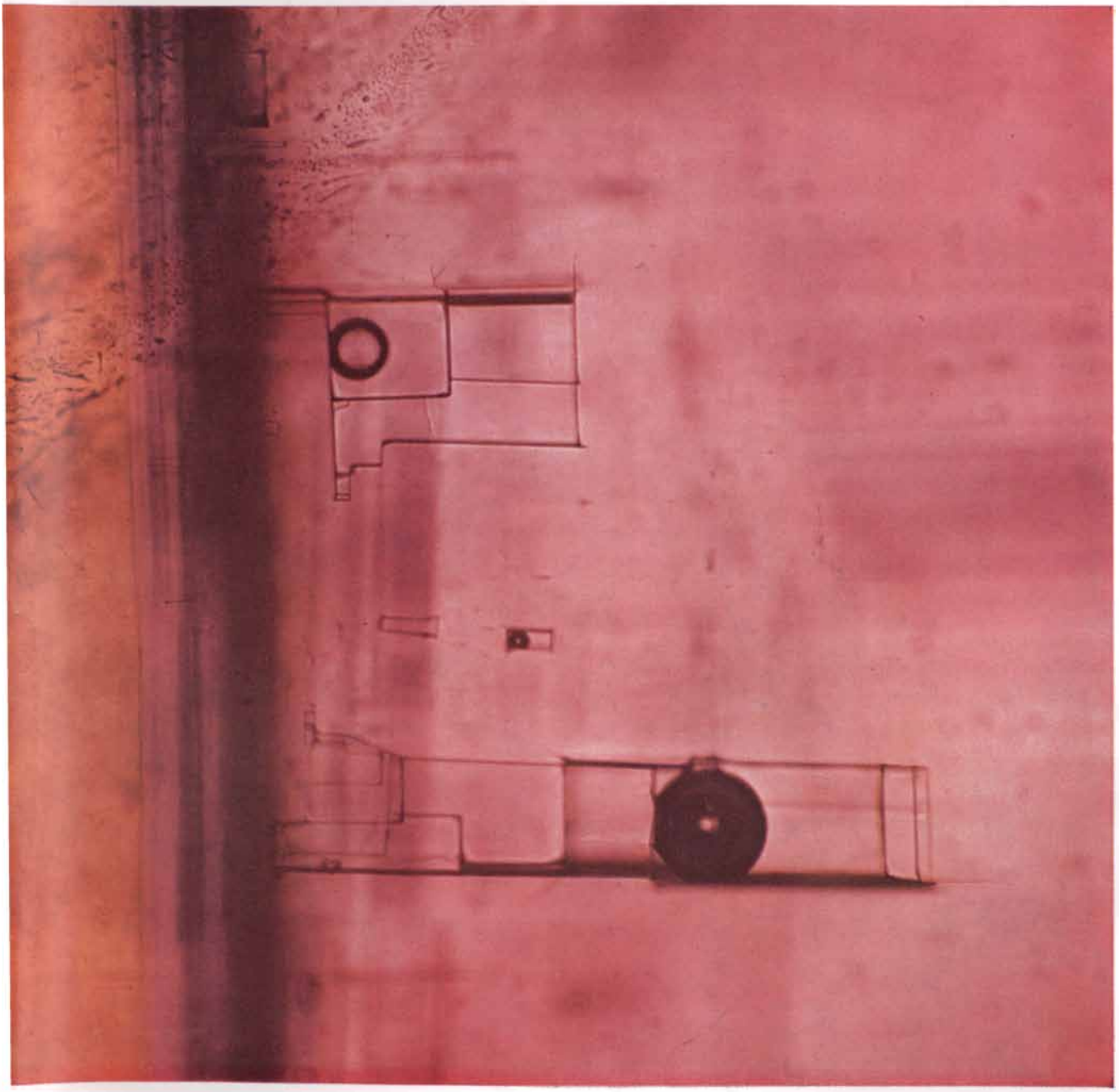
SCIENTIFIC AMERICAN



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October 1962

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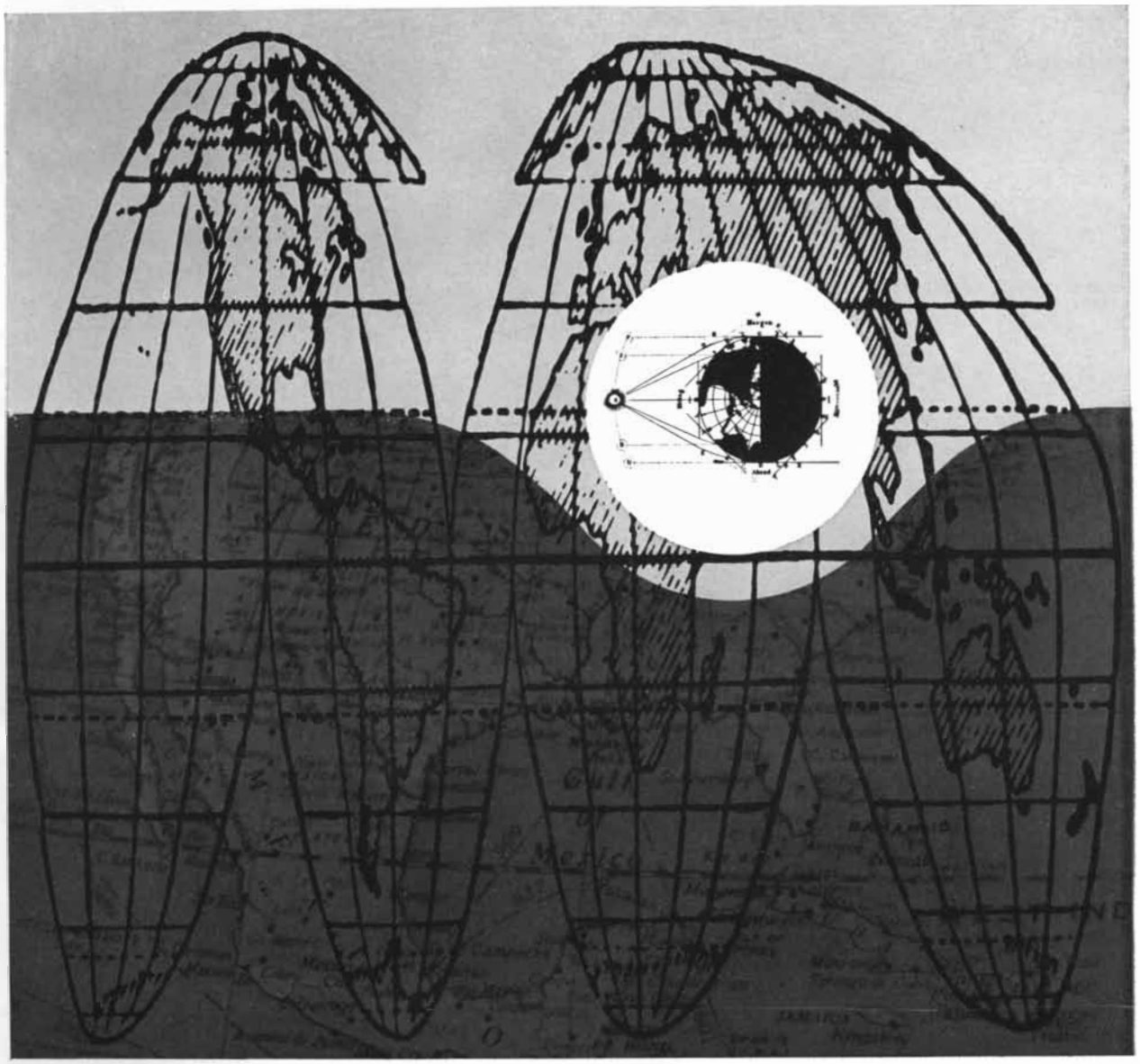

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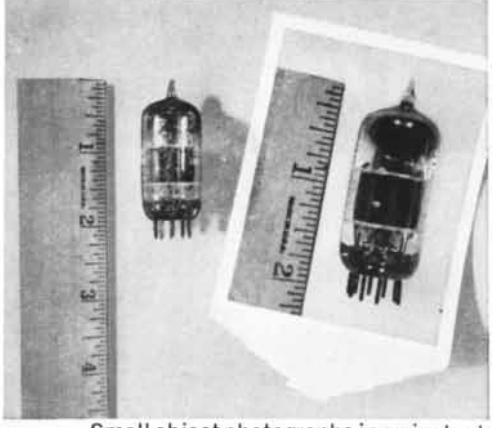
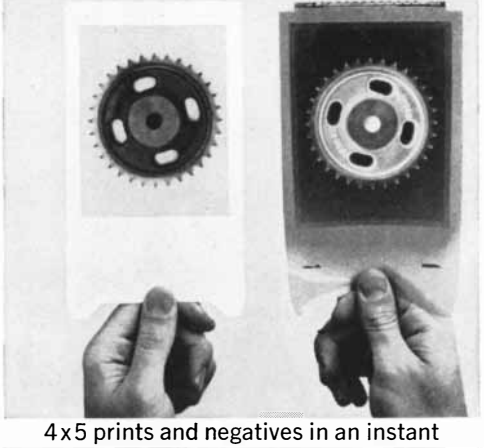
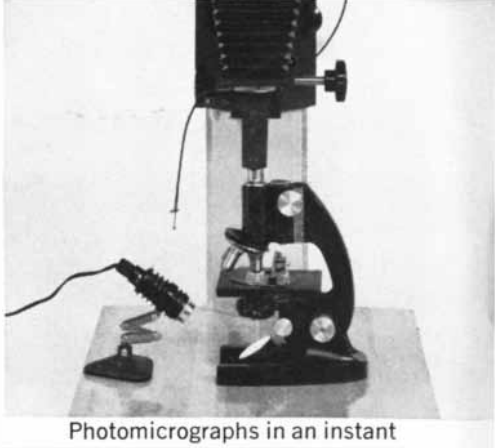


Small object photographs in an instant

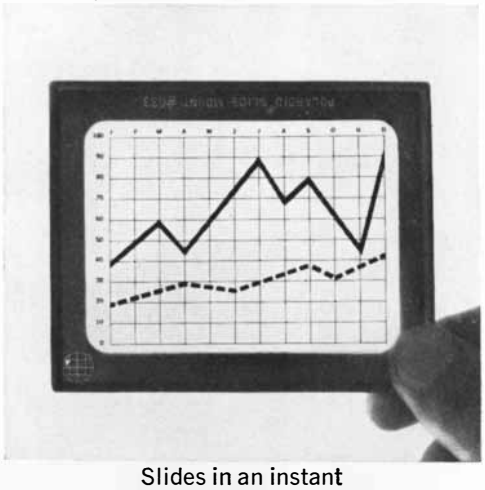


4x5 prints and negatives in an instant

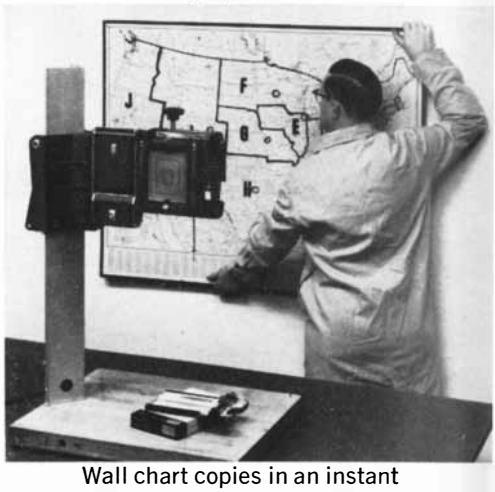


Photomicrographs in an instant

Macrophotographs in an instant



Slides in an instant



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Established 1845 **SCIENTIFIC AMERICAN** October 1962 Volume 207 Number 4

ARTICLES

DEPARTMENTS

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THE COVER

The photomicrograph on the cover enlarges 63 diameters several "fluid inclusions" in a natural crystal of fluorite. The inclusions are within the dark rectangular lines; each consists of saline solution and a round bubble of gas. Such inclusions are samples of the solution from which the crystal grew (see page 38).

THE ILLUSTRATIONS

Cover photograph
by William Vandivert

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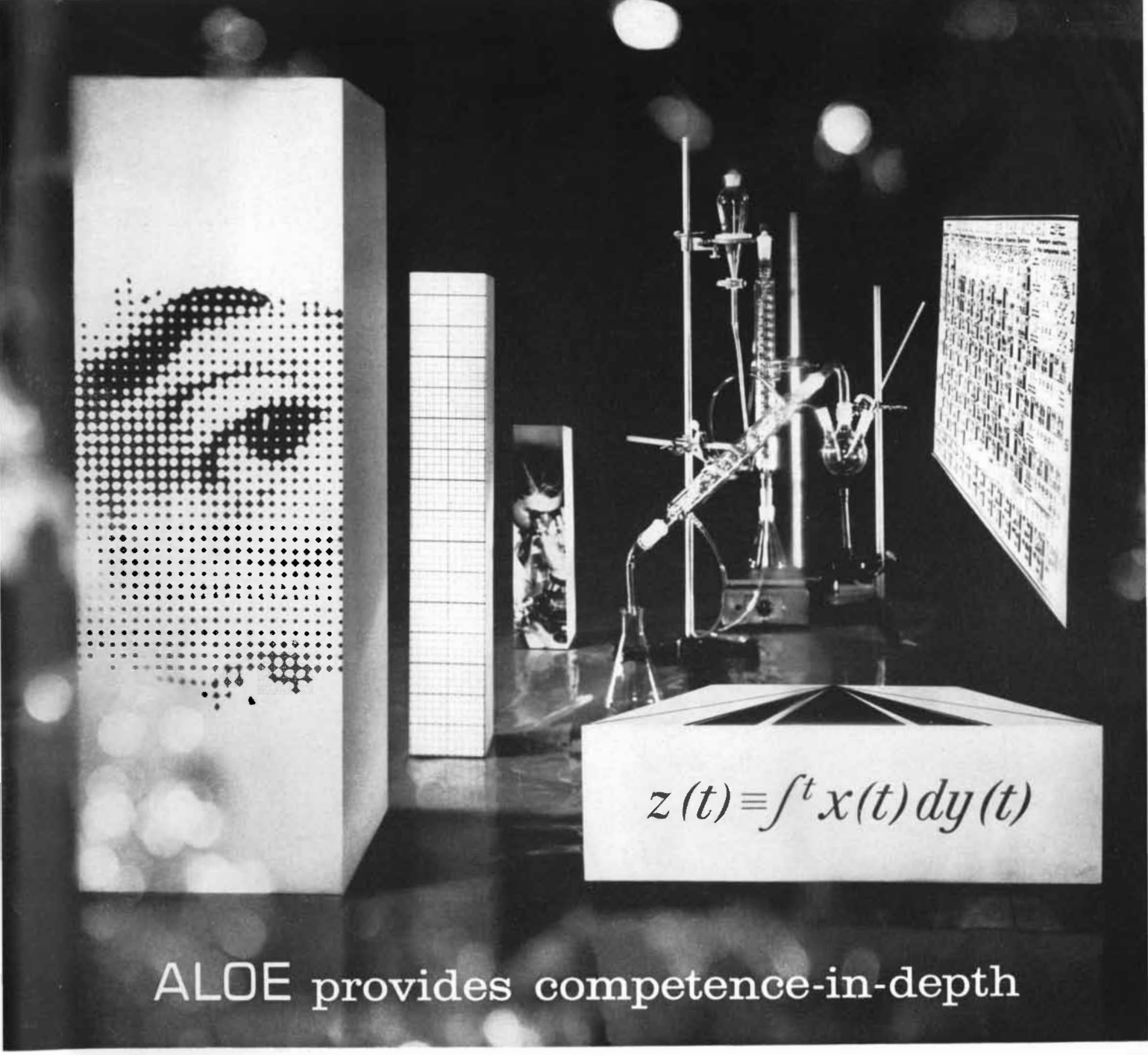

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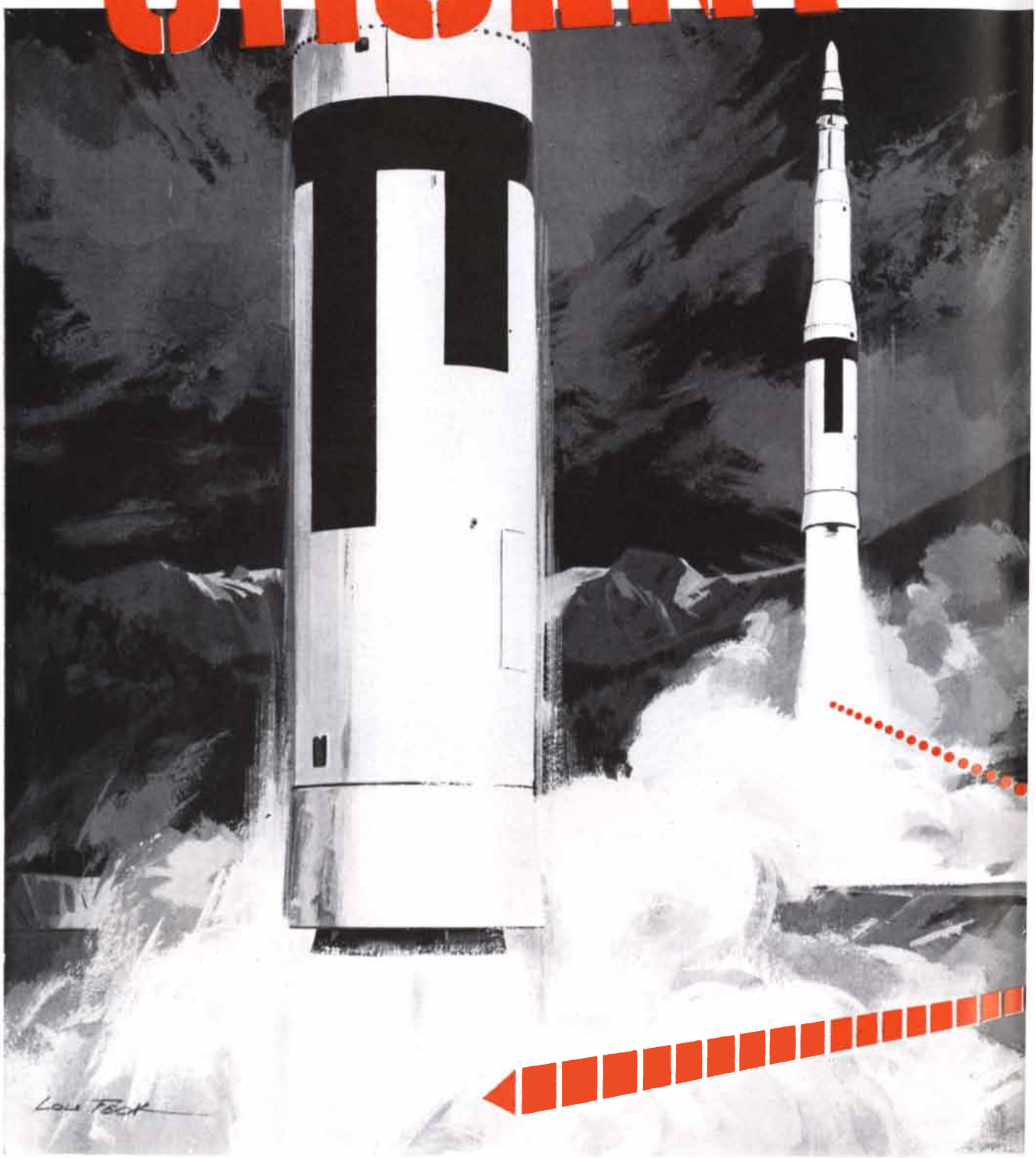

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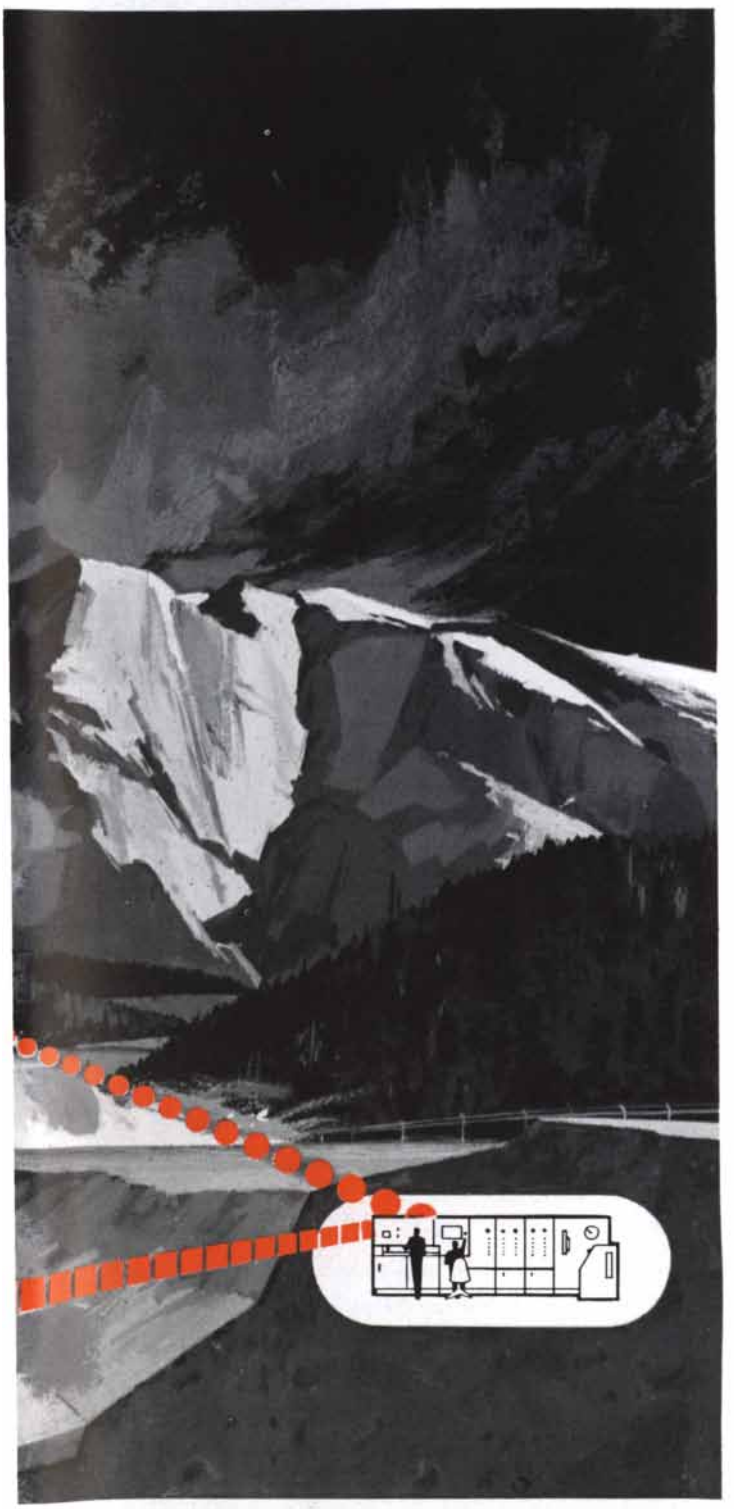

Finding ways to keep our defenses alert and ready—to prevent them from becoming paralyzed during and after an attack—is a challenge we meet at General Telephone & Electronics.

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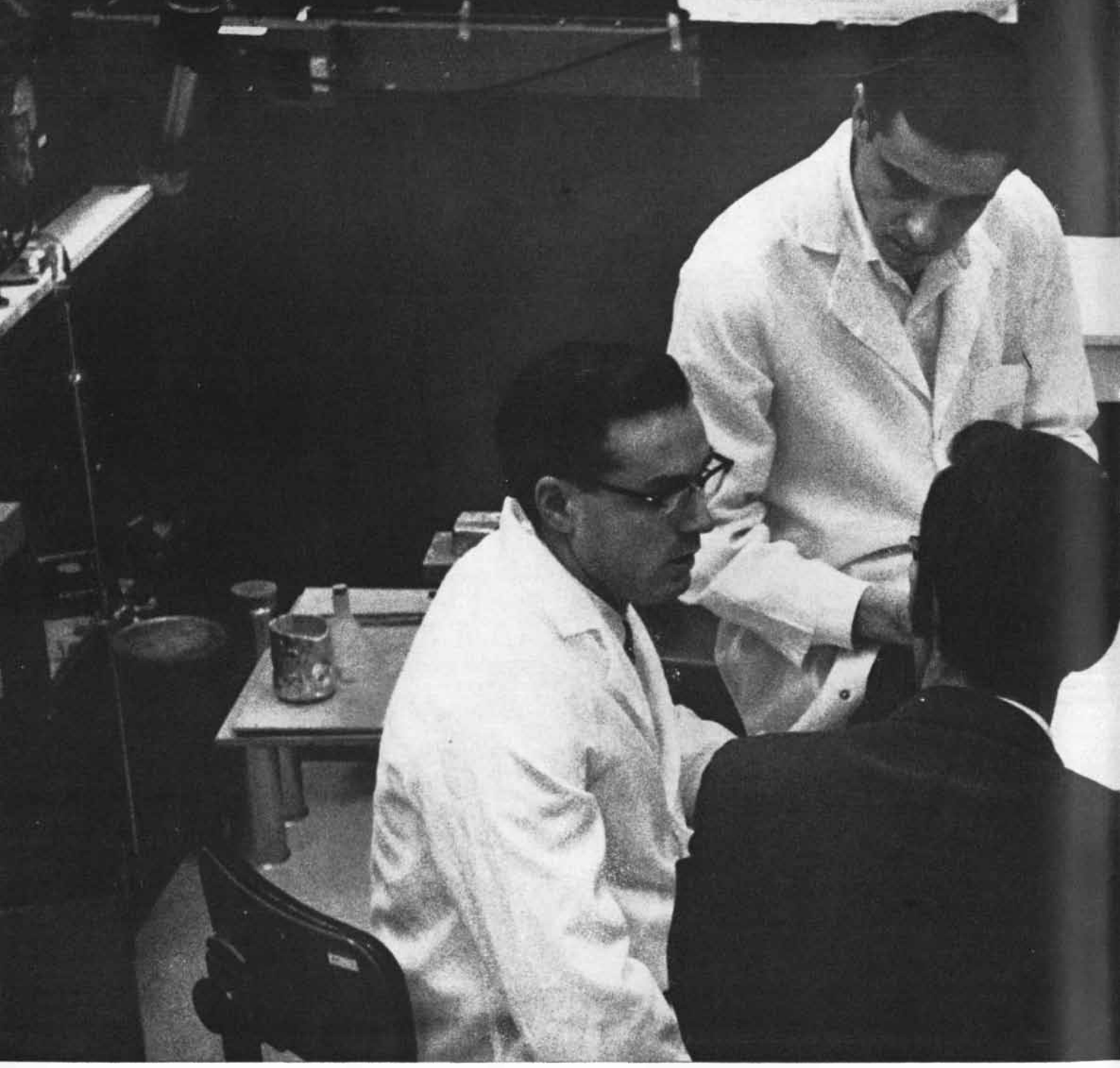

How long does it take to find an error?

