurer of Christ's Hospital, in which Newton analyzes meticulously the in-

adequacies of the Christ's Hospital mathematical curriculum, remarking that "it seems to comprehend little more than the use of Instruments, and the bare practise of Seaman in their beaten road, wch a child may easily learn by imitation, as a Parrot does to speak, without understanding in many cases the reason of what he does; & wch an industrious blockhead, who can but remember what he has seen done, may attain to almost as soon as a child of parts. . . ."

SIR ISAAC NEWTON'S MATHEMATICAL PRINCIPLES OF NATURAL PHILOSOPHY AND HIS SYSTEM OF THE WORLD, edited by Florian Cajori. University of California Press ($4.40). A paperback of Cajori's revision of the English translation by Andrew Motte (1729) of Newton's famous *Principia*. The translation has been revised by Cajori and supplied with a historical and explanatory appendix. Until the promised definitive edition of the *Principia* on which scholars are now engaged appears, the Cajori edition remains the most up-to-date version of this fundamental contribution to human knowledge, and students will be glad to be able to buy the book in an inexpensive format.

THE AEROPLANE, by Charles H. Gibbs-Smith. Her Majesty's Stationery Office ($6.43). An admirable historical survey of the origins and development of the airplane from the work of Sir George Cayley to the present. Gibbs-Smith, who is the author of a standard history of flying and other works on aeronautical history, presents an engrossing narrative the readability of which is unimpaired by the abundant technical data incorporated into it. The book is divided into two main parts: a straightforward chronology and a commentary—consisting of essays of varying length—incorporating the results of new research on the early history of the airplane. Separate sections discuss such topics as the origins of the kite, the rocket, the parachute, the airplane engine and the airscrew; the contributions of Leonardo da Vinci, Cayley and the Wright Brothers; early whirling arms and wind tunnels; claims to the first powered flight and controversies over priorities; the first eyewitness account of a powered airplane flight; the first women to fly; the principal airplanes of 1909 and the celebrated Reims meeting of that year. Also included are a table of the first efforts to fly powered airplanes and of the principal early flights (1874–1909), a chronology of aviation, a bibliography and

an "interlude" of memorable quotations on flight and fliers. Among these are Lord Kelvin's inspired observation made in 1896: "I have not the smallest molecule of faith in aerial navigation other than ballooning"; Wilbur Wright's classic refusal to make a speech in 1908: "I know of only one bird—the parrot—that talks; and it can't fly very high"; the statement of the British Secretary of State for War made in 1910: "We do not consider that aeroplanes will be of any possible use for war purposes"; Walter Alexander Raleigh's epigram (1910): "A machine is the embodiment of human thought, and if it sometimes seems to be almost alive, that is because it springs of live parents"; and the report of the trial of Jane Wenham, accused of witchcraft in 1712: "The judge . . . when it was alleged that the prisoner could fly, remarked that there was no law against flying." Many fine illustrations. A splendid book.

HOMOSEXUALITY: A PSYCHOANALYTIC STUDY, by Irving Bieber and others. Basic Books, Inc. ($8.50). A comparative study of the origins, development and potential treatability of the male homosexual. The authors of this work base their findings on clinical work with 106 male homosexuals and 100 male heterosexuals in psychoanalytic treatment. Sigmund Freud, in a 1935 letter to the mother of a young homosexual, took the position that homosexuality, while assuredly no advantage, "is nothing to be ashamed of, no vice, no degradation" and "cannot be classified as an illness." There is little likelihood, he said, that psychoanalytic therapy can restore a homosexual to normal sexual behavior. The most that can be expected, he indicated, is to help the homosexual to achieve "harmony, peace of mind, full efficiency," and to overcome his conflicts and unhappiness, his feeling of being a social outcast. The authors of this book are more optimistic. They report evidence that through psychoanalytic treatment many homosexuals "became exclusively heterosexual." Heterosexuality, in their view, is the biological norm; unless interfered with, all individuals are heterosexual. Accordingly they infer that homosexuals do not bypass heterosexual developmental phases and "all remain potentially heterosexual." This is an important conclusion, not only for homosexuals but also for the psychoanalysts who treat them. Few aberrations are more stupidly and cruelly treated in the U.S., and in many other countries, than homosexuality. This book is therefore a welcome contribution—regardless of