It always takes too long because the time spent is costly and unproductive.

That's why, in addition to many other built-in system and programming checks, the new IBM 7040 and 7044 Data Processing Systems have internal parity bit checking. Both systems use high-speed parallel binary arithmetic with a word length of 37 bits—36 for information and the 37th for checking.

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LETTERS

Sirs:

Your note on *The Effects of Nuclear Weapons* ["Science and the Citizen," SCIENTIFIC AMERICAN, July] states that Project Gnome was "undertaken last December to show that an underground test could be 'decoupled.' " I would like to call to your attention that this is not an accurate statement of the facts.

Project Gnome was conceived, announced and conducted as a multipurpose experiment aimed at obtaining information on: (1) the possibility of recovering useful power from the heat generated by a nuclear explosion; (2) the feasibility of recovering valuable isotopes produced by such explosions; (3) neutron physics and other scientific theory; (4) effects of a nuclear explosion in salt; and (5) design principles useful in developing nuclear explosive devices specifically for peaceful purposes. In order that as much scientific information as possible could be derived from this experiment the proposed time of firing was included in the information made available to the general public, and a voice countdown was broadcast. It was expected that this experiment would be of especial interest to seismologists, although the study of seismic effects was not among the purposes of the experiment. That this expectation was fulfilled is shown by the fact that 18 papers, based in whole or in part on this experiment, were presented at the recent annual meeting of the Seismological Society of America.

Thus, although the information contained on the revised page 689 of *The Effects of Nuclear Weapons* was derived from data collected as a result of Project Gnome, it is clearly inaccurate to identify Project Gnome as having been "undertaken last December to show that an underground test could be 'decoupled.' "

RICHARD HAMBURGER

Assistant Director
Division of Peaceful Nuclear Explosives
United States Atomic Energy Commission
Washington, D.C.

Sirs:

In your August article "The Thalidomide Syndrome" Helen B. Taussig states:

"A drug with a molecular structure similar to that of thalidomide is Doriden, also used as a sedative. Although in a few cases of phocomelia the mother says she took Doriden, not Contergan, Doriden has been widely used in Switzerland since 1955, and phocomelia did not appear there until 1961. Almost all the few Swiss cases have been traced to Contergan from Germany."

As Dr. Taussig points out, during the six years Doriden was used in Switzerland before the introduction of thalidomide, there were no instances of phocomelia. This experience has been confirmed in the U.S. Approximately one billion tablets of Doriden have been distributed in the U.S. over a period of seven years by our company, and no case of associated phocomelia has been reported. Neither experimentally nor clinically is Doriden phocomelic.

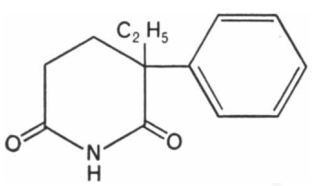
We invite your attention to the formulas of Doriden, phenobarbital and thalidomide [*see illustrations at right*]. You will note that Doriden is actually closer chemically to phenobarbital than to thalidomide, a relation confirmed by pharmacologic and metabolic studies. In our laboratories in the U.S. and Switzerland extensive studies have been made of the metabolism of a number of sedatives and hypnotics. These studies, soon to be published, show that the degradation of thalidomide differs significantly from that of drugs such as barbiturates, succinimides, Doriden and so on. Specifically, the thalidomide molecule splits up by hydrolysis, whereas all the other compounds referred to undergo oxidation.

Dr. Taussig also states: "In West Germany I was told that a Swiss pharmaceutical house, interested in producing a new sedative, had first synthesized thalidomide in 1954. Because it showed no effects on laboratory animals the company discarded it."

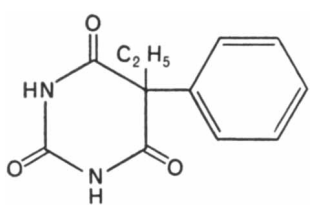
Fortunately Dr. Taussig did not repeat in *Scientific American* her attribution of the compound directly to CIBA as she did in the June 30 issue of *The Journal of the American Medical Association*, but the inference will remain in the minds of many readers of both articles. For the record, the story heard by Dr. Taussig is not accurate, since CIBA neither conceived nor made thalidomide and was never associated with its clinical investigation.

FRANK KOCH

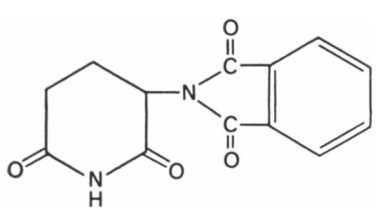
Director of Public Relations
CIBA Pharmaceutical Company
Summit, N.J.



Doriden



Phenobarbital



Thalidomide

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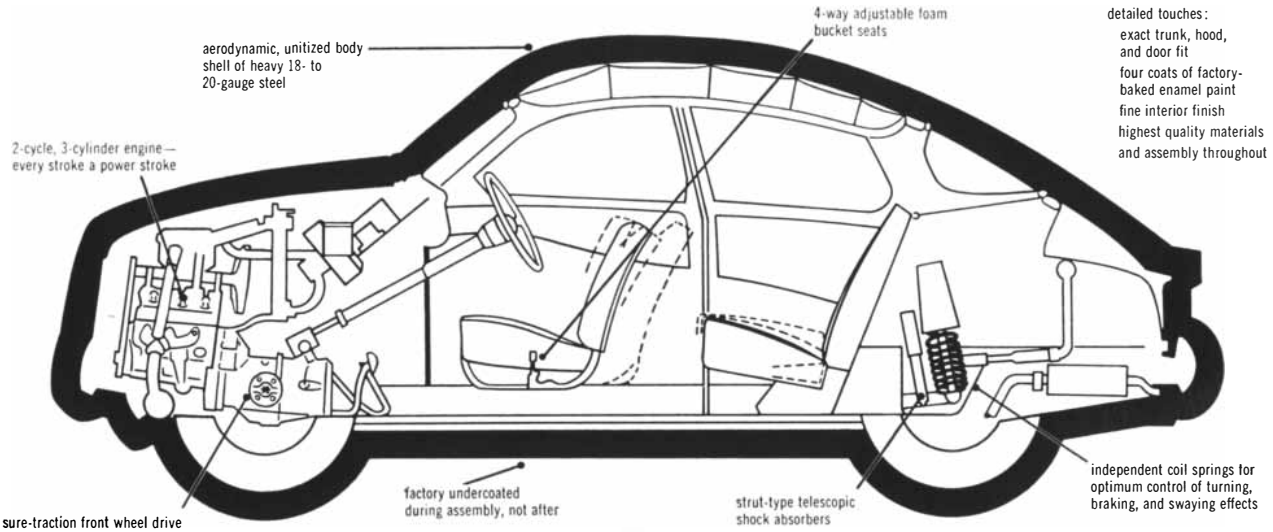

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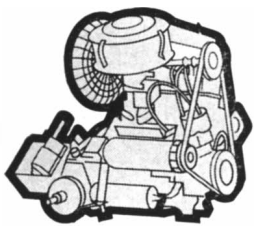
A critical look at all the facts and specifications will prove that SAAB is unquestionably one of the world's best engineered cars.

*Engine, transmission (3- or 4-speed gear box available), and differential have a written warranty for 2 years or 24,000 miles.



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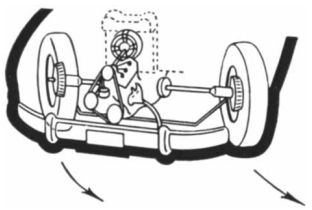

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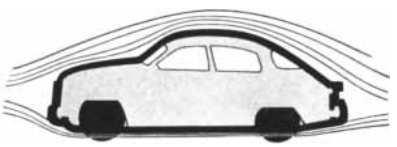

SAAB BODY SHELL is designed and wind tunnel tested for best possible aerodynamic efficiency. Full belly pan further reduces wind resistance and subdues road noise. Result: increased economy, better performance, excellent stability—even in cross-winds of gale force. Moreover, the SAAB body shell is virtually uncrushable, combining 18- to 20-gauge steel (thicker than most American cars) and rigid unitized construction for optimum safety.

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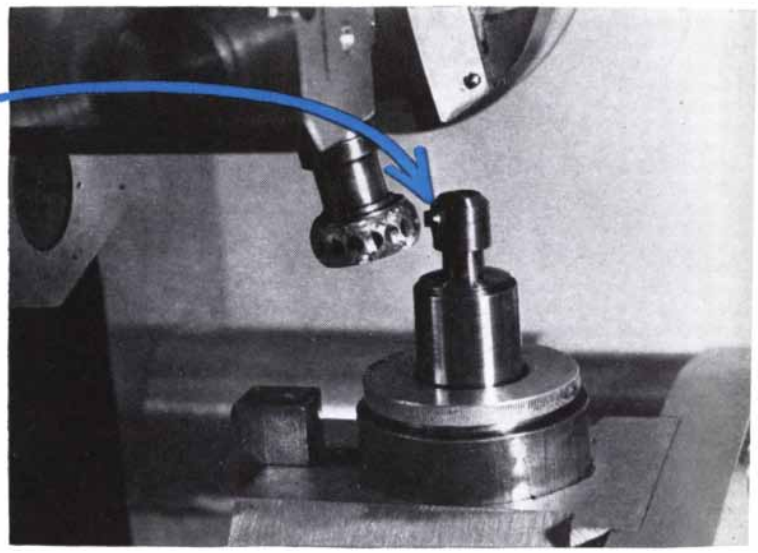
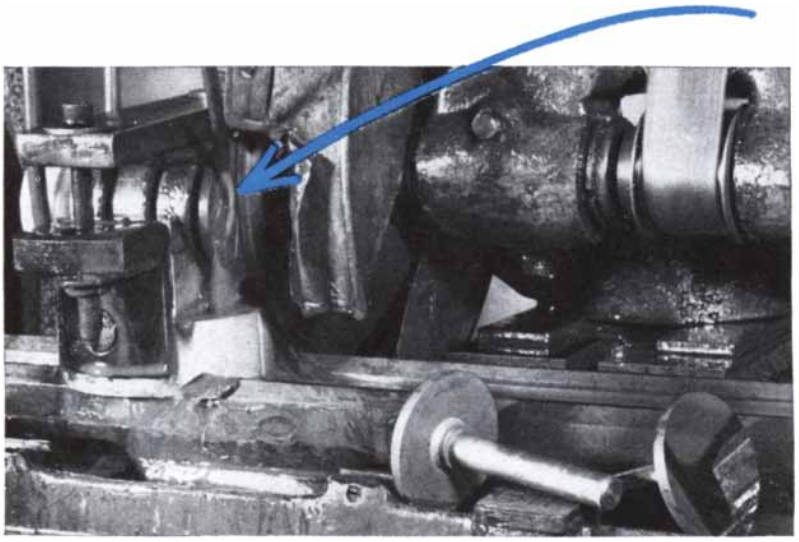
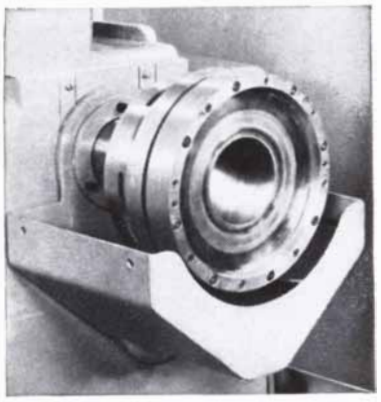


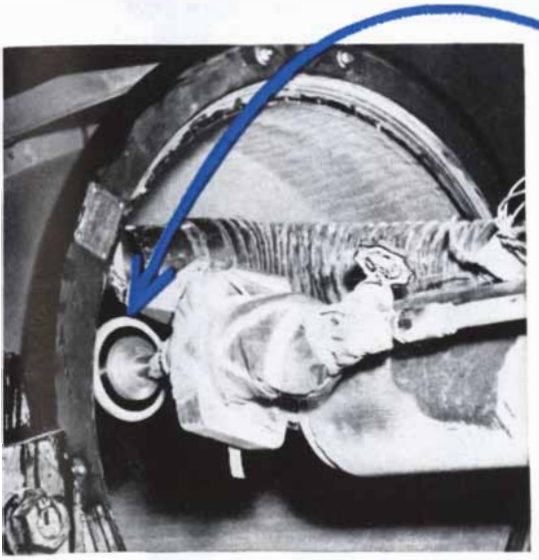
Natural diamond cuts facets with perfect finish. New machine (patent pending) introduced by Alka Precision Tools, College Point, N. Y., precisely cuts wide variety of hollow facets in wedding rings, watch cases, bracelets—in a fraction of the time required by hand-cutting methods. Natural diamond tool revolves at 17,000 rpm. Workpiece is held on adjustable spindle connected to calibrated indexing device. Uncontaminated gold findings (or other precious materials removed) are easily reclaimed.



Tungsten carbide "integrator disks" are ground to near-perfect flatness at Acroscope Engineering Co., Los Angeles. Disks, used for aircraft and electronics, are ground to within .0002 inch of specified dimensions, then finished on lapping machine to one-half microinch surface finish. Dia-Chrome wheel has grinding surface of 60/80 mesh natural diamonds coated to the steel body of the wheel, which is still in use after having ground 2,541 disks.

Germanium crystal rods are sliced to thin wafers at Texas Instruments Incorporated. Natural diamond blades have internal-diameter cutting edges. Thin blades (.009 inch thick) were developed to conserve costly germanium, since material the width of the cutting blade is lost at every stroke. Bronze blades with cutting edges of natural diamond powder are held along outside diameter by metal rings to give required rigidity.





Missile components of high-resistant, reinforced plastics require precise fabrication and close-tolerance finishing. H. I. Thompson Fiber Glass Company, Gardena, Calif., uses a horizontal lathe and a 5-inch diamond wheel to grind the inside of a large-diameter missile tube. Material is Refrasil reinforced plastic, which is extremely hard, abrasive and weighs 100 pounds per cubic foot. Grinding head, coated with natural diamonds, turns at 17,000 rpm.

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The Department of Defense is required to make hundreds of decisions daily that affect the well-being and security of every one of us. It must have the highest possible quality of technical advice before making its far-reaching and consequential decisions. * For one major source of such advice, the Department has turned to the Institute for Defense Analyses, a non-profit corporate entity sponsored by eleven great universities. The Institute has assembled a staff from the national sources of professional talent—from industry, from research and development laboratories, from university faculties and graduate circles. * Thus IDA is a bridge between two worlds, the Department of Defense on one side and the academic and professional scientific community on the other. In serving as a bridge for a traffic of ideas and recommendations on major national problems, IDA contributes to the development of the immediate and future posture of our national security. IDA employs particularly talented individuals, from all sources of such talent, who can contribute to this great challenge with the highest degree of competence and imagination. * IDA welcomes inquiries from qualified people of professional and academic backgrounds in the scientific and engineering disciplines who feel they can contribute at this level and want to do so. Professional people in the social sciences would also find an IDA career stimulating and challenging. Please communicate with us.

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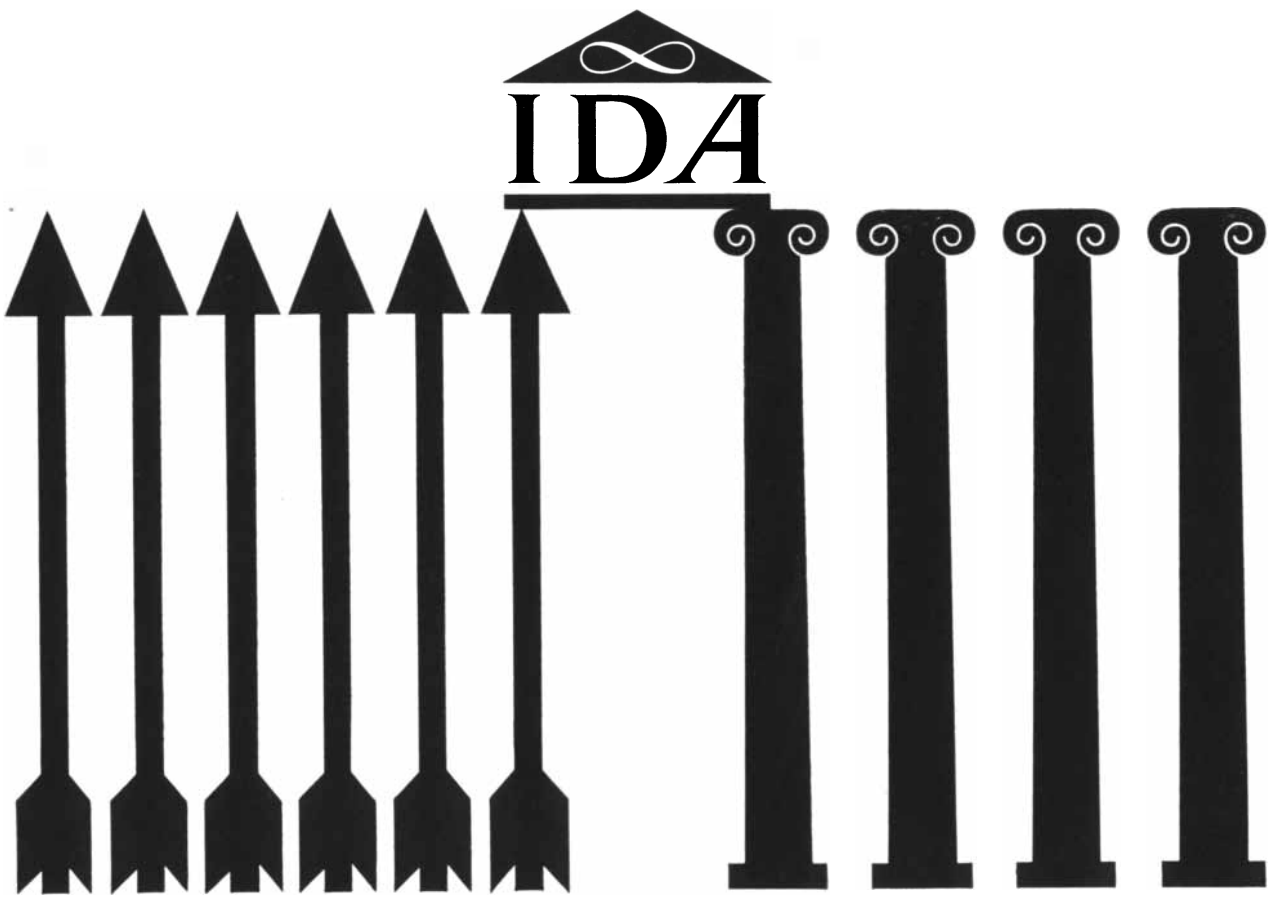
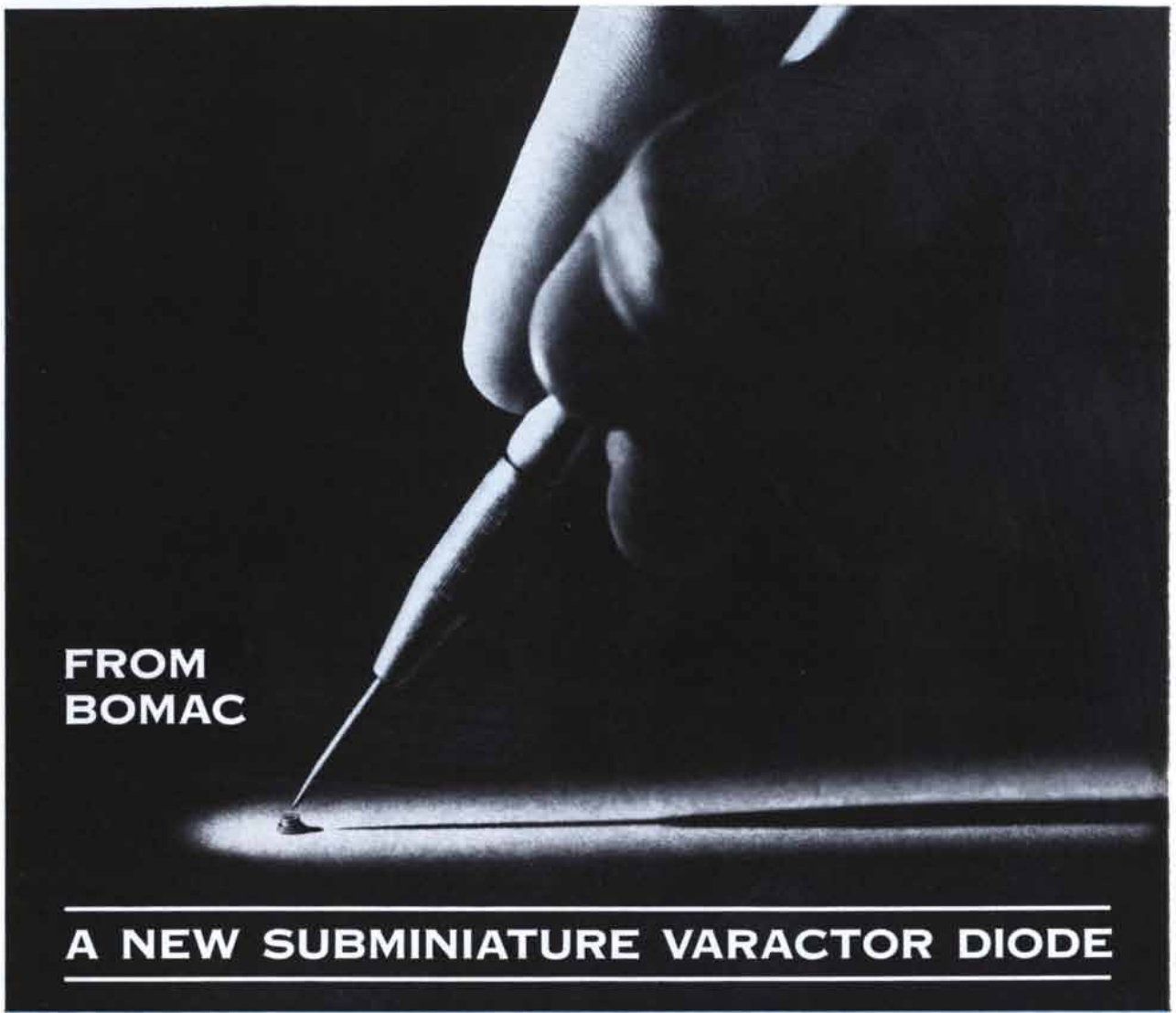




A NEW SUBMINIATURE VARACTOR DIODE

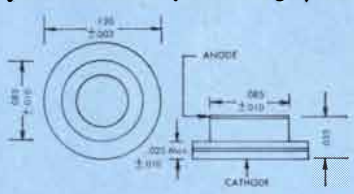
Bomac Laboratories' new ThermoBond* silicon varactor diode provides the microwave designer with a subminiature silicon component offering great reliability, uniformity, packaging simplicity, and size advantages.

Reliability is achieved through matching metal-to-ceramic seals and welded construction. There is no C-spring to work loose from environmental shock, and extreme temperature; an important noise source is eliminated. Uniformity is assured through heat bonding and batch process manufacturing techniques. Packaging simplicity is evident in the extremely small size of the ThermoBond diode. It easily withstands normal soldering temperatures. In addition, hermetically-sealed case construction provides long-life stability, independent of environmental conditions. Retrofit packaging is available. A single case dimension covers 252 electrical values.

Bomac ThermoBond silicon varactor diodes are designed for use in microwave limiters, sideband modulators, harmonic generators, low-noise parametric amplifiers, as tuning elements in voltage control oscillators, and in solid state duplexers.

Write for technical data on the ways in which ThermoBond diodes by Bomac can aid your microwave system design problems.