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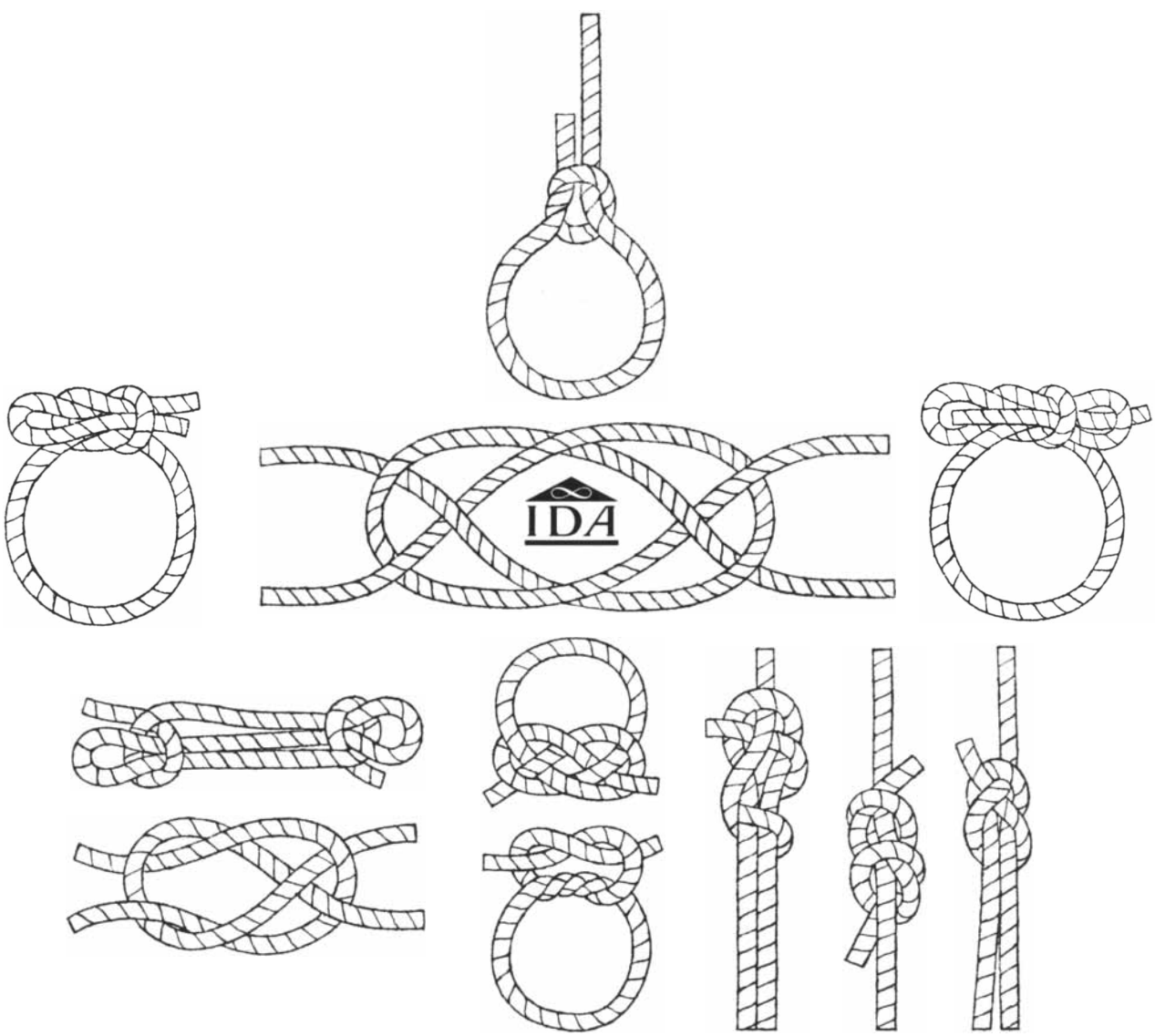

whether or not its findings are wholly confirmed—to social responsibility and enlightenment.

THE ORIGINS OF SCIENTIFIC THOUGHT, by Giorgio de Santillana. The University of Chicago Press ($5.95). From Anaximander to Proclus (600 B.C. to A.D. 500) is the span of this survey, by far the largest part of which has to do with Greek contributions to mathematics, physics and astronomy. The analysis of the ideas and theories of scientific pioneers of antiquity, including Archimedes, Aristarchus, Apollonius, Democritus, Empedocles, Eudoxus, Heraclitus, Hippocrates, Parmenides, Plato, Ptolemy and Pythagoras, is rounded out by extracts from their writings. De Santillana travels a well-worn road, and in straining for fresh effects he is apt to put too fine a point on some of his interpretations. But there is merit and vigor in much of what he says, and he has drawn freely on the best work of the specialists who in recent years have enlarged considerably our understanding of Greek science. The illustrations, consisting of a few text figures, are a poor lot; there is a brief but helpful bibliography; the index, confined to people and schools of thought, is wholly inadequate.

CAMONICA VALLEY, by Emmanuel Anati. Alfred A. Knopf ($5.95). A few years ago the author of this book, a young Israeli scholar, undertook an important archaeological investigation in the Camonica Valley, a wide, deep fault in the heart of the Italian Alps north of the city of Brescia. He examined some 15,000 carvings chiseled into the rocks of the Alpine mountainside by the inhabitants of the valley over a period from about 2000 B.C. to their conquest by the Romans in 16 B.C. An article describing his conclusions appeared in SCIENTIFIC AMERICAN for January, 1960. The present volume gives a full account of the work. Both the descriptions of the carvings and the explanation of the methods used in interpreting them make this one of the best popular archaeology stories in a long while. Copiously illustrated.

ATOMIC THEORY AND THE DESCRIPTION OF NATURE, by Niels Bohr. Cambridge University Press ($1.65). A reissue of a collection of Bohr's essays first published in book form in 1934. The essays discuss atomic theory and mechanics, the quantum postulate, the quantum of action, the atomic theory and the fundamental principles underly-

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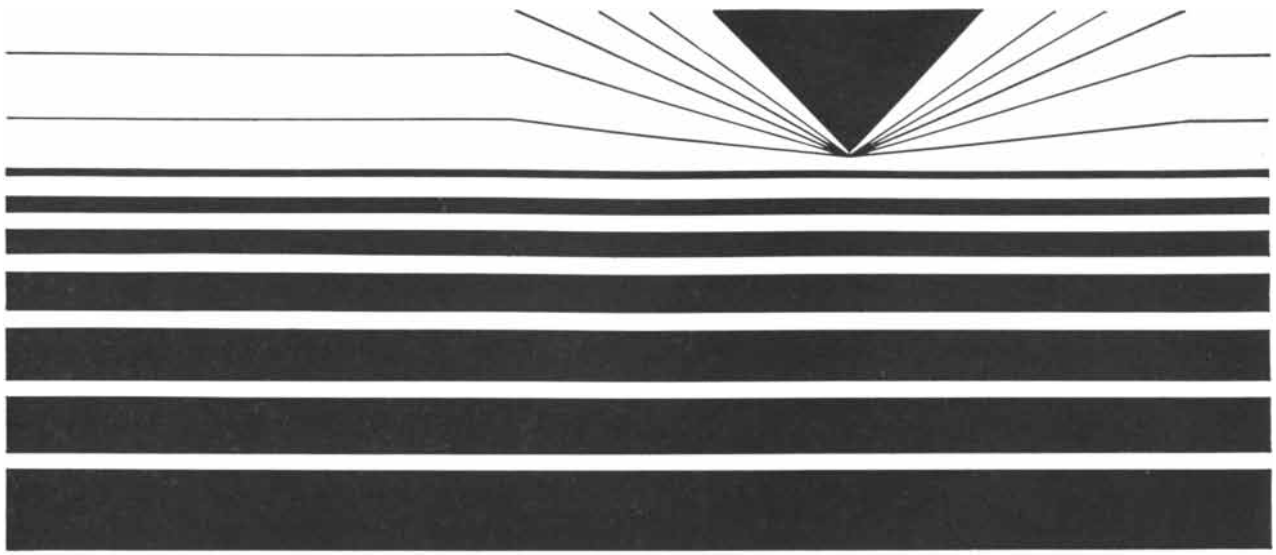