*Trademark



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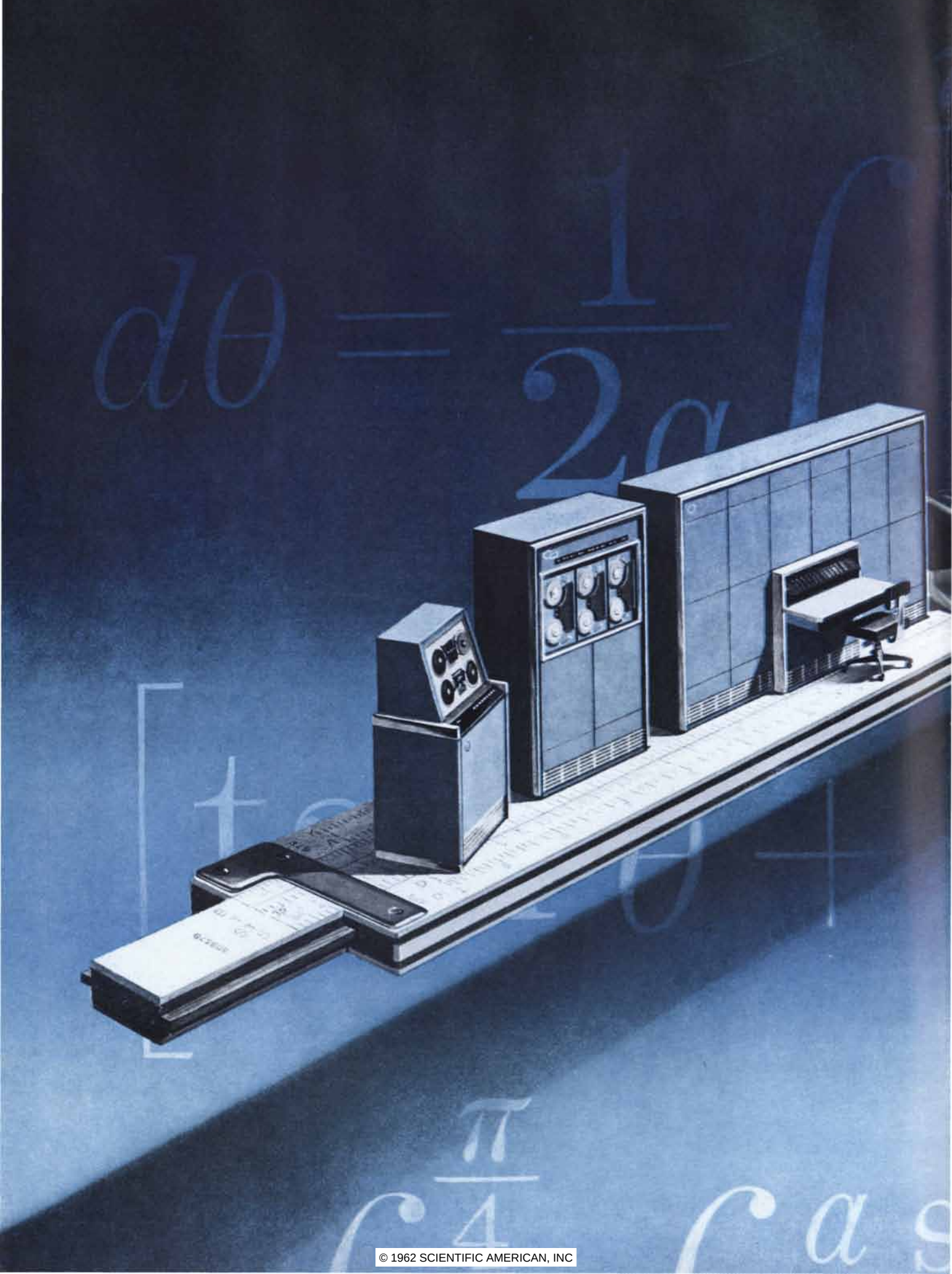

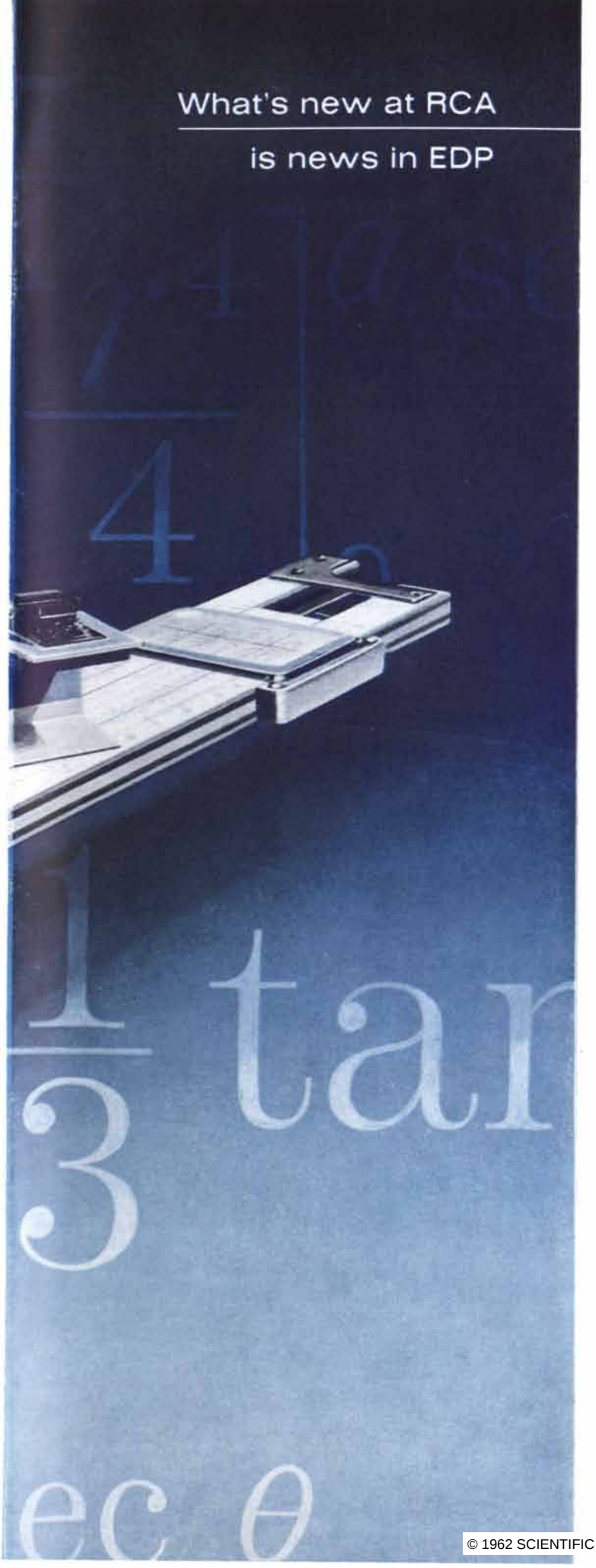

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Check the specifications below and find out what the new 301 features can do for you. Then contact RCA Electronic Data Processing, Cherry Hill, Camden 8, N.J.

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SCIENTIFIC AMERICAN

OCTOBER, 1912: "It is with especial gratification that we Americans note the award of the Nobel Prize for Medicine to Dr. Alexis Carrel of the Rockefeller Institute for Medical Research. Although Dr. Carrel is French by birth and training, his epoch-making researches have been for the most part conducted on American soil. The tissues of the higher animals, including man, can now be developed in a culture, and such development can be made to correspond to a rigidly precise technique. Dr. Carrel has found that the medium that in normal life surrounds each tissue is not the one best adapted for its growth. This implies on the one hand the possibility of perhaps stimulating the growth of certain organs or tissues, as the need may arise, by medication with specific substances affecting that particular tissue. It suggests, on the other hand, the possible opposite procedure of checking the growth of abnormal structures, such as tumors and cancers, by medication."

"An interesting hypothesis has been suggested by an English physicist to explain how it is that electro-magnetic waves emitted at a wireless telegraph station in Cornwall can be received at a station on the coast of America. If we compare such a sending station to a source of light on the surface of a sphere about 1/4 inch in diameter, obviously no light from the source could reach even one-quarter of the way around the sphere; but if the sphere is surrounded by thin envelopes of mediums whose refractive indices decrease from the inner to the outermost, light will be transmitted all around the sphere by successive refractions and reflections. According to the new hypothesis the electric waves are transmitted in an analogous way, viz., by the variation in ionization of the earth's atmosphere."

"A bacterial epidemic has within two years freed Yucatán of the locust swarms that periodically invaded the country. M. d'Hérelle, having been asked by the Argentine government to test the effects of the same microbe on another locust species that every year devastates large portions of the Paraná district, has reached surprisingly favorable results. Tests made on a large scale were quite as successful. The speed with which the malady was spread can be inferred from the fact that a few days after the first infection it occurred at a distance of 50 kilometers (31 miles) from the center of infection."

"The diving outfit designed by the Messrs. Drägerwerk of Lübeck, Germany, makes the diver independent of atmospheric air by supplying him with oxygen and regenerating the air he expires. The outfit consists of an apparatus worn like a knapsack where the air circulating in the helmet and the diving suit is purified automatically of the deleterious gases produced by breathing and regenerated by an addition of oxygen. The diver thus has at his disposal 60 to 70 liters of air per minute."

"The president of the Chinese Republic, Yuan Shih-K'ai, recently suppressed the newspaper *King-pao,* which undoubtedly was the oldest paper in the world. For 1,500 years it has reported the more important news not only of China but also of foreign countries. At a time when the art of printing and journalism was as yet unknown in Europe, the Chinese Gong-Chung invented a means for making types from lead and silver, and in A.D. 400 the first edition was printed on 10 sheets of yellow silk and sent to all the high officials of the Chinese Empire."

Scientific American.

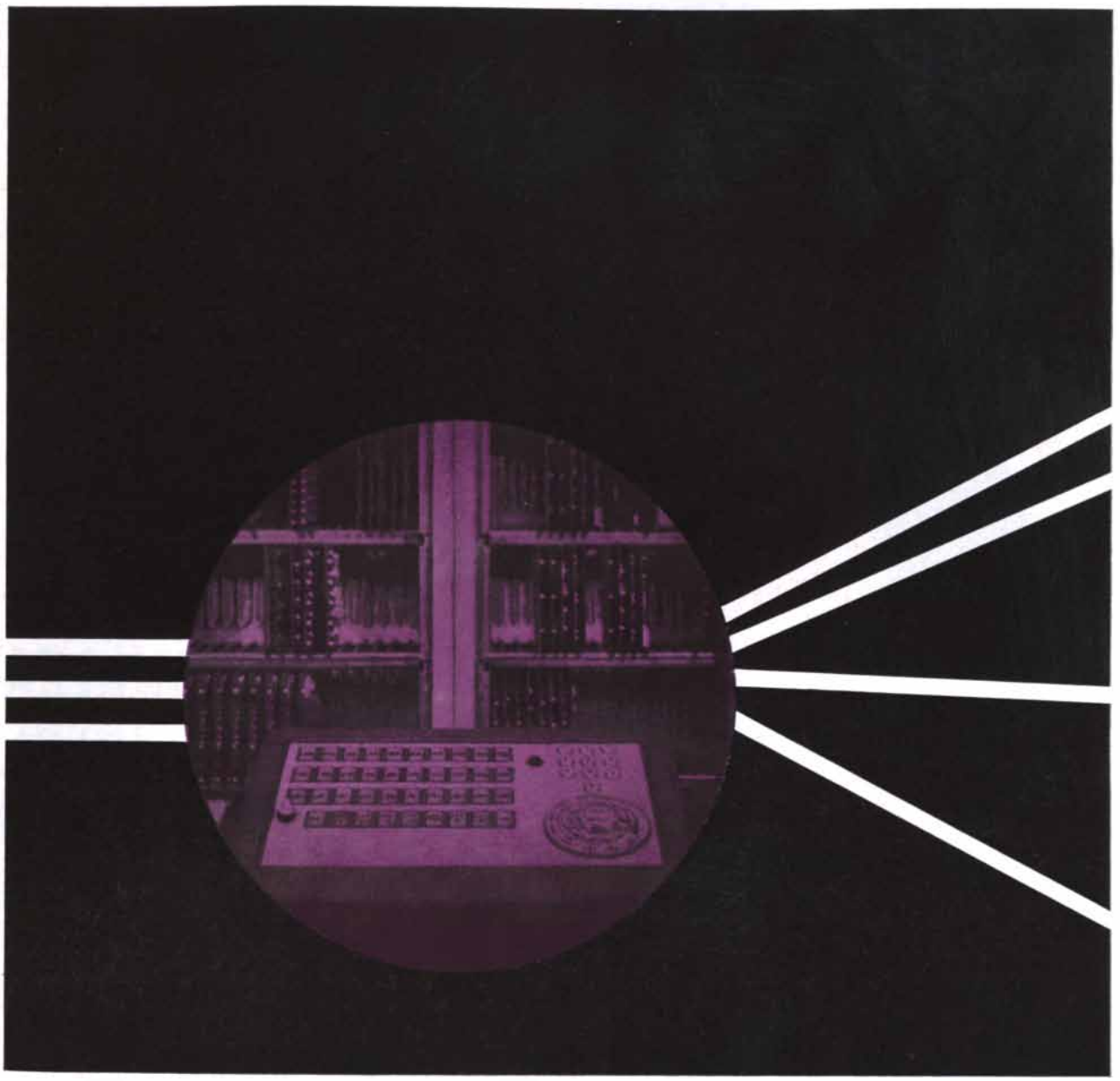
OCTOBER, 1862: "The loss that England already sustains by the blockade of the secession ports can hardly be stated at less than $250,000 per week, including the cessation of employment and wages for the operatives, and the waste and loss of interest on capital sustained by the employers, in the staple manufacture of Lancashire. A deputation sent from Birmingham into the cotton districts to make inquiries calculate that the diminution of wages in the distressed districts during the coming winter months will be at least £150,000 a week and that, when the distress has reached its hight, it will require advances at the rate of £100,000 ($500,000) a week to keep the population from starving."

"The *Journal de l'Instruction Publique* contains a curious article by M. Oscar de Watterville, in which he announces the fact, not generally known, that in the lakes of Sweden there are vast layers or banks of iron, exclusively built up by animalcules, not unlike those that have laid the foundations of large islands in the ocean. The iron thus found is called 'lake ore,' distinguished, according to its form, into gunpowder, pearl, money or cake ore. These iron banks are from 10 to 200 *mètres* in length, from five to 15 broad and from a fourth to three-fourths of a *mètre* and more in thickness."

"The new metal thallium, which was discovered by Mr. William Crookes of London, has lately been described by the discoverer in *Chemical News.* Thallium, in most of its physical properties, resembles lead. It is not so white as silver, but when freshly cut, it presents a brilliant metallic luster. It is soft, malleable and easily cut with a knife. According to the researches of MM. Bunsen and Kirchhoff, its single green ray is as sharply defined as the yellow ray of sodium. Thallium rapidly tarnishes in the open air, and it becomes covered with a thin pellicle of oxide."

"An odd relic was found not long since at the terminus of the Pontchartrain railroad near New Orleans. The relic is a submarine ram of cigar shape, made of iron, hollowed so that a number of men can inclose themselves in it. It is 24 feet long and has a propeller that can be worked by hand. On each side of the ram there is a sort of fin made of iron three feet long and a foot and a half wide. With the raising of these wings, or fins, the ram rises to the surface, and it sinks with their depression. The bow is sharply pointed, and when run against any ordinary vessel below the water mark, would be able to sink it."

"According to the United States census of 1860 there were at that time about 730,000 more males than females in the United States, a fact unprecedented in the census of any other civilized nation. In most of the older States there is an excess of females, whereas in Illinois there is an excess of 92,000 males; in Michigan, 40,000; in Texas, 37,000; in Wisconsin, 43,000; in California, 67,000; and in Colorado there are 20 males to one female."



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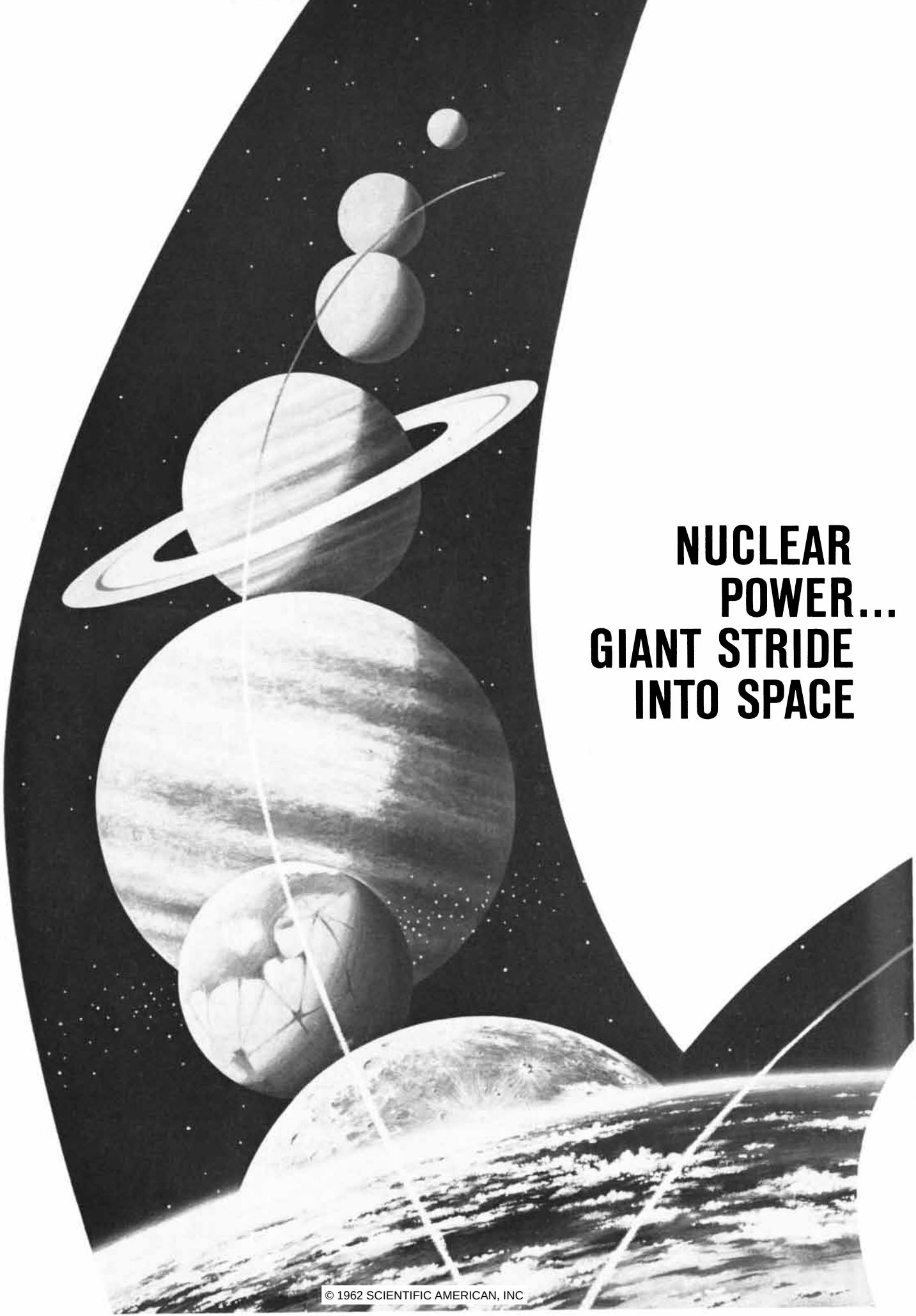

NUCLEAR POWER... GIANT STRIDE INTO SPACE

■ Nuclear propulsion is moving swiftly to the forefront of space exploration. For challenging solar and planetary missions or scientific investigations beyond the plane of the ecliptic, nuclear propulsion is essential. For lunar missions, it is highly attractive. This is substantiated by Dr. Glenn T. Seaborg, Chairman of the Atomic Energy Commission: "I believe that nuclear propulsion could provide the most feasible means of accomplishing space missions involving heavy payloads and long voyages in the foreseeable future."

As NASA's industrial partner in the management and accomplishment of the RIFT (Reactor-In-Flight Test) program, Lockheed is a leader in this dramatic application of nuclear power to space flight. Lockheed's role is the design, development, integration, application and testing of the first nuclear-propelled space vehicle. Its purpose: To demonstrate the feasibility of nuclear propulsion in a space flight environment.

Moreover, Lockheed is involved in another important space application of nuclear energy: its use in nuclear electrical systems to operate auxiliary equipment, and eventually in electrical propulsion systems.

Nuclear space applications is but one of many areas being explored by Lockheed Missiles & Space Company. As one of the industrial leaders in current space investigations, many new positions are continually being opened for scientists and engineers of proved ability in all disciplines. And Lockheed's ideal location in Sunnyvale, on the beautiful San Francisco Peninsula, makes living as well as working invigorating and stimulating.

If you have proved ability and wish to work in a challenging environment, please write: Research & Development Staff, Dept. M-40C, 599 North Mathilda Avenue, Sunnyvale, California. Lockheed is an equal opportunity employer.

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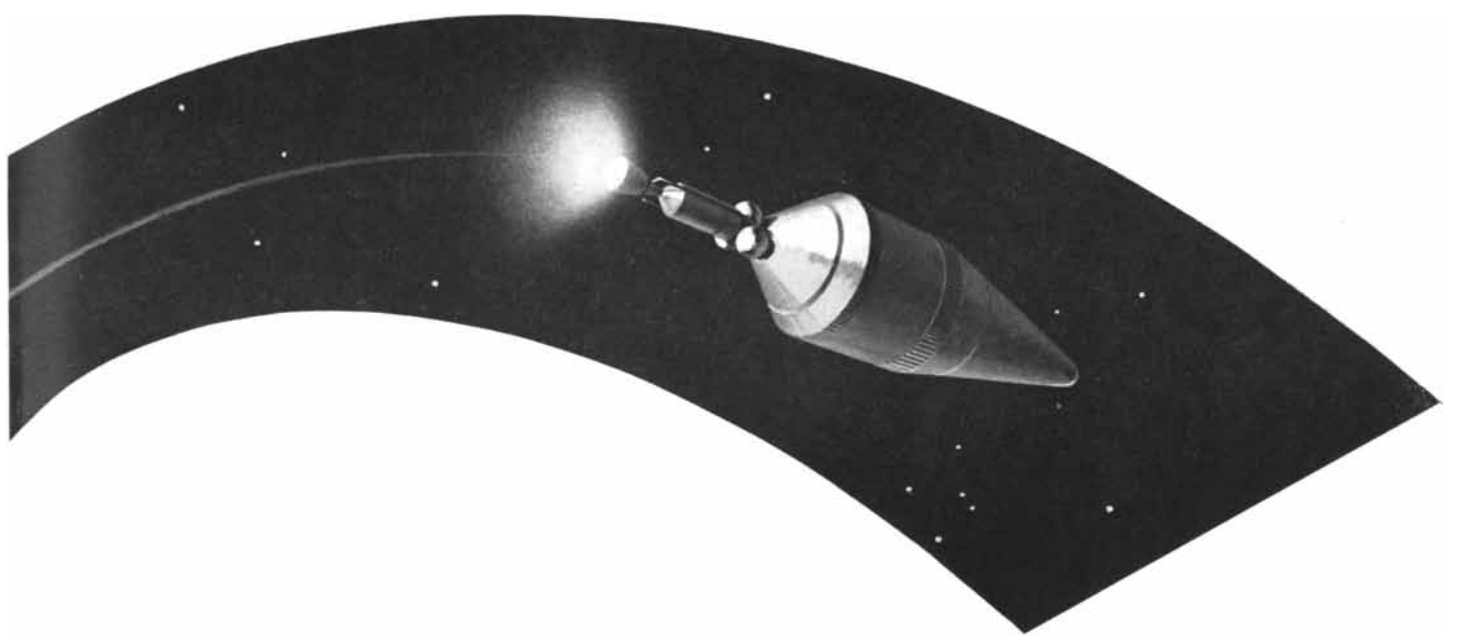

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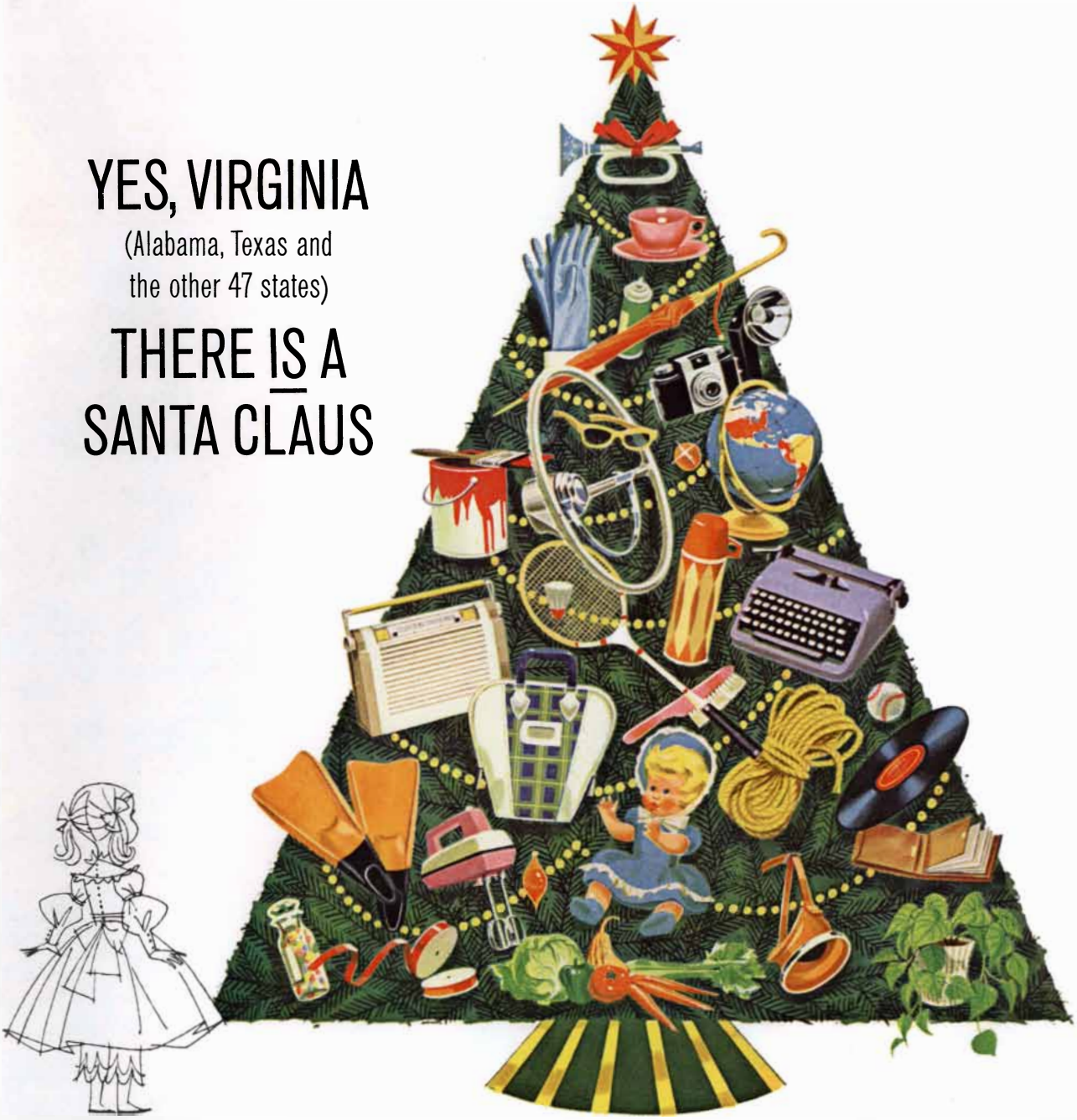

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This STEELMARK of the American Steel Industry tells you a product is made of Steel. Look for it when you buy.

New Republic IN-TER-LINE Pipe fights corrosion with a low-cost plastic lining

A new epoxy lined pipe that cuts the cost of effective corrosion protection joins the family of plastic coated products pioneered by Republic Steel.

New IN-TER-LINE Pipe*, seen at left, will prove ideal for a wide variety of applications. A flawless, .008-.010-inch epoxy lining is applied to pipe in one high-speed operation. It is the success of this one-coat mill operation that minimizes cost.

Produced in 2⅜" through 6⅝" O.D., IN-TER-LINE Pipe resists a wide range of corrosive fluids. The lining increases flow capacity due to its extremely smooth surface. It can endure continuous operation over a wide range of temperatures up to 250°F.

Republic introduced X-TRU-COAT® Plastic Coated Steel Pipe in 1955. Customers have already bought more than 80 million feet of this amazing product. "DEKORON®-COATED" Electrical Metallic Tubing is another plastic coated product by Republic Steel.

*Patent applied for.

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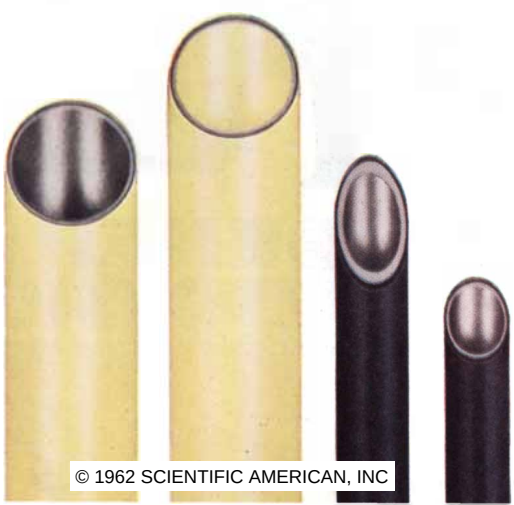

PLASTIC PROTECTS STEEL (left to right): X-TRU-COAT Plastic Coated Steel Pipe; new IN-TER-LINE Epoxy Lined Pipe with X-TRU-COAT Coating; "DEKORON-COATED" Electrical Metallic Tubing or Rigid Steel Conduit. For information, write: Republic Steel Corporation, Department A-3401, 1441 Republic Building, Cleveland 1, Ohio.

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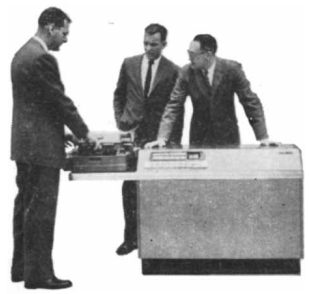


GENERAL PRECISION

COMMERCIAL COMPUTER DIVISION / GENERAL PRECISION, INC. / BURBANK, CALIFORNIA

THE AUTHORS

PHILIP M. HAUSER ("More from the Census of 1960") has for the past two years served as chairman of the Technical Advisory Committee for the census of 1960. He also heads the department of sociology at the University of Chicago and directs its Population Research and Training Center. Hauser, who was acting director of the census of 1950, served in the Bureau of the Census from 1938 to 1947. He gave up his position as deputy director of the bureau to become professor of sociology at the University of Chicago, where he had previously taken three degrees, including a Ph.D. From 1947 to 1951 Hauser was the U.S. representative to the Population Commission of the United Nations.

EDWIN ROEDDER ("Ancient Fluids in Crystals") is a geologist with the Geological Survey of the U.S. Department of the Interior. Roedder's first "scientific paper" (the quotation marks are his), on the subject of mineral collecting, was published in a collectors' magazine while he was still a junior in high school. Although he became interested in fluid inclusions in crystals as an undergraduate at Lehigh University, he did not begin to study them until 1950, when he went to the University of Utah to teach mineralogy. In the interim he had been a research engineer for the Bethlehem Steel Company from 1941 to 1947 and had taken a Ph.D. in geology at Columbia University. He joined the Geological Survey in 1955.

R. F. MALLINA, THEODORE R. MILLER, PHILIP COOPER and STANLEY G. CHRISTIE ("Surgical Stapling") are a retired mechanical engineer and three surgeons involved in the development of the stapler for suturing blood vessels that is described in their article. Mallina, who invented solderless electrical wiring, was a member of the technical staff of the Bell Telephone Laboratories from 1929 to 1957. The development of the American stapler began officially in 1960 with the establishment of the Foundation for Medical Technology, with Mallina and Miller among the charter members. Miller, associate attending surgeon at Memorial Hospital for Cancer and Allied Diseases in New York, had long been interested in the possibility of such an instrument and had obtained the support of a philanthropist friend, David Rose. Mallina designed the stapler and Cooper and Christie operated with it, first on animals and then on humans. Cooper is professor of clinical surgery at the Albert Einstein College of Medicine, director of the college's Surgical Laboratory of Cellular Physiology and Chief of Surgical Services at the Bronx Veterans Administration Hospital in New York City. Cooper has been chief of surgery at various VA hospitals since 1943. Christie, chief resident in thoracic surgery at the Bronx VA Hospital, is completing his training in surgery.

F. H. C. CRICK ("The Genetic Code") is a molecular biologist who works for the Medical Research Council Laboratory of Molecular Biology at the University Postgraduate Medical School in Cambridge, England. Originally a physicist, Crick turned to basic research on the structure of viruses, collagen and nucleic acids. He is best known for putting forward (with James D. Watson) the idea that the molecule of the genetic material deoxyribonucleic acid (DNA) is a double helix. Earlier this year Crick was appointed a nonresident fellow of the newly founded Salk Institute for Biological Studies in San Diego, Calif. This is his third article for SCIENTIFIC AMERICAN; the first two, "The Structure of the Hereditary Material" and "Nucleic Acids," appeared in October, 1954, and September, 1957, respectively.

OLEXA-MYRON BILANIUK ("Semiconductor Particle-Detectors") is assistant professor of physics at the University of Rochester. He was born in the western Ukraine, where he received his early schooling. After World War II Bilaniuk studied electrical engineering at the University of Louvain. Coming to the U.S. in 1951, he took degrees in physics, mathematics and nuclear physics at the University of Michigan, the last in 1957. Since 1958, when he joined the faculty of the University of Rochester, Bilaniuk has been engaged in research on the structure of atomic nuclei. The present article resulted from his work on the substitution of arrays of semiconductor counters for nuclear photographic emulsions. Last year Bilaniuk was a U.S. delegate at the United Nations conference on nuclear electronics in Belgrade. Currently he is doing research at the cyclotron facility in Buenos Aires at the invitation of the Argentine Atomic Energy Commission.

LEON FESTINGER ("Cognitive Dissonance") is professor of psychology at Stanford University. Festinger took his B.S. in psychology at the College of the City of New York in 1939. He received M.A. and Ph.D. degrees from the State University of Iowa, where he specialized in the field of child behavior, in 1940 and 1942 respectively. He remained at Iowa as a research associate until 1943 and for the next two years served as senior statistician on the Committee on Selection and Training of Aircraft Pilots at the University of Rochester. From 1945 to 1948 he taught at the Massachusetts Institute of Technology, and he was program director of the Research Center for Group Dynamics at the University of Michigan until 1951. Festinger went to Stanford from the University of Minnesota, where he had been professor of psychology since 1951. In 1959 the American Psychological Association awarded Festinger its Distinguished Scientific Contribution Award.

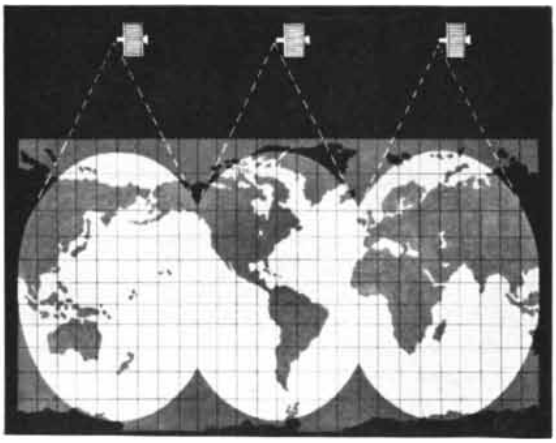
BRUCE I. H. SCOTT ("Electricity in Plants") is senior lecturer in physics at the University of Tasmania, where he also directs the biophysics laboratory. Scott, who was born in Tasmania, has taught at the university since 1945; he received his Ph.D. in 1956. "As a physicist," he writes, "I have been fascinated by the complexity of even the simplest organism and my particular interest has been the problem of how an organism controls its future development. It seems possible that the bioelectric field has been exploited for purposes of control and communication." A National Science Foundation Fellowship last year took him to the Rockefeller Institute for nine months of research on the electric fields associated with cells and tissues.

THEODORE H. SAVORY ("Daddy Longlegs") is vice-principal of Stafford House, a tutorial college in Kensington, England. One of the world's foremost experts on arachnids (which include spiders and harvestmen), Savory acquired a B.A. at the University of Cambridge in 1918. Two years later he introduced the teaching of biology at Malvern College, where he remained until 1951. From that year to 1958 he was senior biology master at the Haberdashers' School in Hampstead.

ERNEST M. GRUENBERG, who in this issue reviews *Mental Health in the Metropolis: The Midtown Manhattan Study* by Leo Srole, *et al.*, is associate clinical professor of psychiatry at the College of Physicians and Surgeons of Columbia University.

Turning potential into products

Syncom satellites for 'round the world communications



Capable of blanketing the earth with 24-hour international TV and telephone service, the advanced Hughes Syncom system promises to be the next step in communications satellites. Rather than orbiting many satellites at low altitudes, a Syncom system would need just three in *synchronous* orbits. Launched to an altitude of 22,300 miles and positioned by small rocket motors, the Syncoms would "park" over assigned longitudes. From these positions, Syncom "switchboards" could simultaneously handle 900 phone calls as well as relaying a TV program to every inhabited place on earth.

Getting set for space, Syncom I will be launched by NASA soon. Aboard will be Hughes-built components such as this advanced traveling wave tube. Capable of amplifying weak signals so they may be relayed from the satellite back to earth, these tubes are tested to meet almost incredible standards of performance and reliability in compact, lightweight packages.

New 3-D radar to read the enemy's mind

The "hardened eyes" of the Enterprise are new Hughes long-range detection and 3-D target tracking radar. Developed from the original invention of *frequency scanning* by Hughes engineers, these antennas eliminate mechanical movement. Instead of moving they position radar beams electronically. Mounted to the four sides of the Enterprise tower, (and "hardened" to withstand even atomic blasts) Hughes antennas can simultaneously track great numbers of supersonic targets through hundreds of miles of air space. Hughes delivered the first frequency-scanning radar units to the Navy in 1957. Today, Hughes radar is also patrolling the skies for the Army and Marine Corps, and is being further developed for advanced space applications—such as tracking missiles, satellites and space vehicles.

Hughes Display and Computer Systems keep pace with the increased capability of Hughes 3-D radar. Integrated into complete air or truck-transported air defense systems they enable today's commanders to "read the enemy's mind"—by supplying them with evaluations of threats as well as automating the assignment of weapons and targets for counter actions.

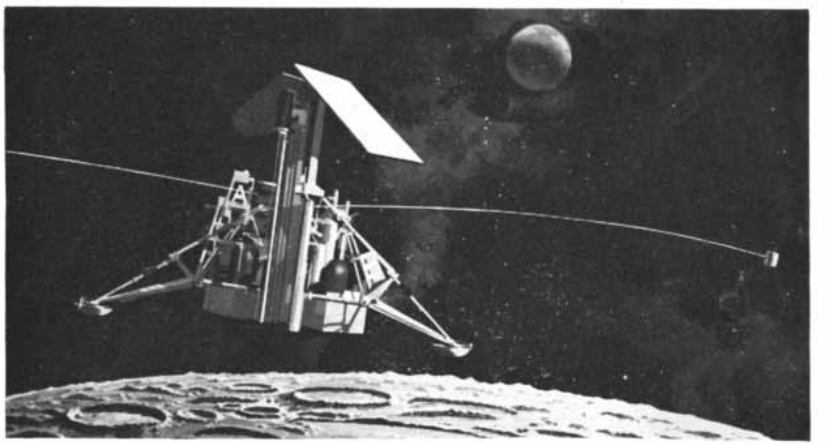
at Hughes

Mark of the Falcon's claw

Falcon Fin Marks on the metal target prove the bulls-eye accuracy of this infrared heat-seeking air-to-air missile. In test after test, Falcons fired from long distances sensed the infrared radiated by such targets (heated to simulate the exhaust from a jet tailpipe) scoring bulls-eyes.

The F-106 realizes potential Hughes engineers saw 14 years ago for an integrated missile/electronic control/aircraft weapons system. Hughes has produced more than 33,000 infrared and radar guided Falcons, together with over 16,000 "seek, find and kill" electronic airborne weapons control systems. Today, Hughes design and development capability is being applied to meet new and even more advanced tactical fighter mission needs.

A Surveyor to take the measure of the moon



Before our Astronauts can land on the moon, we must know more about what they will encounter. The Hughes Surveyor, designed to "soft land" about 150 lbs. of scientific instruments on the moon, will gather, analyse and transmit vital lunar data back to earth. Even now, Surveyor test vehicles are being dropped on various surfaces to be sure they successfully "soft land" their precious cargos. For once on the moon, Surveyor's TV cameras will be capable of sending high-quality pictures of the earth *back* to earth. This moon-to-earth TV network will also give scientists pictures of the lunar surface and will enable them to watch Surveyor at work: drilling into the lunar surface and making chemical analyses, measuring geophysical characteristics, the magnetic and radiation fields. The National Aeronautics and Space Administration is scheduled to launch seven Hughes Surveyors which are being built under the technical direction of California Institute of Technology Jet Propulsion Laboratory.

How do you define capability?

One way is to see it as potential—a dynamic total of human knowledge and experience combined with facilities built to make these skills most productive.

At Hughes this potential is built on sound strengths: 15 years of continuing scientific achievement; facilities covering 5.3 million square feet; over 100,000 man-years of systems experience; the abilities of 28,000 people—including 5,300 engineers and scientists who have found an environment uniquely suited to the development of their own potential—where skill and imagination can find full expression.

At Hughes these factors mesh together into a functioning unity—with *total* capability. The several examples on these pages are just a few examples of Hughes accomplishments in helping to create a new world with electronics.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY

Established 1845 SCIENTIFIC AMERICAN October 1962 Volume 207 Number 4

More from the Census of 1960

A sequel to the author's article of last year, which reported on the first data tabulated. Now deeper analysis has made new material available on U.S. education, occupations and incomes

by Philip M. Hauser

The gathering of facts about ourselves is one of the engrossing preoccupations of contemporary U.S. society. It is the full-time occupation of such large agencies of the Federal Government as the Bureau of the Census, the National Center for Health Statistics of the Public Health Service, and the Bureau of Labor Statistics; of such academic agencies as the Survey Research Center of the University of Michigan, the Bureau of Applied Social Research at Columbia University and the National Opinion Research Center at the University of Chicago; and of numerous profit-making business enterprises. It is a necessary incidental activity of every substantial governmental, political, financial, industrial, mercantile, labor, educational, religious, civic and welfare organization across the country. In all of this seeking for self-knowledge the ultimate reference source is the decennial census of population. The census constitutes the one body of data predicated on a house-to-house canvass and person-by-person enumeration of the population as a whole. The census figures establish the bench marks for statistical series that otherwise are based on surveys of samples of the population and supply the framework for designing these samples.

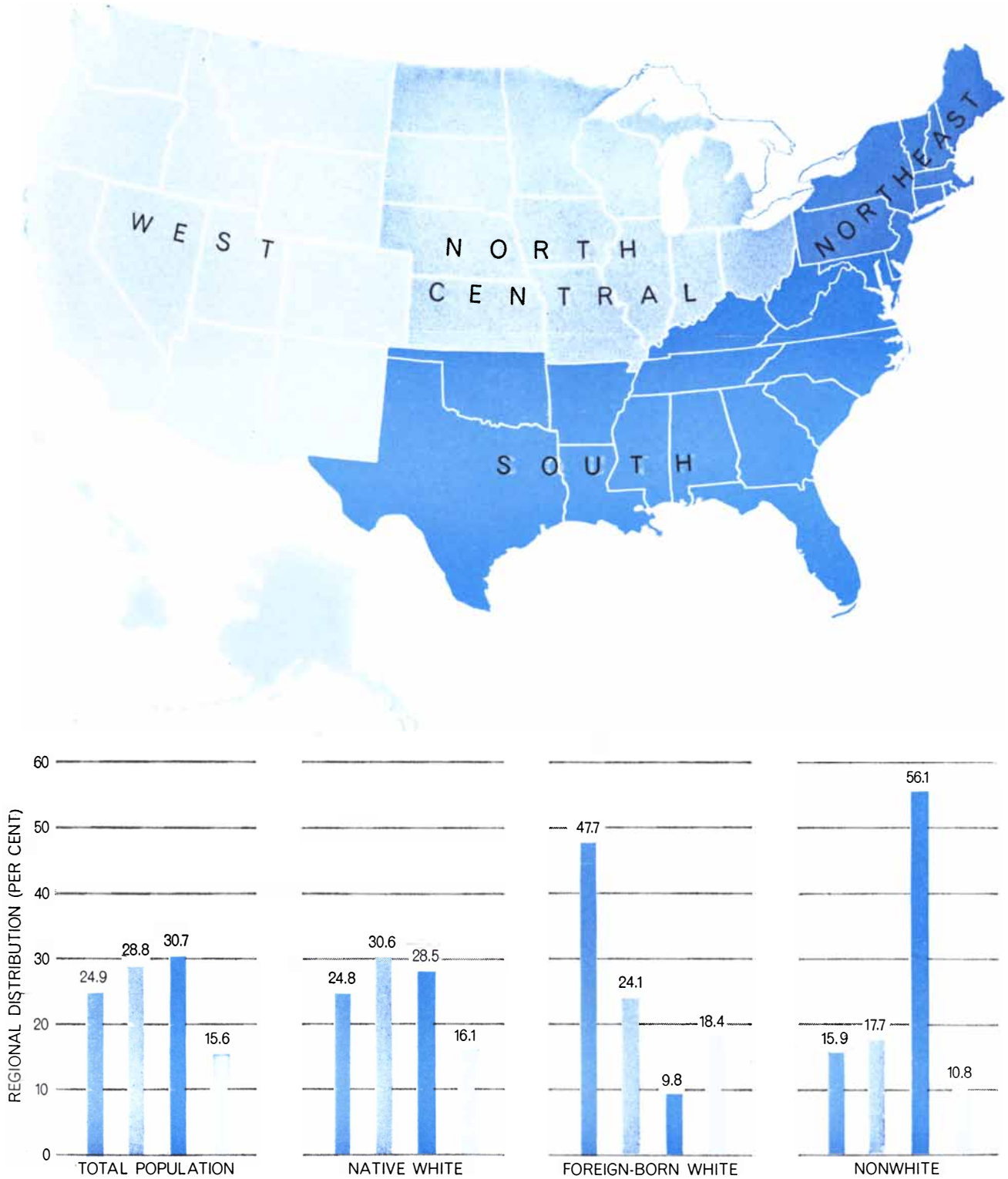
The significance of the census in the management of the nation's affairs is symbolized by its constitutional function: to provide a basis for the apportionment among the states of the seats in the House of Representatives. In accordance with the findings of the 1960 census, for example, California is about to elect eight additional congressmen, for a total of 38, and New York, which is slowly yielding its place as the most populous state in the Union, will elect only 41, two fewer than before. The 1960 figures have now assumed even greater political significance because of the decision of the U.S. Supreme Court in June holding that the seats in the legislatures of the states must also be reapportioned on the basis of the distribution of population shown by the census. The character of the U.S. society of a century ago is reflected in the preponderance of seats held in state legislatures by representatives of small-town and rural populations. This situation is now to be corrected in favor of a more faithful reflection of the urban civilization that the U.S. has become. With the restoration of representative government in the states, basic changes can be anticipated in state and national policy on many social and economic issues.

The direct political impact of the census flows from its most elementary findings about the size and distribution of the population. Over the next decade the wealth of other kinds of information developed in the national self-portrait will play an equally fundamental role in defining the social and economic issues and in shaping the policies that resolve them. This information is flowing from the census of 1960 at greater speed and in greater detail than it did from any previous census. With the aid of electronic computers the population statistics by states and political subdivisions were released for all states by October, 1960, four months ahead of the comparable 1950 figures [see "The Census of 1960," by Philip M. Hauser; SCIENTIFIC AMERICAN, July, 1961]. The full program of publication, including detailed subject reports, will be completed nine months to five years earlier. In this article it is possible to present figures concerning the crucial topics of education, livelihood and income. This information came from interrogation not of the entire population but of a substantial 25 per cent sample. Such sampling, made possible by developments in mathematical statistics, provides reliable data at greatly decreased cost. The data show that the educational attainment of the average American has continued to rise, that less than half of the labor force is now engaged in the production of physical goods and that the median real family income advanced by nearly 50 per cent in the decade from 1950 to 1960. But the figures reveal great disparities under all three headings, among different regions of the country and between the urban and the small-town and rural populations. Evidence of the relatively disadvantageous position of the nonwhite (principally Negro) minority of the population recurs in every table. On the other hand, the 1960 census shows that the members of another "minority" group—women—are

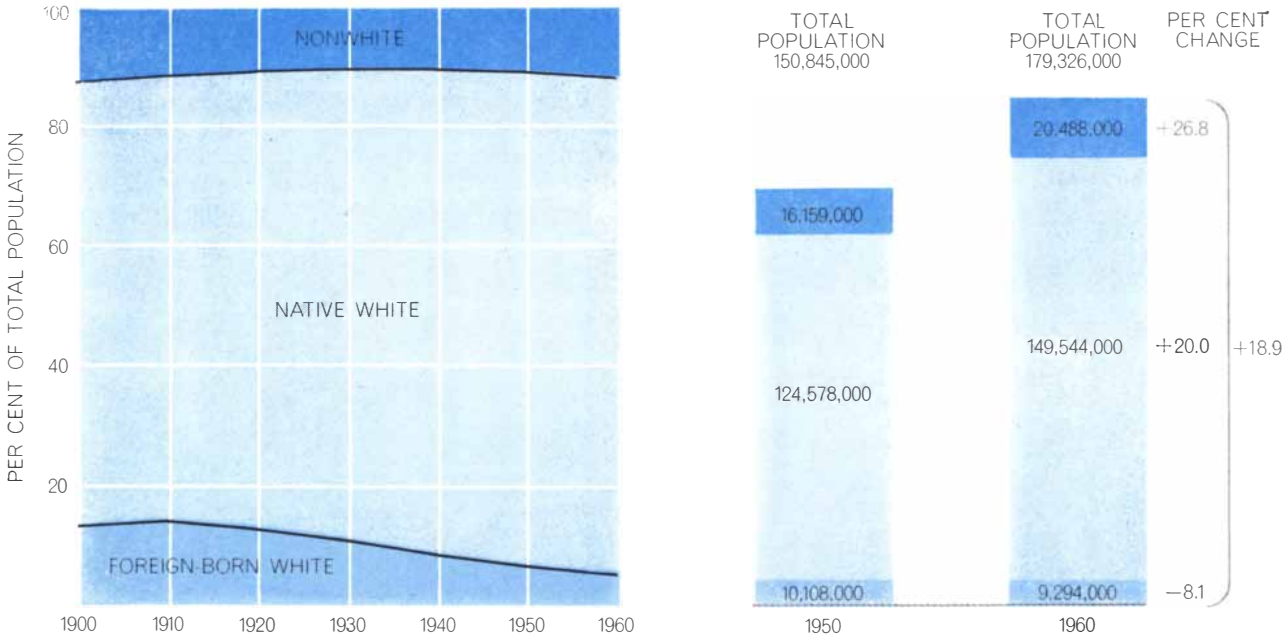
playing an ascendant role in the nation's economic life.