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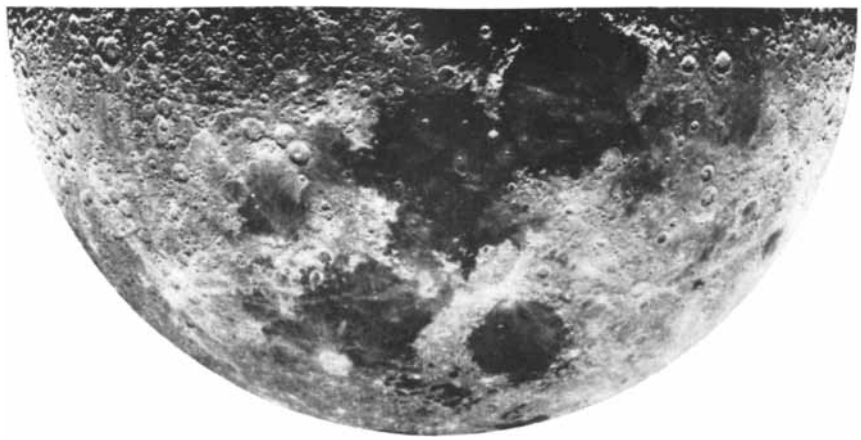

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ing the description of nature. The essays are not only of historical interest; they touch on questions that are still unresolved and are still being debated. A paperback.

TWINS IN HISTORY AND SCIENCE, by Luigi Gedda. Charles C. Thomas, Publisher ($12.50). A scholarly, comprehensive, richly illustrated study of twins in mythology and the arts, in history and science, in plant and animal life. The author, professor of genetics at the University of Rome, also deals with such topics as the frequency of the twinning phenomenon, etiological background factors in twinning, the embryology of twinning and the physiology and pathology of pregnancy.

MODELS AND METAPHORS, by Max Black. Cornell University Press ($5.75). A collection of essays on language, logic and the philosophy of science. Some of the studies, such as "Can the Effect Precede the Cause?" "Metaphor," "The 'Direction' of Time," are unusually pleasing. Black writes very well, and it is a source of intellectual gratification to watch his keen mind moving skillfully and patiently back and forth, like a mine detector, over an innocent-looking terrain, searching out the traps and hidden dangers underneath.

Notes

THE NEW AGE IN PHYSICS, by Sir Harrie Massey. Harper & Row, Publishers ($5). This clear, readable account by a leading British scientist of the concepts, theories and observations of modern physics treats quantum mechanics, relativity, artificial satellites, radio astronomy, particles and the uncertainty principle, among other subjects.

MY BEST PUZZLES IN LOGIC AND REASONING, MY BEST PUZZLES IN MATHEMATICS, by Hubert Phillips ("Caliban"). Dover Publications, Inc. ($1 each). CALIBAN'S PROBLEM BOOK: MATHEMATICAL, INFERENTIAL AND CRYPTOGRAPHIC PUZZLES, by Hubert Phillips, S. T. Shovelton and G. S. Marshall. Dover Publications, Inc. ($1.25). The well-known British paradoxer Caliban is not in the same league with Sam Loyd and Henry Ernest Dudeney, with whom he is sometimes compared, but his creations show a pretty ingenuity and wit.

MODERN CONCEPTS OF PSYCHOANALYSIS, edited by Leon Salzman and Jules H. Masserman. Philosophical Library, Inc. ($4.75). A group of essays appraisal

ing certain aspects of contemporary psychoanalysis—its relation to experimental psychology, the scientific basis of psychotherapy, psychoanalysis and social science, psychoanalytic training.

MODERN THEORIES OF DEVELOPMENT: AN INTRODUCTION TO THEORETICAL BIOLOGY, by Ludwig von Bertalanffy. Harper Torchbooks ($1.50). This exploration of theoretical biology, first published in German in 1928, discusses applications of physics and chemistry to the understanding of living organisms, and the logic and methodology of this approach. A paperback.

ATLAS OF EUROPEAN BIRDS, by K. H. Voous. Thomas Nelson & Sons ($15). A zoogeographical survey of all the species of birds of Britain and Europe west of the Urals. There are 419 distribution maps, for each of 419 species, together with an account describing each bird and giving information on its distribution, habitat, food, nests and movements. There are also 355 gravure plates, many of them very good.

PARTICLE ACCELERATORS, by M. Stanley Livingston and John P. Blewett. McGraw-Hill Book Company, Inc. ($17.50). A comprehensive monograph on the different classes of particle accelerator, which discusses the physical principles involved, major technical problems and limitations, the theory of particle orbits, the components common to several accelerators, ion sources, magnet design and shielding requirements.

THE SEXUAL LIFE OF SAVAGES, by Bronislaw Malinowski. Harvest Books ($2.95). A soft-cover reissue of Malinowski's celebrated account, first published in 1929, of courtship, marriage and family life on the Trobriand Islands southeast of New Guinea. Illustrated.