Measured by nativity, the U.S. population in 1960 was more homogeneous than ever before: the native white population was 83.4 per cent of the total, compared with 74.3 per cent in 1900. Foreign-born whites, reflecting the force of the immigration and exclusion laws, had declined to the lowest level ever recorded: 5.2 per cent. The percentage of nonwhites, however, had increased for the second decade in a row and for the third time since 1810; as a result nonwhites made up 11.4 per cent of the population in 1960. Since Negroes constitute 92.1 per cent of the nonwhite total, the increase in the proportion of nonwhites is a product principally of the gain in Negro population.

Other figures explain this gain as the

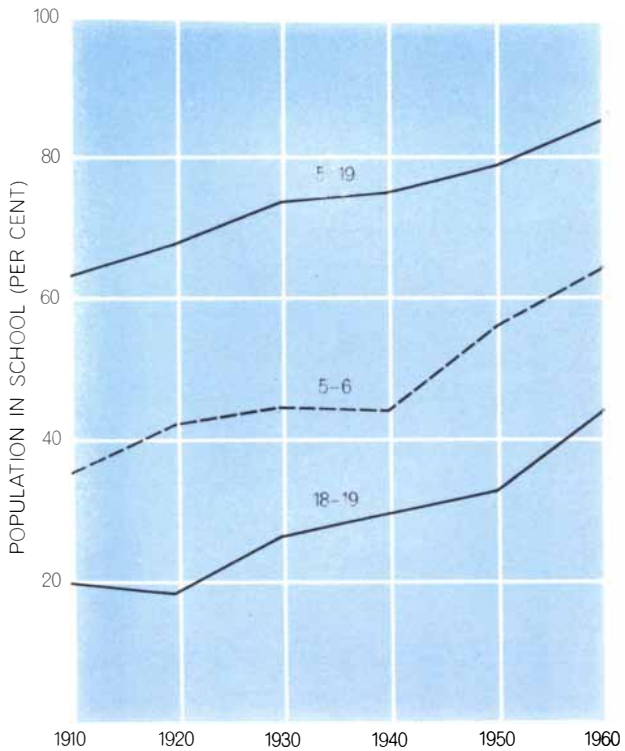


REGIONAL DISTRIBUTION of the population is illustrated. The map shows the four census regions into which the U.S. is divided. The bars (*keyed by color to each region*) show what per cent of the total, native white, foreign-born white and nonwhite populations lived in each of the regions in 1960. The South's share of the nonwhite population fell 9.6 per cent between 1950 and 1960.

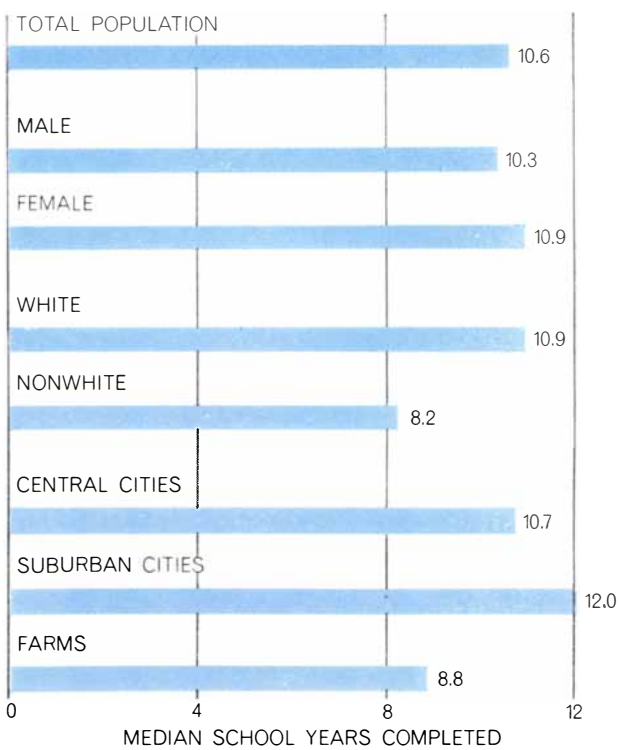


CHANGING COMPOSITION of the U.S. population since 1900 is traced at left in terms of percentages. The actual numbers for 1950 and 1960 are given at right for the total population and each subgroup, together with the amount of change for each since 1950.

result of the continuing migration of the Negro away from rural habitations and occupations and away from the South. In evidence of this migration 64.4 per cent of the nonwhite population resided in the 212 Standard Metropolitan Statistical Areas (central cities of more than 50,000 population and their surrounding county or counties) compared with 62.9 per cent of the total population. Higher levels of living and better health conditions in the metropolitan areas, in the South as well as in the North and West, have brought a simultaneous decrease in mortality and increase in net fertility of the Negro population, greatly increasing the nonwhite growth rate. Should this trend continue, the nonwhite increase will more than offset the foreign-born white decrease and so diminish the native-white proportion of the



SCHOOL ENROLLMENT rate has increased over the years. Specifically, as the chart shows, education starts earlier and continues longer for an increasing proportion of the nation's children.



LEVEL OF EDUCATION in the U.S. has risen steadily: the national median for years of schooling completed was only 8.6 in 1940. The level varies widely with race and place of residence.

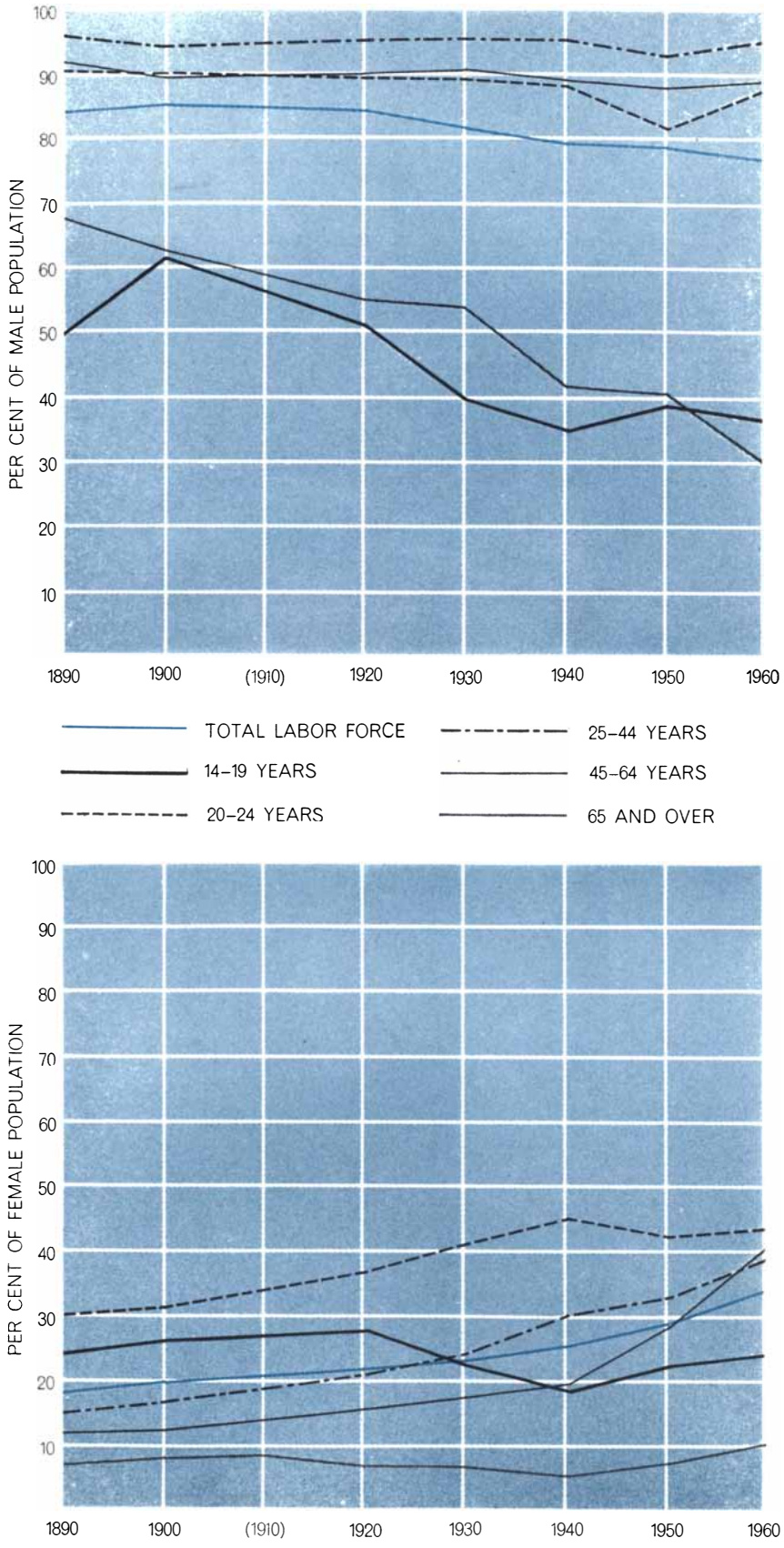
total population. In fact, the present trend would bring nonwhites up to a fifth of the U.S. population by 2050—about the same percentage as in the first census in 1790. But this is a remote prospect, because it is likely that the Negro birth rate will decline, as did the white, with the achievement of increasing education and income.

The education figures, perhaps more than any other set of data, characterize the changed and changing American way of life. Children are going to school at an earlier age, and young people are staying in school longer than ever before. Between 1910 and 1960 the percentage of students in the age group from five to 19 increased from 62.6 to 84.4. In this period the enrollment of five- and six-year-olds almost doubled (from 34.6 to 63.8 per cent); the enrollment of 16- and 17-year-olds did the same (from 43.1 to 80.9 per cent), and the enrollment of 18- and 19-year-olds more than doubled (from 18.7 to 42.2 per cent). The earlier enrollment plainly reflects the shift from rural to urban living that occurred in this half-century and the concomitant changes in the function of the family as the basic social institution. Similarly, the prolongation of formal schooling reflects the changes in the mode of employment and the need for increased education in preparation for life in a more complex society. It is no coincidence that the 1920 census, which first showed that more than half of the population was living in urban communities, was also the first to show that 90 per cent of the 7-to-13-year-olds were going to school.

Increased rates of school enrollment from one generation to the next have of course raised the educational level of the people as a whole. By 1930, 96 per cent of the population 10 years old or older was reported as being "literate." In the census of 1940 the "illiteracy question" was abandoned in favor of a question about "years of school completed." In that year the average adult 25 years old or older had completed 8.6 years of schooling, or a little more than an elementary school education. By 1960, 77.8 per cent had at least elementary schooling and 41.1 per cent had graduated from high school; by 1970, if the present trend continues, the average American will have achieved a high school education. College graduates accounted for 7.7 per cent of the adult population in 1960, up nearly 25 per cent from 1950. At the other end of the scale of attainment, the total of "functionally" illit-

STATE	MEDIAN SCHOOL YEARS COMPLETED
UTAH	12.2
ALASKA	12.1
CALIFORNIA	12.1
COLORADO	12.1
NEVADA	12.1
WASHINGTON	12.1
WYOMING	12.1
IDAHO	11.8
OREGON	11.8
DISTRICT OF COLUMBIA	11.7
KANSAS	11.7
MASSACHUSETTS	11.6
MONTANA	11.6
NEBRASKA	11.6
ARIZONA	11.3
HAWAII	11.3
IOWA	11.3
NEW MEXICO	11.2
DELAWARE	11.1
CONNECTICUT	11.0
MAINE	11.0
FLORIDA	10.9
NEW HAMPSHIRE	10.9
OHIO	10.9
VERMONT	10.9
INDIANA	10.8
MICHIGAN	10.8
MINNESOTA	10.8
NEW YORK	10.7
UNITED STATES	**10.6**
NEW JERSEY	10.6
ILLINOIS	10.5
MARYLAND	10.4
OKLAHOMA	10.4
SOUTH DAKOTA	10.4
TEXAS	10.4
WISCONSIN	10.4
PENNSYLVANIA	10.2
RHODE ISLAND	10.0
VIRGINIA	9.9
MISSOURI	9.6
NORTH DAKOTA	9.3
ALABAMA	9.1
GEORGIA	9.0
ARKANSAS	8.9
MISSISSIPPI	8.9
NORTH CAROLINA	8.9
LOUISIANA	8.8
TENNESSEE	8.8
WEST VIRGINIA	8.8
KENTUCKY	8.7
SOUTH CAROLINA	8.7

MEDIAN SCHOOL YEARS completed in each state ranged in 1960 from a high of 12.2 (equivalent to more than a high school education) in Utah to a low of 8.7 in Kentucky and South Carolina. In each state the median for nonwhites was below the median for whites.



AGE COMPOSITION of the labor force has changed significantly since 1890. These charts show what per cent of all males (*top*) and females (*bottom*) in the specified age groups were in the labor force (that is, at work or seeking work) in each year. No figures are available for 1910. A smaller proportion of the men and more of the women are at work now.

erate people—people with less than five years of schooling and functionally illiterate in the sense that they are unable to read a newspaper easily—dropped to 8.4 per cent of the population, down from 11.1 per cent in 1950.

Needless to say, the increasing exposure of the population to formal schooling has implications for all aspects of the society and the economy. It can be expected to effect important changes in the consumption of goods and services, in the content of the mediums of mass communication, in the style of advertising and in the conduct of political campaigns. More important, it opens up broader horizons for larger numbers of people in literature, art, music and science. The goods, services or messages aimed at the "average" American on the assumption that he has had less than a grade school education are likely to find themselves with a declining or disappearing clientele.

The population has by no means shared equally in the opportunity and experience of education. Various groupings by place of residence, region and race are still finding it difficult to achieve an education consonant with contemporary needs. Thus, while the suburban population (defined here as resident in urban places other than central cities) has already attained a high school education, with a median of 12 years, and the population of the central cities is at 10.7 years, about the national average, the rural nonfarm population has nine years of schooling and the rural farm population only 8.8 years. Again, whereas the average adult in the West has had the full 12 years of education through high school, the median schooling of the adult in the South is only 9.6 years, a full year below that of the population as a whole.

The lower averages of the nonmetropolitan populations and of the South are the result in part of the even greater disparity in the educational attainment of the nonwhite population. The census of 1960 was the first to show the nonwhite adult population averaging a grade school education. But 23.4 per cent of the nonwhites were still recorded as being functionally illiterate, and only 21.7 per cent had finished high school. For the nonwhite population as a whole these averages are depressed by the even greater disparities prevailing in the South, where the average nonwhite has had a median schooling of only 7.1 years, compared with 10.4 years for the Southern white.

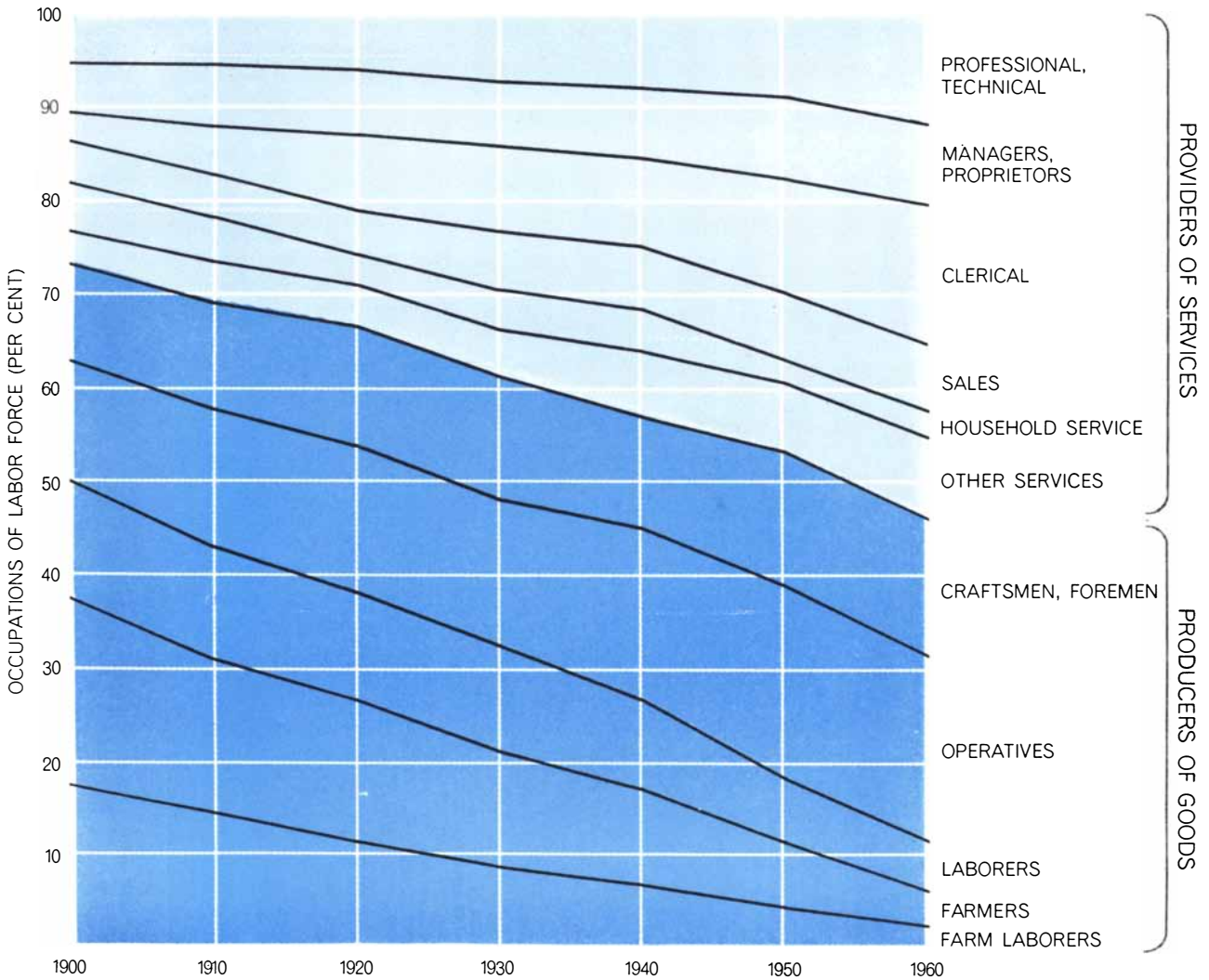
In the decade from 1950 to 1960,

however, the nonwhite population made important gains. The 21.7 per cent with a high school education represented an increase of 56 per cent over 1950, and the number of college students increased at a similar rate, from 2.3 to 3.5 per cent of the adult nonwhite population. Deficient education, however, will continue to be the greatest handicap to the Negro and other nonwhites in their efforts to realize their full potential and to take their place as citizens.

Some of the most significant changes in American life that have occurred in the past half-century are recorded in the statistics of the labor force. The percentage of the population of "working age" (14 years old or older) that is counted in the labor force—55 in 1960—has remained about the same. But the percentage of the male population of working age in the labor force has declined from 84 in 1890 to 77. This has been more than offset by the entrance of women into the labor force; more than a third of the women of working age are employed or are actively seeking employment today compared with less than a fifth in 1890.

The shifts are explained in major part by the increased enrollment in high school and college that nowadays postpones a young man's (and a young woman's) entrance into the labor force. Only a third of the young men from 14 to 19 are in the labor market today; half of the young men of that age group were job seekers in 1890. Of the young women in this age group about a fourth are in the labor force; the same obtained in 1890. Between the ages of 20 and 64 the percentage of males in the labor force has also remained about the same, although increasing numbers of the younger men in this large segment of the population are going on to college. The situation is quite different for older men; the proportion of men 65 years old or older who reckon themselves in the labor force has declined from more than two-thirds in 1890 to less than a third. Between 1950 and 1960 the percentage declined steeply, from 41.4 to 30.5. The departure of older men from the work force is attributable, of course, to the availability of public and private pension funds and to increasingly compulsory retirement at age 65. The older men have been replaced—not in their old jobs but in entirely new functions in the constantly changing work force—by women.

At the turn of the century nearly three-fourths of the labor force were engaged in the production of physical goods and less than a fourth in service



OCCUPATIONS of members of the labor force have changed with the technological, economic and social climate of the nation. Basic trend has been away from production of goods and toward provision of services, as shown by dark and light colored areas here. White-collar (*top four layers*) and service work now occupy more of the labor force; there are relatively fewer laborers and farmers.

STATE	MEDIAN FAMILY INCOME (DOLLARS)
ALASKA	7,305
CONNECTICUT	6,887
NEW JERSEY	6,786
NEVADA	6,736
CALIFORNIA	6,726
ILLINOIS	6,566
NEW YORK	6,371
HAWAII	6,366
MARYLAND	6,309
MASSACHUSETTS	6,272
MICHIGAN	6,256
WASHINGTON	6,225
DELAWARE	6,197
OHIO	6,171
DISTRICT OF COLUMBIA	5,993
WISCONSIN	5,926
UTAH	5,899
OREGON	5,822
WYOMING	5,877
INDIANA	5,798
COLORADO	5,780
PENNSYLVANIA	5,719
UNITED STATES	**5,660**
NEW HAMPSHIRE	5,636
RHODE ISLAND	5,589
MINNESOTA	5,573
ARIZONA	5,568
MONTANA	5,403
NEW MEXICO	5,371
KANSAS	5,295
IDAHO	5,259
MISSOURI	5,127
IOWA	5,069
VIRGINIA	4,964
VERMONT	4,890
TEXAS	4,884
MAINE	4,873
NEBRASKA	4,862
FLORIDA	4,722
OKLAHOMA	4,620
WEST VIRGINIA	4,572
NORTH DAKOTA	4,530
LOUISIANA	4,272
SOUTH DAKOTA	4,251
GEORGIA	4,208
KENTUCKY	4,051
NORTH CAROLINA	3,956
TENNESSEE	3,949
ALABAMA	3,937
SOUTH CAROLINA	3,821
ARKANSAS	3,184
MISSISSIPPI	2,884

MEDIAN FAMILY-INCOME figures were gathered by asking a sample of the population for 1959 earnings. The data showed a 48 per cent rise since 1949, even allowing for inflation. But Alaska's median family income was more than two and a half times that of Mississippi.

occupations. In 1960 most of the labor force were engaged in service occupations—42.2 per cent in white-collar occupations and 12 per cent in household service and other service occupations—and only 46 per cent were engaged in work directly contributing to the production of physical goods. This transformation of the labor force continues today in response to technological advances, particularly in agriculture, and to the rise in material well-being that generates increasing demand for services as well as goods.

The decline in production workers is entirely attributable to the reduction in the number of farmers, farm laborers and nonfarm laborers. Since 1900 agricultural employment has fallen from 37.5 per cent to only 6.3 per cent of the labor force; the percentage of nonfarm laborers, from 12.5 to only 5.5. These declines more than offset the increases in employment in other lines of production. On the other hand, the percentage of the labor force employed in clerical functions increased fivefold; that in sales, almost twofold; that in professional, technical and kindred occupations, threefold; and that in management and proprietorships (except farms) by almost half. Service occupations, a large category, increased by only a third, but this increase represents the net effect of a 50 per cent decline in household workers and a doubling of "other" service workers: barbers, beauticians, cooks, policemen, firemen, janitors, waitresses and so on.

In sum, the economic life of the country is now much less dependent on muscle power and much more dependent on professional, technical and clerical skills. This shift in emphasis from brawn to brain, dexterity and education has opened the ranks of the labor force to women. Since men are still engaged primarily in the production of goods (three-fifths of the male work force in 1960, compared with four-fifths in 1900), the white-collar and service functions that have come to the fore have been taken over to a large extent by women. This has not only increased the employment of women but has also changed the character of the work that women do. Thus the proportion of service workers among women has declined by about a third—the net effect of a three-fourths decline in the proportion of household workers and a doubling of the proportion of female workers in other services—and even the proportion of women employed

in factory work has fallen. On the other hand, the percentage of clerical workers in the female labor force has increased almost eightfold; the percentage of salespeople has doubled; the percentage of managers and proprietors has more than doubled; and the percentage of professional and technical workers has increased by nearly 50 per cent.

As the more detailed tabulations of the 1960 census will show, in corroboration of previous census data, the change in the nature of the occupations offered by the economy and the changing role of women have combined to make the U.S. wife and mother an increasingly important factor in the work force and a major contributor to the U.S. national and family income. Although men predominate among the college graduates in the population, the adult woman has been shown to have a higher median education in each of the three censuses in which the question about years of schooling has been asked: in 1960 it was 10.9 years compared with 10.3 years for the male. With this schooling young women have been equipped to fill the white-collar and service and sales functions for which the economy has set up an increasing demand, particularly over the past 25 years.

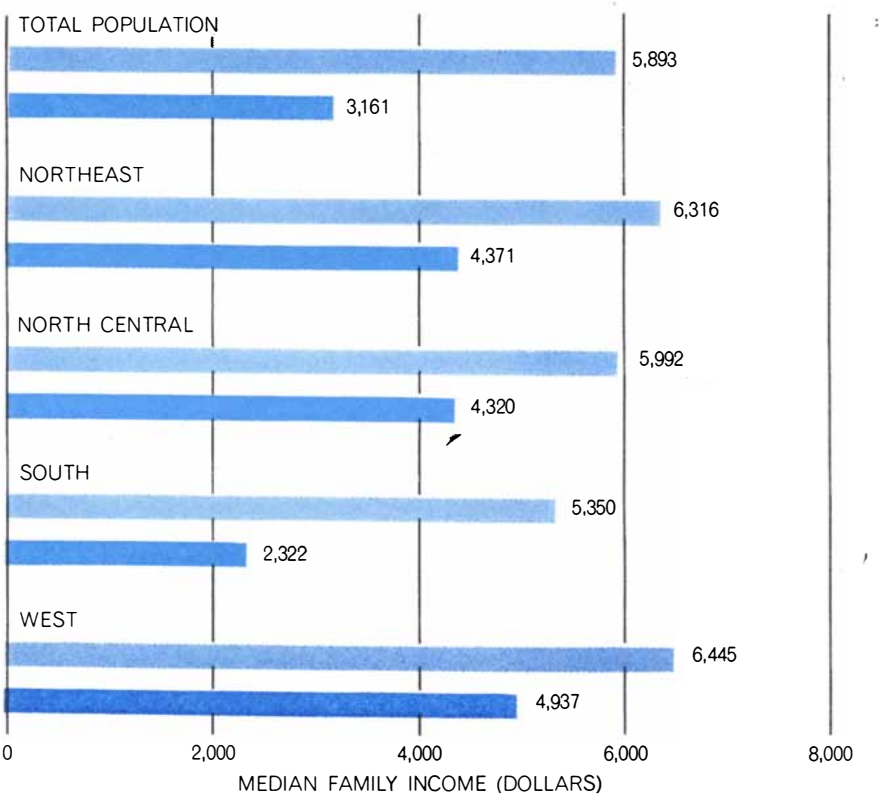
Young married women work after leaving school and continue to work until their childbearing and child-rearing activities begin. With the birth of their first child they tend to leave the labor force, beginning at about age 23, and they remain homemakers until their last child goes off to school. Then, at about 35, they re-enter the labor market and remain until age 45, when they begin to taper off their work activities. Thus according to the 1950 census the proportion of married women with husbands living who were in the labor force showed a peak of 28 per cent at age 22, declined to 22 per cent at age 29, rose gradually to almost 28 per cent again at age 40 and declined to 10 per cent by age 60. The working life of the unmarried woman is quite different. In 1950 some four-fifths of the single women between 25 and 35 were in the labor force, three-fourths at 45 and more than half at 60. The 1960 figures, when available, will not materially change these patterns.

The family-income figures secured by the census of 1960 are also now available. The major sampling effort that produced these figures serves to calibrate the continuing income surveys of smaller samples that are conducted from month to month and year to year by the Bureau of the Census and by other governmental, academic and commercial agencies. In the decade from 1950 to 1960, the census shows, median family income increased by a spectacular 86 per cent, from $3,083 in 1949 to $5,657 in 1959. To be sure, inflation made part of this increase illusory. Even after allowance for the decrease in the purchasing power of the dollar, however, real family income rose by 48 per cent.

Significant disparities in the distribution of income are shown by the census, and the pattern of disparities parallels that developed in the analysis of the education figures by region, degree of urbanization and race. Some 13.1 per cent of the families had incomes of $2,000 or less, whereas 15 per cent had incomes of $10,000 or more. The West showed a median family income of $6,348, 12.2 per cent above the national average; the South, with a median income of $4,465, fell 20 per cent below the national average. Within metropolitan regions families in the suburbs had a median income of $7,002 and families in the central cities a median income of $5,940. Rural nonfarm income, at $4,750, and rural farm income, at $3,228, were respectively 16.1 and 43 per cent below the national average.

The disadvantageous position of the Negro is evidenced in the income figures for nonwhite families, which in all parts of the country run lower than those of corresponding white groups. The nonwhite national median of $3,161 was only 54 per cent of the national median for whites; in the South, at $2,322, it was 43.4 per cent of the median white income in that region. In the West the nonwhite median, at $4,937, runs 56.2 per cent above the national nonwhite median and up to 76.6 per cent of the regional median of white families, but here the Negro constitutes only 48.8 per cent of the nonwhite population.

So much could not have been said so soon about the state of the nation after any other census. The findings, still being tabulated, will serve the interests of wise policy the more fully because of the earlier publication and deeper analysis made possible by the machines that are turning out these figures.



INCOME LEVELS varied most sharply with race, as indicated by this chart. In each region the median income of whites (*lighter bars*) was higher than that of nonwhites (*darker bars*).

Ancient Fluids in Crystals

When a mineral crystallizes out of a brine, some of the brine is trapped in small "fluid inclusions." Thus the inclusions provide samples of a solution that may be more than a billion years old

by Edwin Roedder

The geologist works like a detective in attempting to reconstruct the events of the remote past from the evidence of the present. Unlike the detective, however, he works with events that occurred millions or even billions of years ago, and the clues he has to piece together are unusually meager. It is well known that most sedimentary rocks formed in sea water; it is less commonly recognized that most other geologic processes in the apparently solid crust of the earth, including the formation of most ore deposits, have taken place in a bath of salty water. Droplets of these ancient mother liquors, preserved in the form of "fluid inclusions" in many rocks and minerals, are clues to such processes. Although the droplets are minuscule, they enable the geologist to tell a number of things about the events of the past that would otherwise be completely hidden. These tiny samples of fluids long since gone from the face of the earth have been known for almost 150 years, but they still conceal many secrets and merit much more investigation.

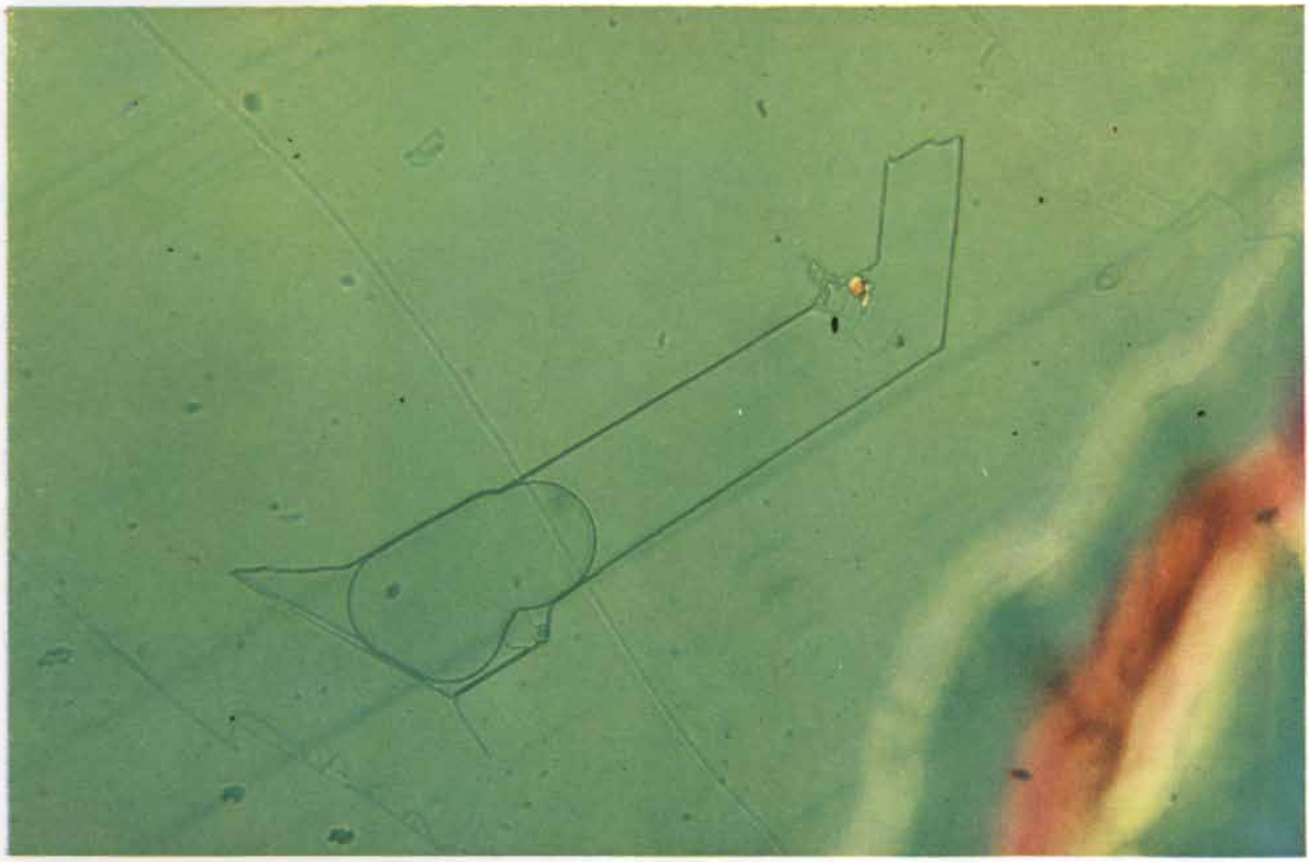
Just about any crystal, natural or man-made, that is grown from an aqueous solution will have fluid inclusions. They are easily seen in a clear quartz crystal. Ordinarily the crystal will have a clear tip, but its base will show faint whitish streaks. A 10-power glass will generally resolve these streaks into innumerable separate liquid inclusions, each containing a tiny bubble. Most of them will look black, because light entering them is trapped by total reflection at the walls, but a few may be flat enough to transmit light clearly. The photomicrographs that illustrate this article were made by light transmitted through polished mineral plates and nearly perpendicular to the planes of somewhat flattened inclusions.

In size fluid inclusions range from a diameter of probably less than one micron (a thousandth of a millimeter), below the limit of resolution of the light microscope, to a few centimeters. Inclusions bigger than a millimeter in diameter are rather rare; those in the centimeter range are museum pieces. Most of them contain a water solution of various salts, in concentrations ranging from nearly fresh water to highly concentrated brines. Most also enclose a bubble of gas. When the bubble is small enough to respond to statistical irregularities in the number of molecules striking it, and is free of the inclusion walls, it can be seen to wander continuously in a jerky Brownian movement. It is fascinating to watch such a bubble under the microscope and to think that it has been nervously pacing its cell for perhaps a billion years. Some inclusions have one or more crystals in the liquid; some are composed of two immiscible liquids; a few, of gas alone. In extremely clear crystals a careful microscopic search may be required to find even a single inclusion. Ordinary white minerals such as quartz and calcite may have as many as a billion inclusions per cubic centimeter. Although fluid inclusions in natural crystals are a welcome source of information to the geologist, they may produce disfiguring flaws in gem stones. In artificial crystals intended for use in electronic circuits inclusions are serious defects.

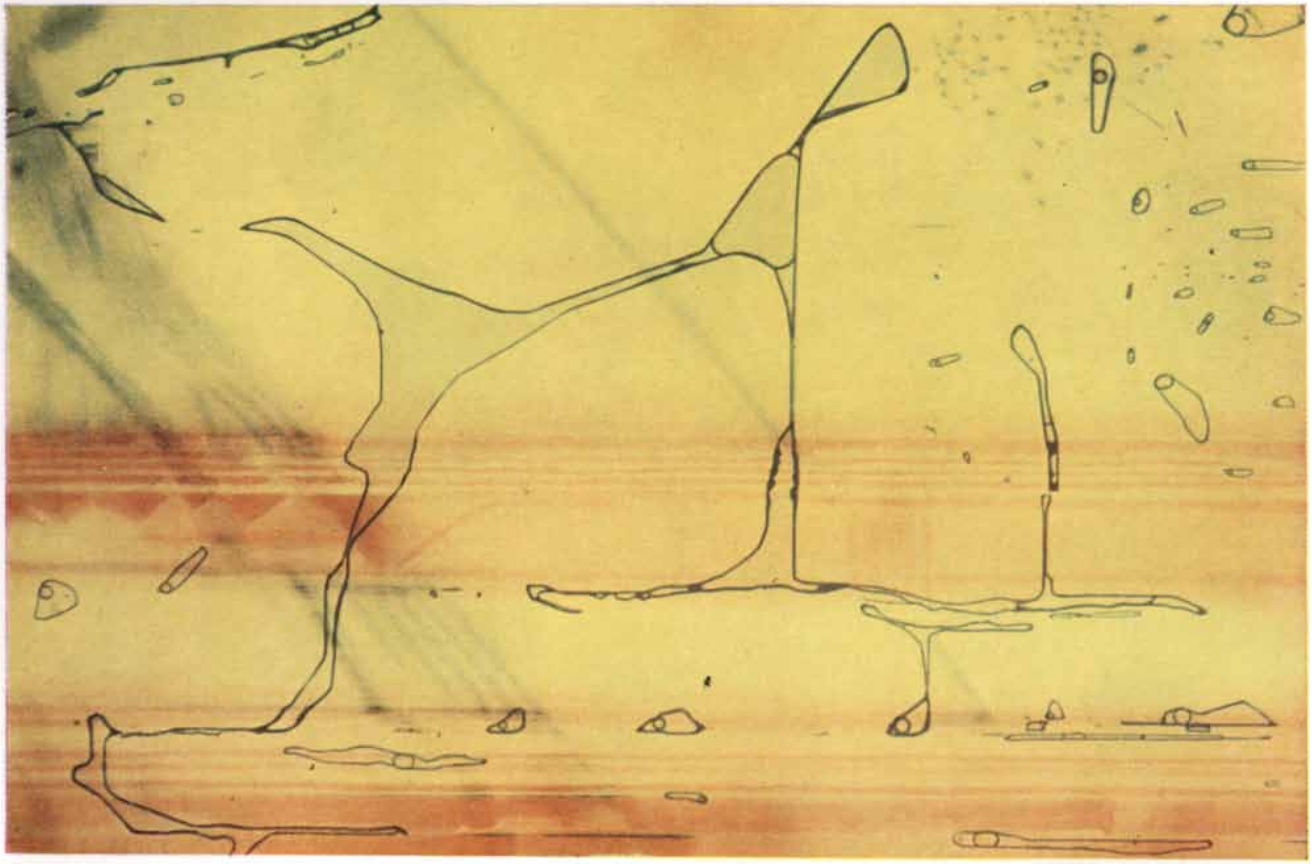
Careful studies of both synthetic and natural mineral specimens have shown that inclusions can be created in several different ways. One of the most common is by dendritic, or branching, growth of a crystal. When this is followed by a solid, perfect growth that covers the imperfect region, portions of the fluid from which the crystal was growing are trapped in the open spaces. Anything that temporarily halts or slows the growth of a small part of the crystal, such as another mineral grain, a globule of an immiscible liquid or a gas bubble, may also cause trapping of fluid. Inclusions made in this way are called primary, because they form simultaneously with the enclosing crystal.

Even more common are secondary inclusions, which originate in the rehealing of cracks in a crystal. The additional surfaces exposed by a crack in an otherwise perfect crystal represent an increase in the energy stored in the crystal. If the crystal is immersed in a liquid in which it is even slightly soluble, healing starts immediately, returning the structure to a lower energy state. Moreover, if the crack is a curving fracture, the atomic planes exposed are not the normal crystal planes but surfaces of even higher energy and therefore higher solubility; the processes of solution and redeposition rapidly generate a system of two-dimensional dendritic crystals that join together and eliminate most of the new surface [*see illustration on page 41*]. At first the resulting inclusions still have a high surface energy and resemble a family of amoebae with a flair for geometry. In time they smooth out; material is dissolved from the jutting, convex portions and even from the flat walls and is deposited in the concave areas. Two competing but exceedingly weak forces decide what will be the ultimate goal of this process: either an approach to the smallest amount of surface, yielding a spherical inclusion, or an approach to the lowest-energy surface, yielding a faceted negative crystal inclusion. Perhaps the composition of the liquid is involved, since a single crystal may show both types of inclusion, although as separate groups.

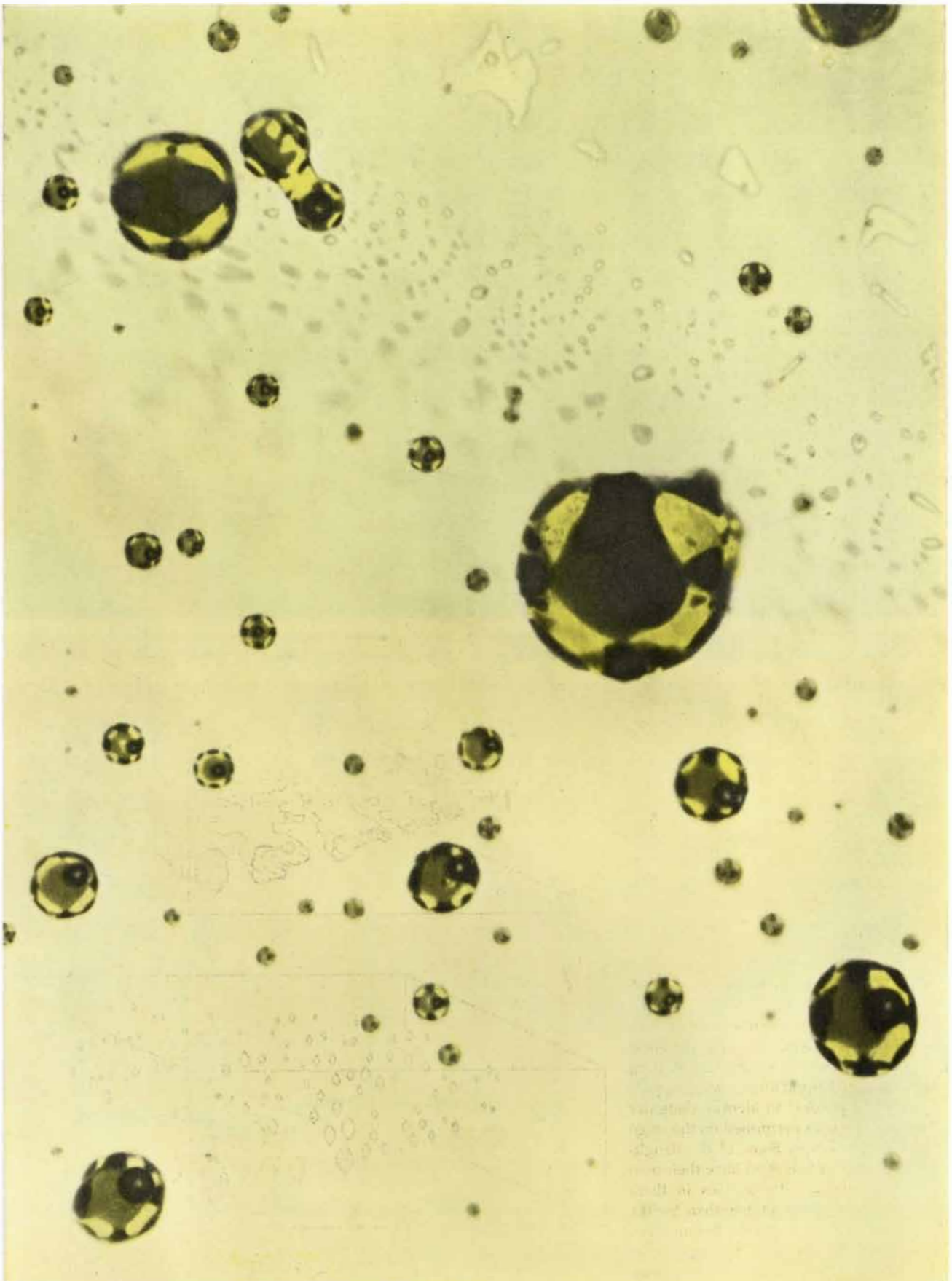
Primary inclusions, then, constitute a sample of the fluid in which the crystal grew, whereas secondary ones contain



INCLUSION IN TOPAZ, magnified 198 diameters in this photomicrograph, is straight-edged area at center. Rounded area is gas bubble; the rest is saline water. Small reddish spot is a crystal that grew in inclusion; other daughter crystals are also visible.



INCLUSION IN SPHALERITE extending over most of this photomicrograph of a polished plate is magnified approximately 46 diameters. Surrounding it are numerous smaller inclusions. Each of the inclusions consists of saline water and a rounded bubble of gas.

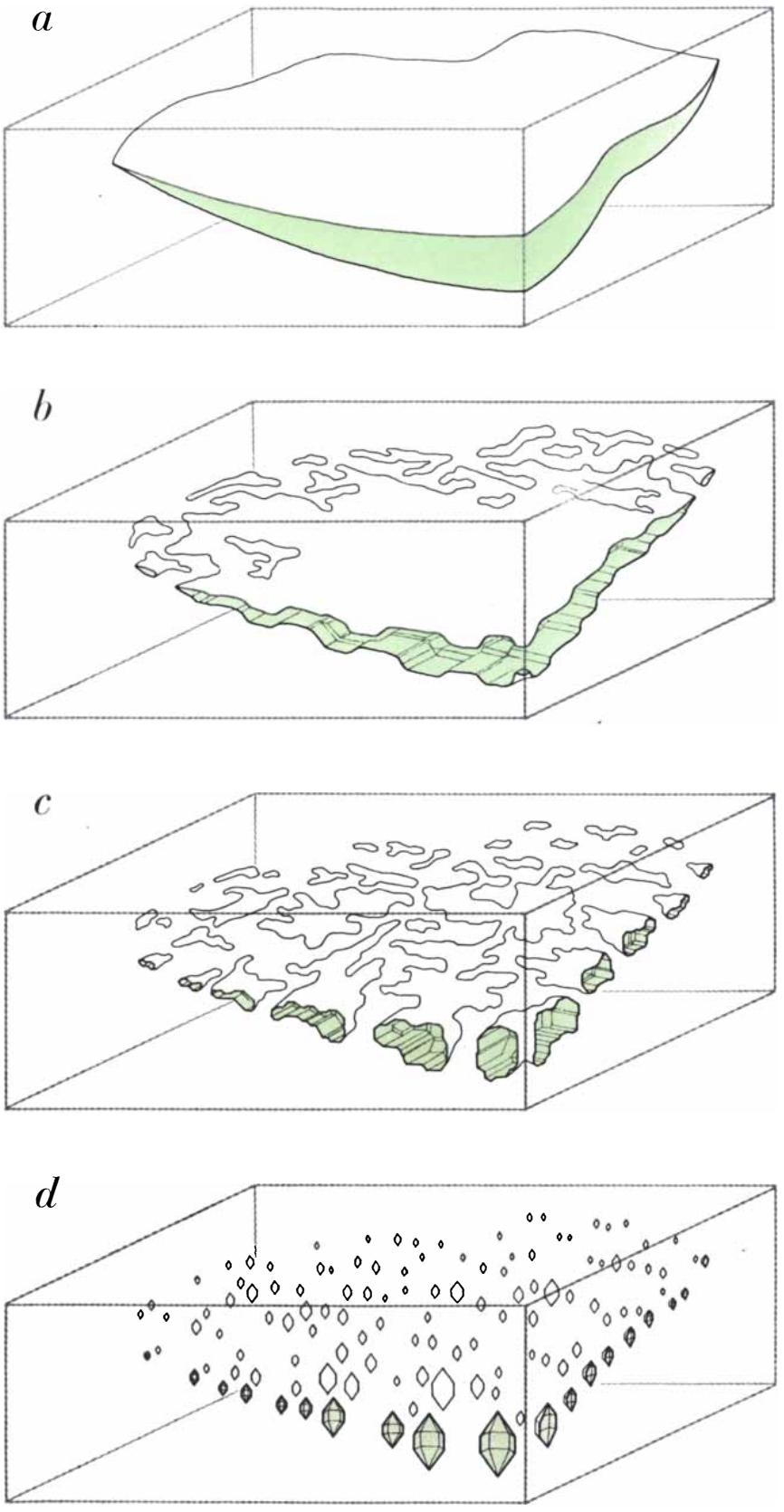


PETROLEUM INCLUSIONS in fluorite, magnified 266 diameters, have undergone degradation into several phases since the time of crystallization. A globular mass with four darker appendages is a phase that preferentially wets certain surfaces, thereby appearing to divide the lighter phase into four quadrants. The dark circle in each inclusion is a bubble of gas under high pressure.

fluids that bathed the crystal at some later time. The great abundance and widespread occurrence of fluid inclusions indicate that many geologic processes went on in an environment where every crack and pore was filled with liquid. Those rocks that do not contain fluid inclusions—meteorites and certain types of igneous and metamorphic rocks—were formed under special water-deficient conditions. The time elapsed between the trapping of primary and secondary inclusions in a given crystal can be quite short in geological terms; there is considerable evidence that many secondary inclusions actually were trapped in fractures that occurred while the crystals were still growing. On the other hand, the crystals in many rocks and veins have been sheared one or more times by earth movements that took place ages after the original formation. Large numbers of tiny inclusions were trapped in the shear planes when they rehealed. Thus adjacent inclusions may differ greatly in age.