PHYSICAL OCEANOGRAPHY, by Albert Defant. Pergamon Press ($35). A two-volume survey of the general geography of the oceans, the physical and chemical properties of sea water, the various types of ocean current, the periodic movements of the water masses (waves, tides and related phenomena). Many illustrations and extensive bibliographies.

THE STORY OF X-RAYS FROM RÖNTGEN TO ISOTOPES, by Alan Ralph Bleich. Dover Publications, Inc. ($1.35). An illustrated popular account of X rays from their discovery in 1895 to their present widespread uses in medicine, industry, research and art. A paperback.

INDEX OF ADVERTISERS

JULY 1962

BIBLIOGRAPHY

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

THE EFFECTS OF SMOKING

CHANGES IN BRONCHIAL EPITHELIUM IN RELATION TO SEX, AGE, RESIDENCE, SMOKING AND PNEUMONIA. Oscar Auerbach, A. P. Stout, E. Cuyler Hammond and Lawrence Garfinkel in *The New England Journal of Medicine,* Vol. 267, No. 3; July 19, 1962.

LUNG CANCER AND OTHER CAUSES OF DEATH IN RELATION TO SMOKING. Richard Doll and A. Bradford Hill in *British Medical Journal,* Vol. 2, No. 5001, pages 1071–1081; November 10, 1956.

SMOKING AND DEATH RATES—REPORT ON FORTY-FOUR MONTHS OF FOLLOW-UP OF 187,783 MEN. I: TOTAL MORTALITY. E. Cuyler Hammond and Daniel Horn in *The Journal of the American Medical Association,* Vol. 166, No.10, pages 1159–1172; March 8, 1958. II: DEATH RATES BY CAUSE. E. Cuyler Hammond and Daniel Horn in *The Journal of the American Medical Association,* Vol. 166, No. 11, pages 1294–1308; March 15, 1958.

SMOKING AND HEALTH: SUMMARY AND REPORT OF THE ROYAL COLLEGE OF PHYSICIANS OF LONDON ON SMOKING IN RELATION TO CANCER OF THE LUNG AND OTHER DISEASES. Pitman Publishing Corporation, 1962.

SMOKING: ITS INFLUENCE ON THE INDIVIDUAL AND ITS ROLE IN SOCIAL MEDICINE. C. van Proosdij. Elsevier Publishing Company, 1960.

TOBACCO CONSUMPTION AND MORTALITY FROM CANCER AND OTHER DISEASES. Harold F. Dorn in *Acta Unio Internationalis contra Cancrum,* Vol. 16, No. 7, pages 1653–1665; 1960.

THE PLASTIC LAYER OF THE EARTH'S MANTLE

THE EARTH AND ITS GRAVITY FIELD. W. A. Heiskanen and F. A. Vening Meinesz. McGraw-Hill Book Company, Inc., 1958.

THE EARTH'S CRUST AND UPPER MANTLE. Frank Press in *Science,* Vol. 133, No. 3463, pages 1455–1463; May 12, 1961.

ELEMENTARY SEISMOLOGY. C. F. Richter. W. H. Freeman and Co., 1958.

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OCEAN, AND ATMOSPHERE. Beno Gutenberg in *Science,* Vol. 131, No. 3405, pages 959–965; April 1, 1960.

PHYSICS OF THE EARTH'S INTERIOR. Beno Gutenberg. Academic Press Inc., 1959.

THE BEHAVIOR OF SHARKS

THE PHYSIOLOGY OF FISHES. VOL. II: BEHAVIOR. Edited by Margaret E. Brown. Academic Press Inc., 1957.

THE SENSE OF SMELL IN FISHES. G. H. Parker and R. E. Sheldon in *Bulletin of the United States Bureau of Fisheries,* Vol. 32, pages 35–46; 1912.

THE SENSE OF SMELL IN SELACHIANS. Ralph Edward Sheldon in *The Journal of Experimental Zoölogy,* Vol. 10, No. 1, pages 51–62; 1911.

THE VERTEBRATE EYE AND ITS ADAPTIVE RADIATION. G. L. Walls. Cranbrook Institute of Science Bulletin No. 19; 1942.

INCLUSION COMPOUNDS

INCLUSION COMPOUNDS. Friedrich D. Cramer in *Reviews of Pure and Applied Chemistry,* Vol. 5, No. 3, pages 143–164; September, 1955.