The composition of the fluids in inclusions has been studied by a variety of methods. With the rare large inclusions it is possible simply to drill into them, draw out the fluid and analyze it, as Sir Humphry Davy did in 1822. To obtain enough material for chemical analysis from smaller inclusions the mineral sample is crushed, which opens a large number of inclusions. Then the powder is leached with water, and the salts are separated from the crushed mineral by filtering or by electrodialysis, in which the ions are forced through permeable membranes by an electric current. Although 100 billion small inclusions of brine may be opened in grinding a 100-gram sample, they usually yield only a few milligrams of soluble salts. As a result it is necessary to take particular care to avoid contamination during extraction and analysis.

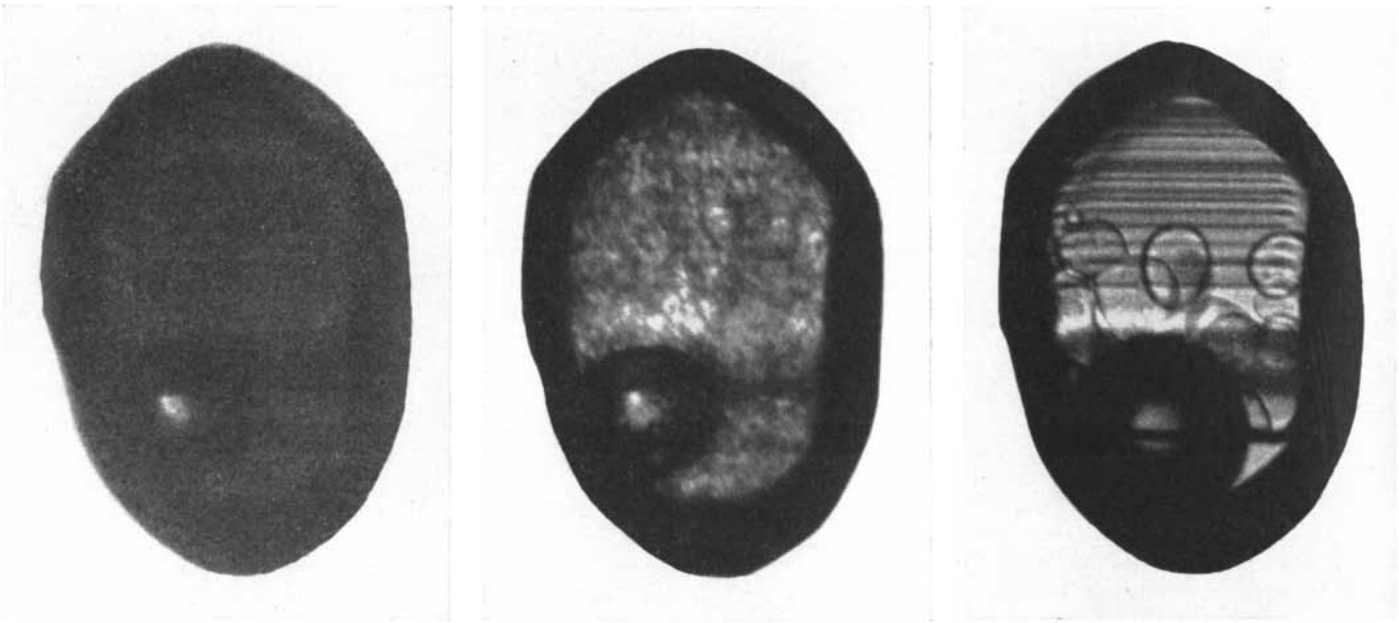
Some inclusions contain solid crystals in their fluid. Generally these daughter minerals formed by crystallization from the saturated liquid after it was trapped. It is often possible to identify daughter minerals by tests performed on the stage of the microscope. Some of the daughter-mineral crystals even have their own fluid inclusions with bubbles in them and, as in the case of Jonathan Swift's celebrated fleas, so on ad infinitum. The most common crystals turn out to be sodium chloride, as is shown by such evidence as their shape, their behavior in polarized light, their small increase in solubility with temperature and their odd behavior at subzero temperatures.



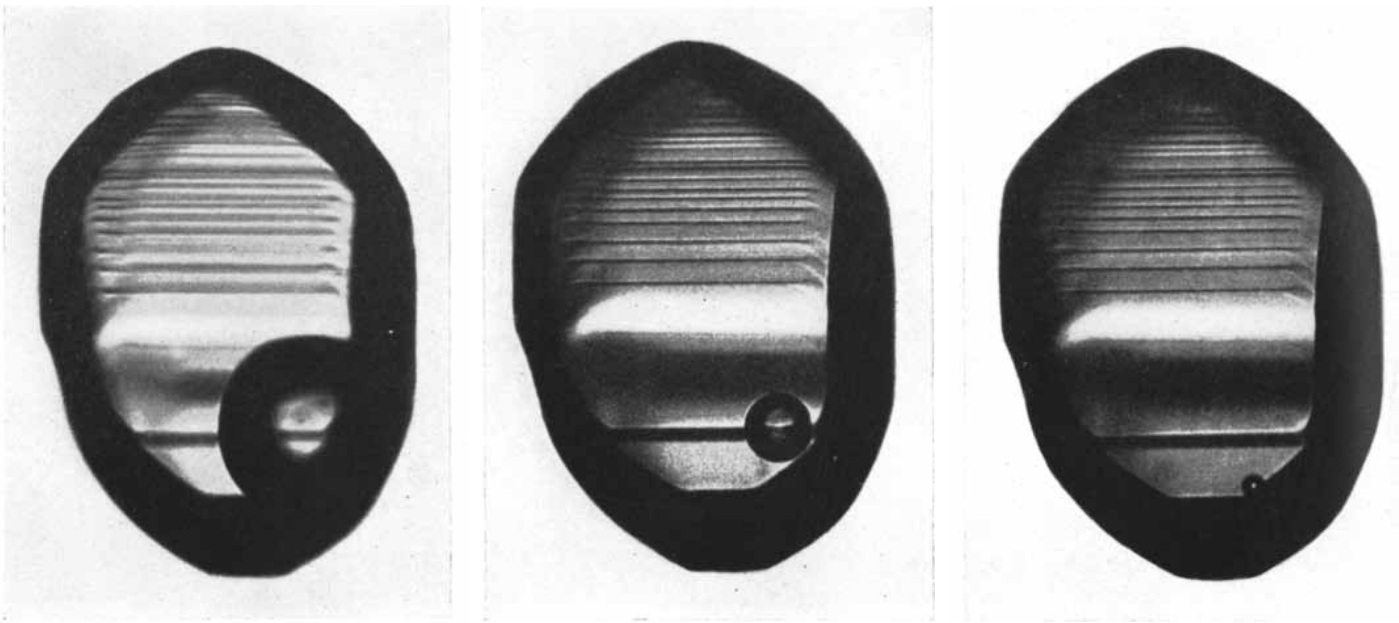
SECONDARY INCLUSIONS form in the fracture of a crystal (*a*) embedded in a liquid (*color*). Solution and redeposition of material from the liquid on the fracture surfaces results in dendritic growths (*b*), which meet and close off small volumes of liquid (*c*). These gradually lose surface area and become rounded masses or hollow negative crystals (*d*).

The finding is consistent with the fact that sodium chloride is the major saline ingredient found by analysis in most inclusion fluids. In fact, the amounts of sodium chloride, as crystals and in solution, in the fluid inclusions in many rocks are adequate to explain the known chloride content of the rocks. This was long considered a mystery because no ordinary rock-forming mineral could take chlorine into its crystal structure.

To determine the complete chemical composition of a few milligrams of inclusions, including the concentration of salts, the author and his colleagues in the U.S. Geological Survey laboratories have used a combination of methods. Small portions of the mineral, containing specific inclusions, are cut out and crushed in a high vacuum. The evaporated water and other gases from the inclusion fluids are collected and analyzed both chemically and isotopically. The crushed sample is then leached with about 10 cubic centimeters of very pure water, filtered through a special low-contamination filter and analyzed for eight to 10 elements by sensitive photometric methods. When the amounts of water and salts are known, the original concentrations of salts in the inclusions can be calculated. In general the most abundant ions are sodium and chloride, with lesser amounts of calcium, potassium, magnesium, sulfate (SO_4^-), carbonate (CO_3^-) and bicarbonate (HCO_3^-). Usually only traces of other elements are found. Both concentration and composition vary widely from one type of occurrence to another. Even single crystals from some ore deposits show significant changes in the composition of



FREEZING AND HEATING are employed in the analysis of inclusions. These photomicrographs show a liquid inclusion in sphalerite at — 29.5 degrees centigrade (*frozen solid*), — 28.5 degrees, — 3.65 degrees and — 3.15 degrees (*completely melted*). This inclusion would be said to have a "first melting temperature" of — 29 degrees and a freezing temperature of — 3.15 degrees. Horizontal



"FILLING" TEMPERATURE is that at which the liquid in an inclusion expands to fill the volume (i.e., the gas bubble disappears). Except for pressure corrections it is generally taken as the temperature at which the inclusion formed. The temperatures are

inclusions from one growth zone to the next, indicating changes in the nature of the ore-forming fluid during the formation of the crystal.

The procedure just described requires several milligrams of inclusion liquid—far more than can be obtained in uncontaminated form from many samples. In order to get information on the approximate concentration of salts in single inclusions as small as 10 microns in diameter (a billionth of a gram in weight) the author has devised a freezing stage for the microscope. The only property that depends on concentration, and that is measurable in such small inclusions, is the depression of the freezing point of the fluid. The higher the salt concentration, the lower the freezing temperature. In the author's laboratory this temperature is determined by freezing the inclusion solid, then gradually warming it while watching it through the microscope. The granular mass of solid crystals of ice and salt in completely frozen inclusions is essentially opaque. As it warms up, a small amount of liquid appears abruptly at the first melting temperature—the temperature at which the first of the various solid components melts. This fluid wets the grains of ice and salts, causing the opaque mass to become translucent. With further increase in temperature more of the solids melt until only one tiny ice crystal remains. The temperature at which it finally melts is the freezing temperature.

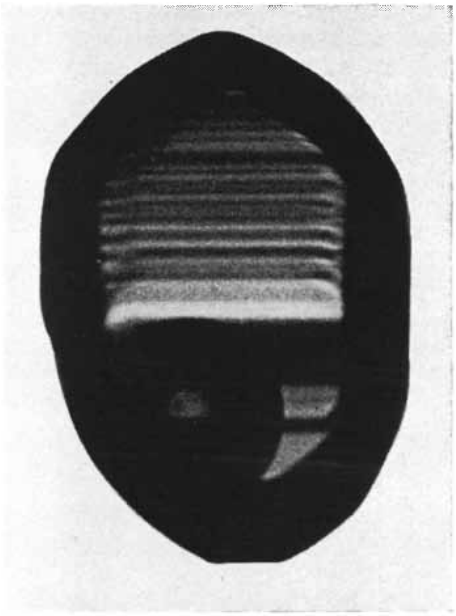
Theoretically this should also be the temperature at which the first ice crystal forms on gradual cooling, but it is not. All inclusions exhibit the phenomenon of supercooling; that is, they must be cooled considerably below their freezing point before the growth of ice crystals starts. This is true even for inclusions containing salt crystals or other crystals. Most small inclusions will remain as supercooled liquid for hours and even weeks at 30 to 40 degrees centigrade below their freezing temperatures; some, such as the inclusion in emerald shown at bottom left on page 46, have failed to freeze after a week at liquid nitrogen temperature (— 196 degrees C.). The strong brines in the emerald were finally frozen after 21 days at — 78 degrees. Their first melting temperature was — 60 degrees, which generally indicates a high concentration of calcium chloride.

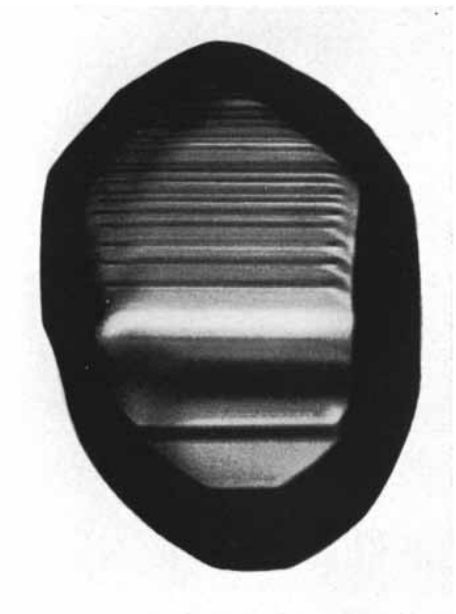
The drastic supercooling in inclusions is apparently due to the absence of extraneous particles suitable for nucleating ice crystals. Such particles are quite common in normal surface waters and in rain and snow [see "The Growth of Snow Crystals," by B. J. Mason; SCIENTIFIC AMERICAN, January, 1961], but the fluids in inclusions were generally of much deeper origin and moved at slow rates, so that practically all particles had been eliminated by one process or another before the fluids were trapped.

In 1823 the Scottish physicist Sir David Brewster described a "remarkable new fluid found in the cavities of rocks." By careful microscopy he found its index of refraction to be less than that of water, its thermal coefficient of expansion to be 30 times that of water, and he noted that it did not mix with water or wet the walls of the cavities. Later workers found that some bubbles of this liquid in otherwise water-filled inclusions could be made to sink or float in the water by adjusting the temperature. Identification of the remarkable fluid had to wait 46 years until the discovery that carbon dioxide can be liquefied. Then it became apparent that the properties Brewster had observed were precisely those of liquid carbon dioxide. The material has since been found in many crystals from certain types of geological environment.

Considerable pressure is required to liquefy carbon dioxide: at 31 degrees C., the highest temperature at which it can be liquefied at all, the pressure must be 73 atmospheres, or more than 1,000 pounds per square inch. The author has verified the magnitude of such pressures in carbon dioxide inclusions, using an adaptation of a method devised by the French mineralogist Georges Deicha. With the help of a vernier micrometer eyepiece on the microscope, the diameter, and therefore the volume, of the bubble of liquid carbon dioxide can be estimated in cubic microns (trillionths of a cubic centimeter). Then the sample is slowly crushed between heavy glass plates immersed in oil. During the process it is under continuous observation with the microscope, lighted from below through the plates. When a crack reaches the inclusion, the liquid carbon dioxide vaporizes and expands tremendously—nearly 400 volumes. The resulting bubble is big enough to measure quite accurately. As little as 10^{-14} (a hundred-trillionth) gram of liquid carbon dioxide will form a gas bubble several microns in diameter, readily visible in the microscope.

At high temperatures water and carbon dioxide mix in all proportions, and such mixtures are sometimes trapped as fluid inclusions. At lower temperatures the mutual solubilities are very low, and an inclusion that was originally a homogeneous, mixed fluid separates into two immiscible fluids, one rich in carbon dioxide, the other rich in water. On dropping still further to some temperature below the critical 31 degrees, the carbon dioxide phase separates into a liquid and a gas, giving a total of three phases. Hundreds of inclusions in a healed crack will all be divided in the same proportions, meaning that they must have been trapped as a homogeneous fluid at high temperature. On reheating they all pass in reverse through the phase changes described above. When they freeze, these inclusions develop large,





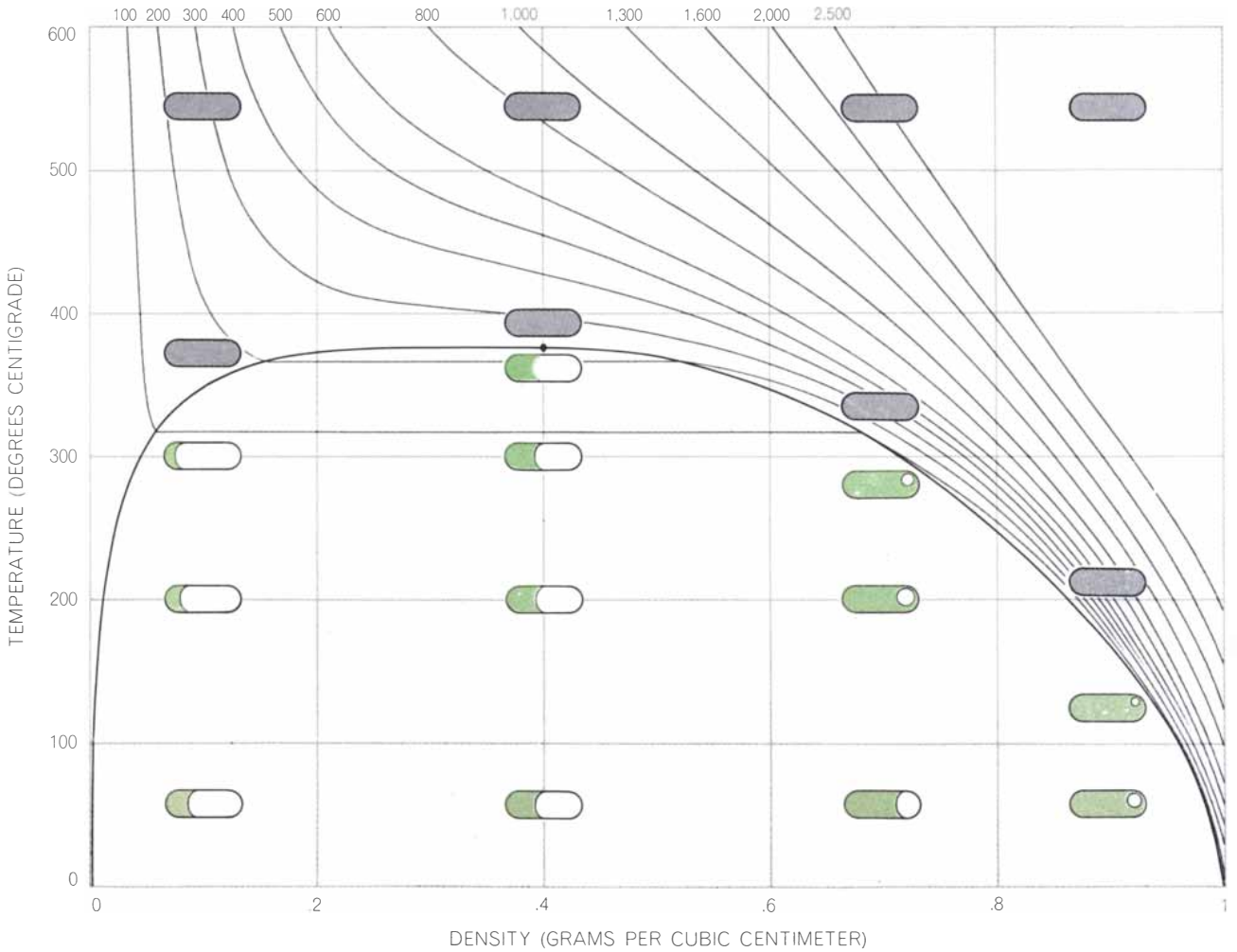
lines are striae on inclusion's inner walls. These micrographs, those below and those on following pages were made by the author.

130, 204.7, 209.8 and 210 degrees. The magnification in both sequences is 242 diameters.

almost invisible crystals of the interesting and improbable-looking compound $8CO_2 \cdot 46H_2O$, in which 46 water molecules form a kind of cage with cells for eight carbon dioxide molecules. Since these crystals are usually stable below about 10 degrees, they probably occur naturally in mixed inclusions of water and carbon dioxide in the rocks of cold climates.

In a few crystals the author has found different ratios of two immiscible fluids in neighboring primary or secondary inclusions. This is clear evidence that the two fluids were present as distinct phases while the crystals were growing. For example, there were minute bubbles of highly compressed carbon dioxide in the slightly salty water solution from which a mercury deposit in Alaska formed, and they were trapped in various ratios with the water. Globules of yellow petroleum are common in the strongly saline brines trapped as both primary and secondary fluid inclusions in the Kentucky-Illinois fluorite and zinc ores. Globules of dense organic gas were present in the liquid that gave rise to the well-known and beautifully clear quartz crystals from Herkimer, N.Y. Although generally trapped along with some brine, on occasion some gas stuck to the surface of the growing crystal and was enclosed without brine.

Not all the bubbles that are found in inclusions consist of carbon dioxide. Most of them, in fact, are water vapor. These minute gaseous cavities make possible one of the most intriguing applications of inclusions to geological problems: they serve as recording thermometers, registering ancient temperatures. More than a century ago the English geologist Henry Clifton Sorby suggested that vapor bubbles result from shrinkage of the liquid in originally full inclusions that were trapped at high temperatures and then cooled. A simple inspection of the bubbles in various samples provides qualitative confirmation of the idea. Inclusions in rocks known from independent geological evidence to have formed at relatively low temperatures have small bubbles or none at all; inclusions in rocks formed at high temperatures have large bubbles. Sorby went further than this. He reversed the process of shrinkage by warming inclusions gradually, watching them under the microscope. Eventually the bubbles disappeared. The temperature at which each one vanished—the "filling" temperature—he took to be the temperature at which the inclusion had originally been trapped millions or even billions of years ago.



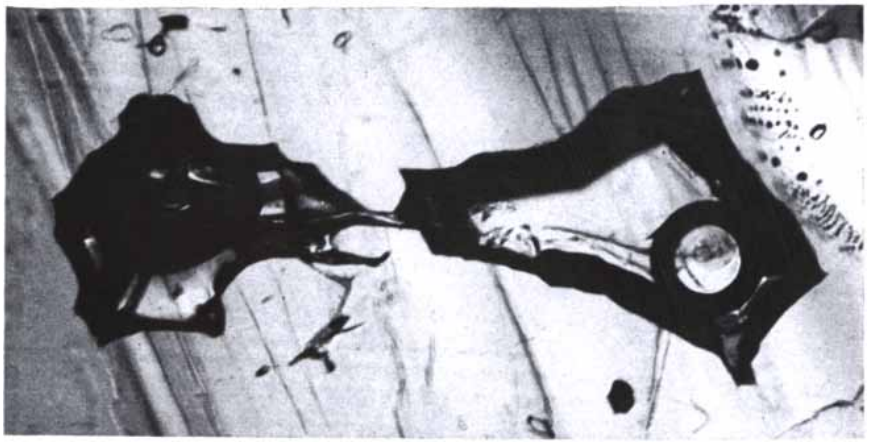
THERMAL BEHAVIOR of four inclusions (*four vertical rows of "capsules"*) that have different liquid-to-gas ratios is superimposed on the phase diagram for pure water. Numbers at top indicate atmospheres of pressure. The density of each inclusion is the volume of liquid (*dark color*) at 0 degrees C. divided by the volume of the inclusion. The liquid-to-gas ratio tends to change with temperature; at a certain temperature for each inclusion the two phases become a single homogeneous fluid (*gray*). In an inclusion with a density of .4 the ratio remains unchanged; at the critical temperature (*dot on solid black line*) the curved meniscus (*dotted line*) between the phases suddenly fades and disappears. The inclusion is now a supercritical fluid (i.e., no amount of pressure alone will cause it to liquefy). The black curve separates two-phase (*light color*) from single-phase region; salts in solution will generally raise the curve.

Some minerals have primary inclusions with large bubbles and secondary inclusions with small ones, indicating that the temperature dropped after crystallization; many crystals with distinct growth zones show lower filling temperatures for primary inclusions in the outer, last-formed zones than for those in the core. Crystals of daughter minerals present in inclusions dissolve on heating and thus may also be used as geological thermometers, giving minimum temperatures of trapping.