A MOLECULAR THEORY OF GENERAL ANESTHESIA. Linus Pauling in *Science,* Vol. 134, No. 3471, pages 15–21; July 7, 1961.

X-RAY ANALYSIS OF ORGANIC STRUCTURES. S. C. Nyburg. Academic Press Inc. See pages 284–296.

MICROPALEONTOLOGY

ATLANTIC DEEP-SEA SEDIMENT CORES. David B. Ericson, Maurice Ewing, Goesta Wollin and Bruce C. Heezen in *Bulletin of the Geological Society of America,* Vol. 72, No. 2, pages 193–286; February, 1961.

CATALOGUE OF FORAMINIFERA. Edited by Brooks Fleming Ellis and Angelina R. Messina. American Museum of Natural History, 1940––.

ECOLOGY AND DISTRIBUTION OF RECENT FORAMINIFERA. Fred B. Phleger. Johns Hopkins Press, 1960.

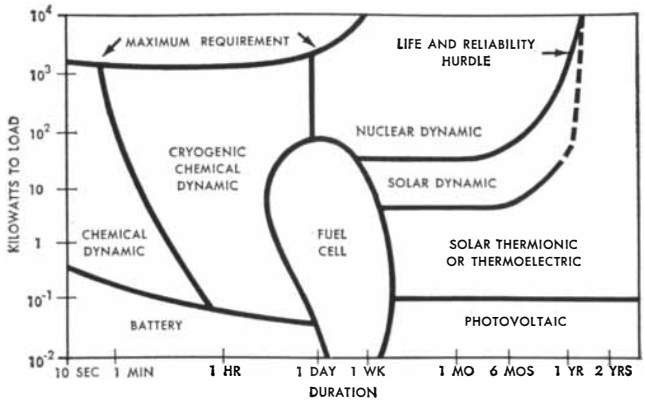
INTRODUCTION TO MICROFOSSILS. Daniel J. Jones. Harper & Brothers, 1956.

PRINCIPLES OF MICROPALAEONTOLOGY. Martin F. Glaessner. John Wiley & Sons, Inc., 1947.

SINGLE-STRANDED DNA

BACTERIOPHAGES. Mark H. Adams *et al.* Interscience Publishers, Inc., 1959.

THE NUCLEIC ACIDS OF THE BACTERIAL VIRUSES. Robert L. Sinsheimer in *The*



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Nucleic Acids, Vol. 3, edited by Erwin Chargaff and J. N. Davidson, pages 187–244. Academic Press Inc., 1960.

THE REPLICATION OF DNA IN ESCHERICHIA COLI. Matthew Meselson and Franklin W. Stahl in *Proceedings of the National Academy of Sciences*, Vol. 44, No. 7, pages 671–682; July, 1958.

SOME UNUSUAL PROPERTIES OF THE NUCLEIC ACID IN BACTERIOPHAGES S13 and φX174. Irwin Tessman in *Virology*, Vol. 7, No. 3, pages 263–275; March, 1959.

THE MOON ILLUSION

EXPERIMENTAL PSYCHOLOGY. Robert S. Woodworth and Harold Schlosberg. Henry Holt & Co., Inc., 1954. See pages 455–491.

THE MOON ILLUSION. Edwin G. Boring in *American Journal of Physics*, Vol. 11, No. 2, pages 55–60; April, 1943.

THE MOON ILLUSION AND THE ANGLE OF REGARD. Alfred H. Holway and Edwin G. Boring in *The American Journal of Psychology*, Vol. 53, No. 1, pages 109–116; January, 1940.

THE PERCEPTION OF THE VISUAL WORLD. J. J. Gibson. Houghton Mifflin Company, 1950.

TELEPHONE SWITCHING

BEGINNINGS OF TELEPHONY. Frederick L. Rhodes. Harper & Brothers, 1929.

COMMON CONTROL TELEPHONE SWITCHING SYSTEMS. Oscar Myers in *The Bell System Technical Journal*, Vol. 31, No. 6, pages 1086–1120; November, 1952.

EFFICIENCY AND RECIPROCITY IN PULSE-AMPLITUDE MODULATION. K. W. Cattermole in *Proceedings of the Institution of Electrical Engineers*, Vol. 105, Part B, pages 449–462; September, 1958.

TELEPHONE THEORY AND PRACTICE. Kempster B. Miller. McGraw-Hill Book Company, Inc., 1933.

MATHEMATICAL GAMES

AN EPISODE OF FLATLAND. Charles Howard Hinton. Swan Sonnenschein & Co., 1907.

A PLANE WORLD. Charles Howard Hinton in *Scientific Romances*, Vol. 1, pages 135–159. George Allen & Unwin Ltd., 1888.

THE AMATEUR SCIENTIST

LIGHT. R. W. Ditchburn. Interscience Publishers, Inc., 1952.

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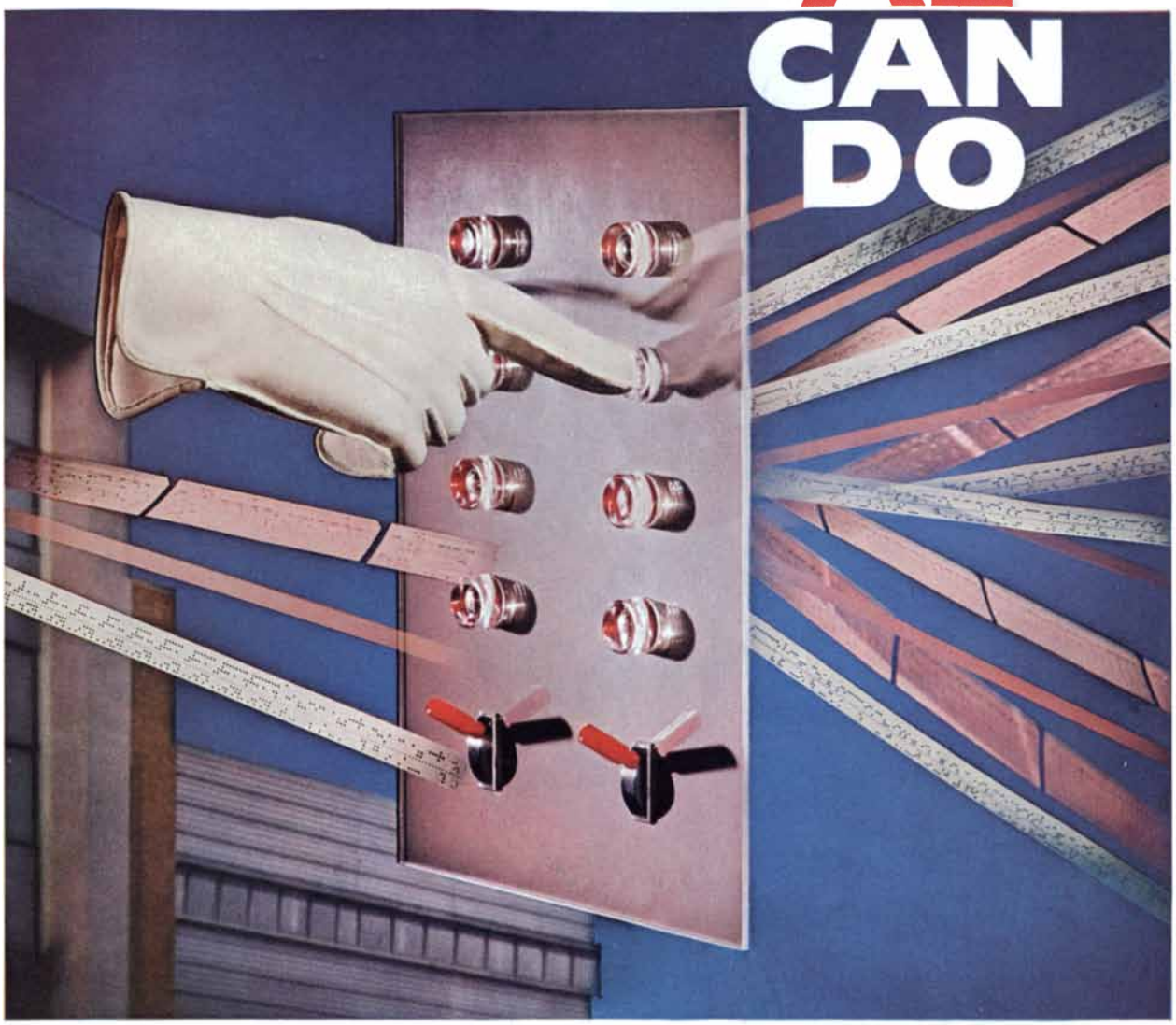

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