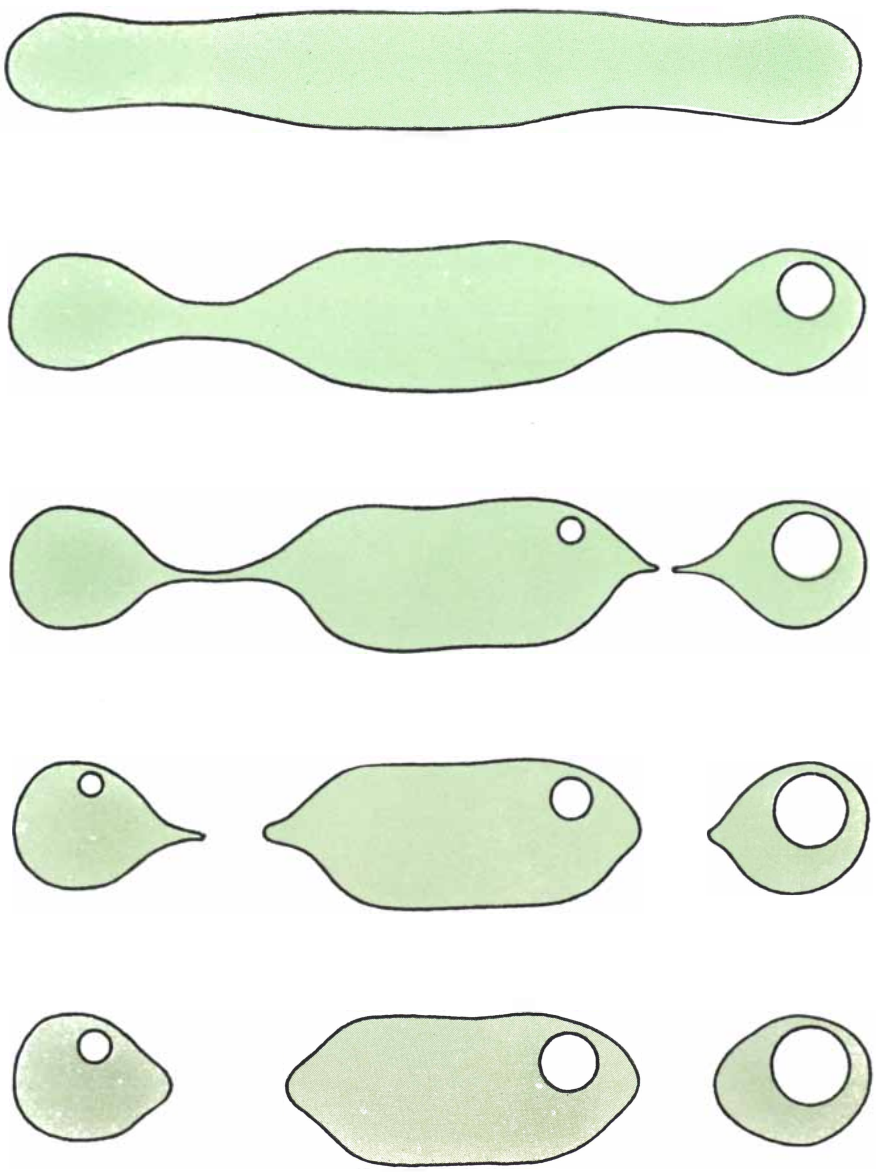
Sorby's experiment gives the true temperature of formation only if the liquid was at its boiling point when it was trapped. In that case the slightest shrinkage would have produced some vapor. If, however, the liquid was under more than sufficient pressure to prevent its boiling, it would have had to cool enough to relieve the excess pressure before it could begin to shrink and form vapor. Accordingly the temperature at which the vapor disappears on warming would be lower than the trapping temperature. From other geological evidence it is often possible to estimate the depth at which the rock sample was formed and therefore the pressure on the liquid. Where this is known, the apparent filling temperature can be corrected to give the true value. There is some evidence that occasionally fluid may leak into or out of inclusions, and that the recrystallization of inclusions with the passage of time may sometimes result in anomalous filling temperatures, but generally these situations can be recognized. One particularly useful check on the whole procedure comes out of studies of the inclusions in synthetic crystals, such as quartz, made under known high temperatures and pressures. These inclusions fill at the correct temperatures.

At room temperature the vapor pressure of water is very low and so a vapor bubble in an inclusion is practically a vacuum, like the "bubble" of mercury vapor at the top of a mercury barometer. This was first discovered by Davy, who pierced some large inclusions while the crystals were immersed in oil and found that the oil was drawn in and the bubbles contracted greatly. In many inclusions on which the author has performed the same experiment the bubbles disappeared completely and instantaneously, indicating that they must have contained considerably less than 10^{-14} gram of noncondensable gases—less than a billion molecules.

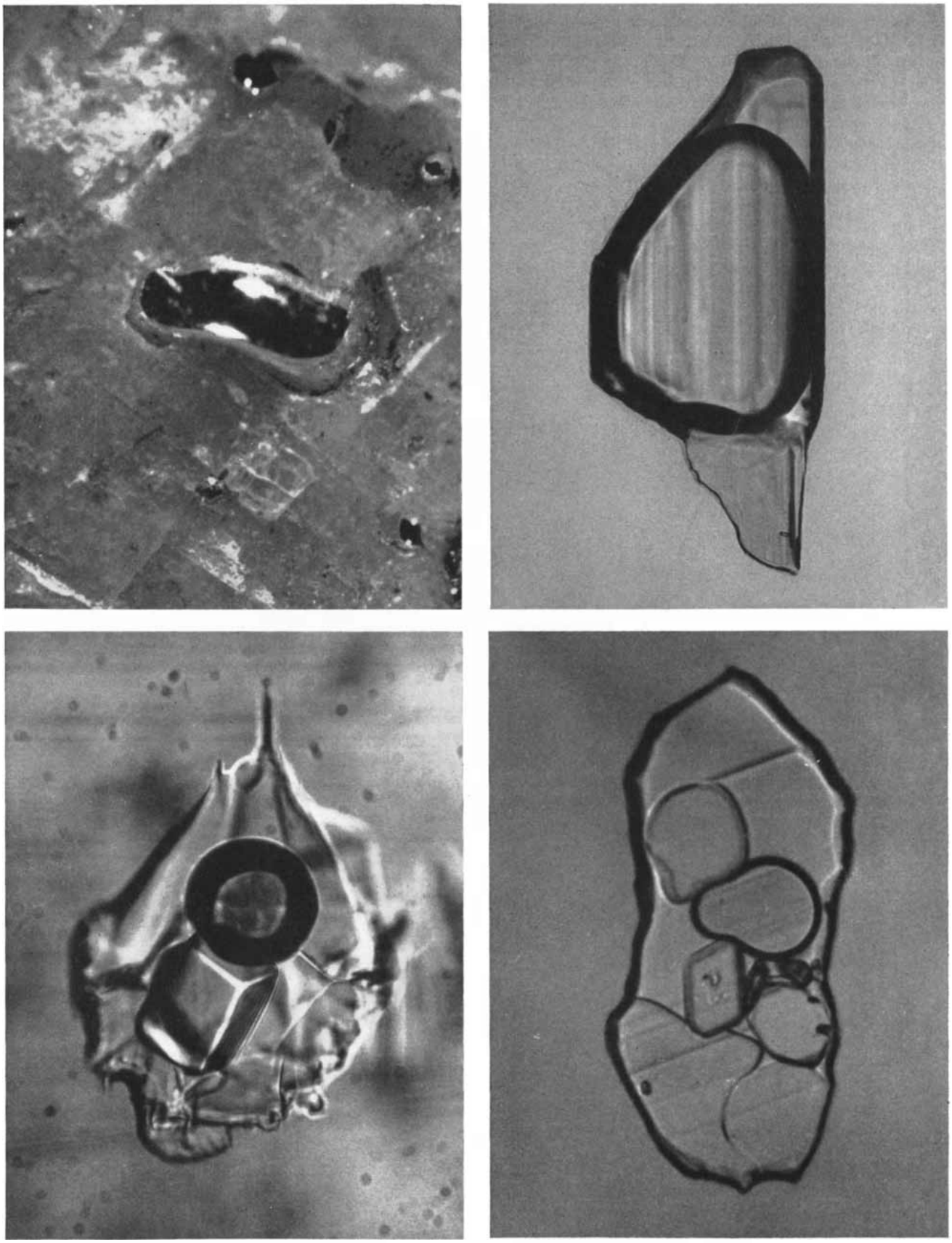
When an inclusion with a bubble is heated, the pressure in it—the vapor pressure of the water solution—increases



SINGLE INCLUSION in topaz at a late stage in the process of "necking down" is magnified approximately 57 diameters. The two parts, one of which contains a large gas bubble and daughter-mineral crystals and the other a small bubble, are still connected by a thin tube.



NECKING DOWN of an inclusion with time from its original state (*drawing at top*) into three inclusions (*bottom*) is depicted. Each stage occurs at a higher temperature than the one below it. If reheated to determine temperature of formation (*see lower illustration on pages 42 and 43*), one at right would yield too high a value; the others, too low. If the process occurred while crystal was at formation temperature, all would give correct value.



NUMBER OF PHASES in an inclusion varies. The black oblong area at center of micrograph at top left is liquid metallic mercury in calcite. At top right is a two-phase inclusion, in an aquamarine crystal, consisting of a large gas bubble and a smaller volume of liquid above it. The three-phase inclusion in emerald at bottom left consists of a cubic crystal of salt and a carbon dioxide bubble under pressure, both surrounded by a strong brine. At bottom right is a multiphase inclusion, from a magnesite crystal, with a pear-shaped gas bubble, a liquid phase and six solid phases. Respective magnifications of the micrographs are 27, 277, 520 and 366 diameters.

rapidly, reaching one atmosphere at 100 degrees C., 15 atmospheres at 200 degrees and 218 atmospheres at 374 degrees, the critical temperature above which water cannot exist as a liquid. The build-up of pressure in large inclusions, or in planes of many small ones, can cause a series of little explosions that make the sample decrepitate, or crackle. If the more compressible gas bubble disappears before the critical temperature is reached, the pressure increases even faster and decrepitation becomes more probable.

In 1870 the German petrographer Ferdinand Zirkel used decrepitation to demonstrate the presence of sodium in inclusions. The experiment is an elegantly simple one that anybody can do. A sample such as a sliver of ordinary white quartz is held in a clean, blue Bunsen burner flame. As the crystal decrepitates one can see tiny, bright flashes of yellow light signaling the explosion of microscopic quantities of sodium-laden steam in the flame. Measurements made in the author's laboratory indicate that as little as a ten-billionth of a gram of sodium will yield a flash visible to the unaided eye.

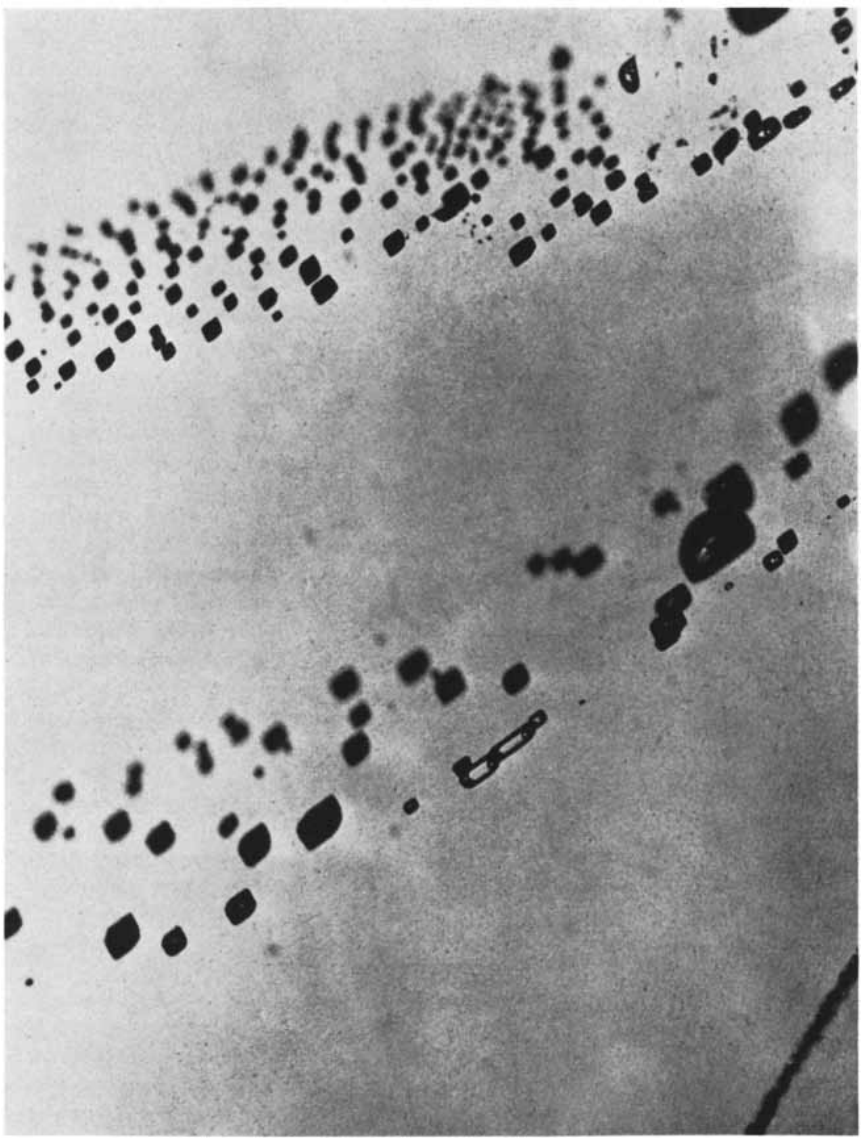
In 1948 a group of workers at the University of Toronto hit on a way to make decrepitation experiments more quantitative. H. S. Scott, P. A. Peach and F. G. Smith recorded the number of explosive sounds at various temperatures by placing a microphone at the end of a tube containing granules of the mineral sample. The peaks in these "decrepigrams" are taken to represent the filling temperatures of various homogeneous groups of inclusions. Many U.S. geologists have questioned the significance and interpretation of the recordings, but the method has been enthusiastically adopted in the U.S.S.R. In fact, the study of fluid inclusions in general has been much more actively pursued in the U.S.S.R. than it has in this country.

One of the most important geologic processes, from man's point of view, and one of the least well understood, is the formation of ores. There must have been a number of different mechanisms whereby metals were removed from dilute sources (rock or magma), transported and finally deposited as a concentrated mass. In many cases water solutions were involved, and here inclusions have been able to offer invaluable help in reconstructing the narrative.

Perhaps the most difficult problem is to understand how minerals, which in general have low solubility in water, were carried by the fluids in concentrations large enough to produce ore deposits. They must have combined with other materials in complex ions yielding higher solubilities, but the nature of many of these complexes is not known. Their formation would partly depend, however, on the salts that were present in the fluids. Therefore the analysis of inclusions may throw some light on the whole chemical cycle involving the formation and transport of the complexes and the conditions under which they eventually broke down, causing the precipitation of ores.

Some rich ore bodies appear to have separated as a result of boiling in rising hot fluids. Inclusions provide the only evidence as to the density of the fluids. Such information might thus help to predict the "bottoming" of the ores—an abrupt pinching off at a certain depth.

Inclusions can help the geologist in many ways in his task of understanding geologic processes long since discontinued, an understanding that is essential to the intelligent search for ores. As Sorby wrote in his classic paper on fluid inclusions, "there is no necessary connexion between the size of an object and the value of a fact, and . . . though the objects I have described are minute, the conclusions to be derived from the facts are great."



TWO HEALED FRACTURES in quartz (magnified 14.8 diameters) contain numerous secondary three-phase inclusions. Phases can be seen in the flattened pair of inclusions at center that resemble paper clips: liquid (*light oblong areas*) and gaseous carbon dioxide (*two adjacent light circular areas*), and saline water (*tiny light area at upper right*).

SURGICAL STAPLING

Ingenious adaptations of a simple fastening device are finding new applications in surgery. They include staplers designed for joining together the ends of severed blood vessels and nerves

by R. F. Mallina, Theodore R. Miller, Philip Cooper and Stanley G. Christie

The staples that hold together the pages of this magazine demonstrate one application of a simple mechanical fastening device that first came into use two centuries ago in France. Whether mechanized for mass production operation, as in a bindery, or designed for manual use in home or office, a stapler consists basically of a pusher that forces the two ends of a U-shaped length of wire through the objects to be joined and, usually, an anvil that bends the ends so that the staple grips the objects. In the two centuries since it was invented the stapler has found so many uses in the office, factory and home that perhaps 100 million staplers are in service today in the U.S. Recently this versatile tool has begun to find its way into the hospital operating room. Even some surgeons are not yet aware that a stapler can be used to join severed intestine, blood vessels and other tubes, as well as nerves, bones and other anatomical structures, with more speed, safety and accuracy than even the highly trained hand of the master surgical craftsman.

The history of surgical stapling goes back to 1922, when Aladàr Von Petz, a Budapest physician, constructed a stapler in an effort to reduce the incidence of peritonitis as a sequel to surgery of the stomach or intestines. This infection of the lining of the abdomen resulted from spillage of the bacteria-laden contents of these organs and was usually fatal in those days. The Von Petz stapler placed two parallel rows of staples close together across the stomach for operations in which part of the stomach was to be removed. The surgeon cut between the rows and the staples prevented any leakage. Although antibiotics and improvements in surgical technique have drastically reduced the danger of peritonitis, improved versions of the instrument remain in use because they shorten the time during which the patient must remain under anesthesia.

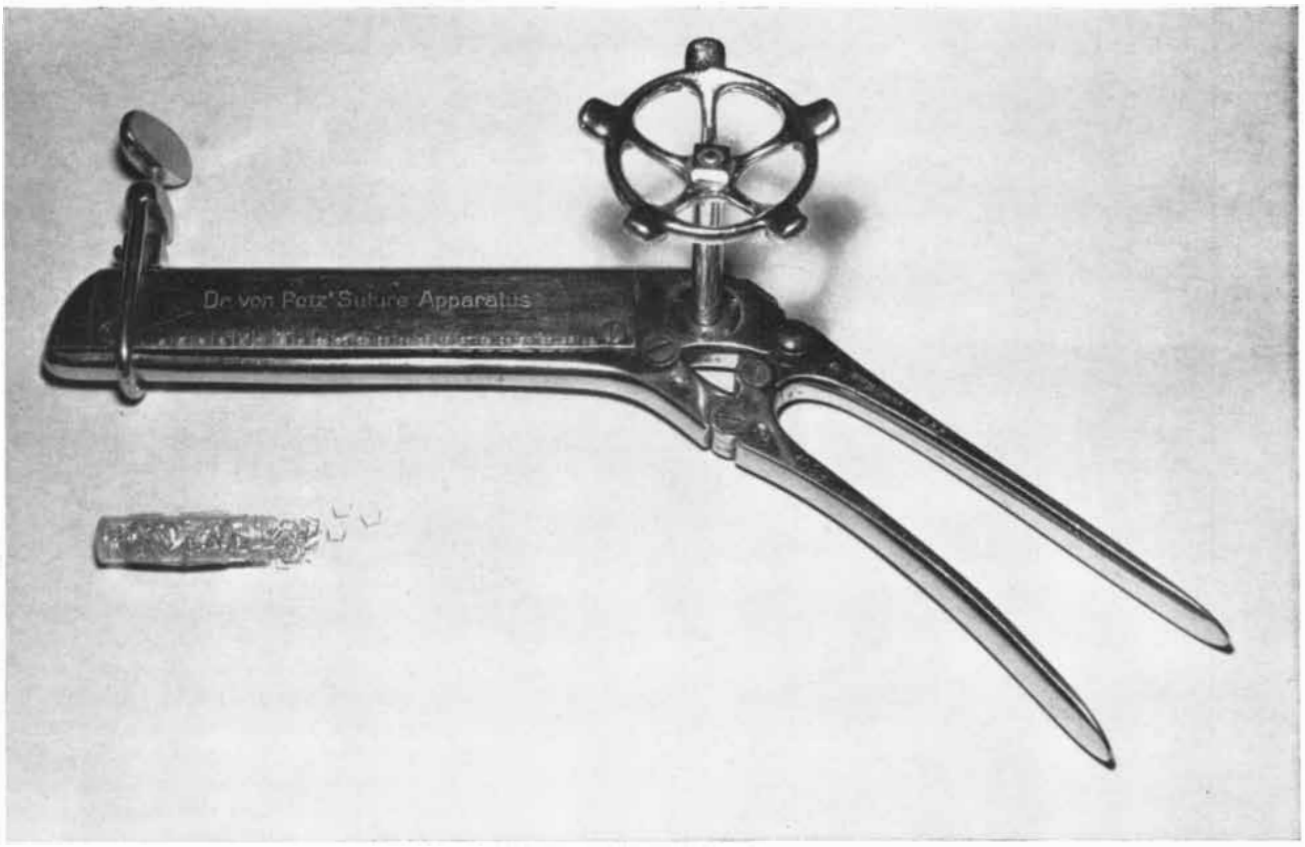
The most extensive development of surgical stapling has come in the U.S.S.R. In 1941 V. F. Gudov, a Soviet engineer, began to design a device for stapling together the ends of blood vessels. His early staplers were successful enough to advance the possibility that general surgeons equipped with such instruments might be able to perform technically difficult feats more simply and rapidly. This would bring to patients throughout the country the skills usually found only in larger medical centers. In 1952 the Soviet Ministry of Health established in Moscow the Scientific Research Institute for Experimental Surgical Apparatus and Instruments, where engineers, physicians and technicians work in close collaboration. Among other things, they have produced at least 15 different staplers that are now available to hospitals in the U.S.S.R. and to users abroad. All employ staples made of the metal tantalum, which does not react with body tissues and fluids. The staples (like silk, certain man-made fibers and other suturing materials) can remain in the body permanently. Some of the staplers insert one staple at a time. Others are special-purpose instruments that deliver all the necessary staples at the same time.

One of the instruments employs staples to close the stump of the bronchial tube after surgery for the removal of all or part of a lung. The problem here is to close off the bronchus so that air cannot leak into the pleural cavity. If the surgeon ties the sutures of catgut, silk or wire too tightly, they will cut off the circulation of blood and kill the tissue, allowing the stump to reopen. If the stitches are not tied tightly enough or are too far apart, a leak may develop. The Soviet stapling device closes the bronchus almost instantly with the right amount of pressure and the right spacing between the staples. The director of the Scientific Research Institute, M. G. Anan'yev, reports that removal of a lung takes only 90 minutes when staplers are used, compared with as much as four hours without them. Mark M. Ravitch, a lung surgeon at the Baltimore City Hospitals, has used the Soviet instrument in several dozen cases. He finds that it gives an excellent closure, particularly when the stump is so short that the open end lies near the trachea.

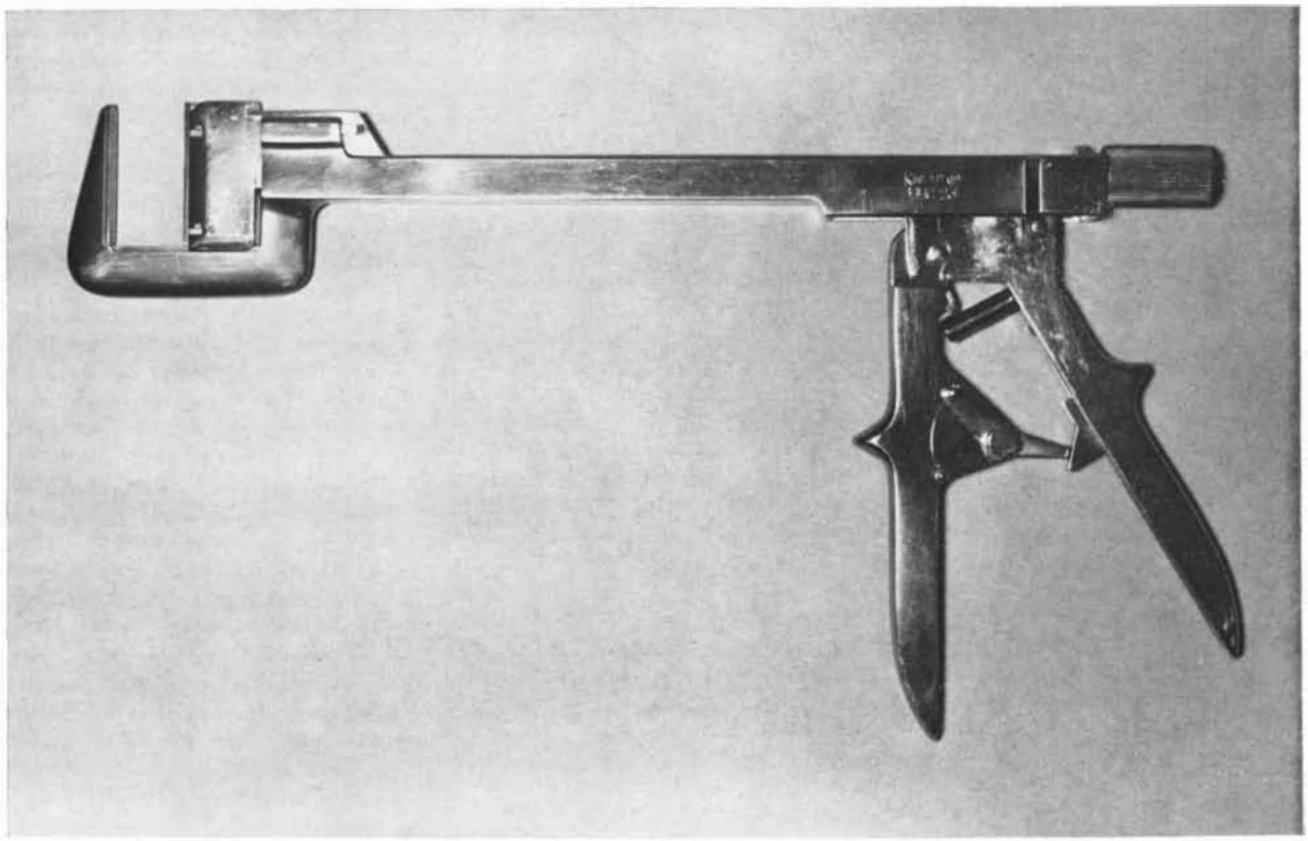
Another Soviet stapler is used directly on the heart. Some operations, such as the freeing of the leaves of a heart valve that have become stuck together, involve the opening and closing of one of the auricular pouches, small pockets that extend from each of the auricles. The closing of the auricular pouch can be accomplished simply and quickly by a row of staples. Adrian Kantrowitz, director of cardiovascular surgery at Maimonides Hospital in New York, has employed the Soviet auricular-appendage stapler with success in a number of cases.

Other Soviet staplers connect severed ends of the intestine, of the ureter and of other tubes. One even attaches ribs to the breastbone. The most interesting and potentially the most useful, however, is the blood-vessel stapler. Actually it can be used for any sort of tube from 1.3 to 15 millimeters (1/20 to 3/5 inch) in diameter. It even has adapters that enable it to be used in rejoining severed nerves as small as one millimeter in diameter. Other adapters make it possible to join the end of one blood vessel to the side of another.

It is the development of the blood-

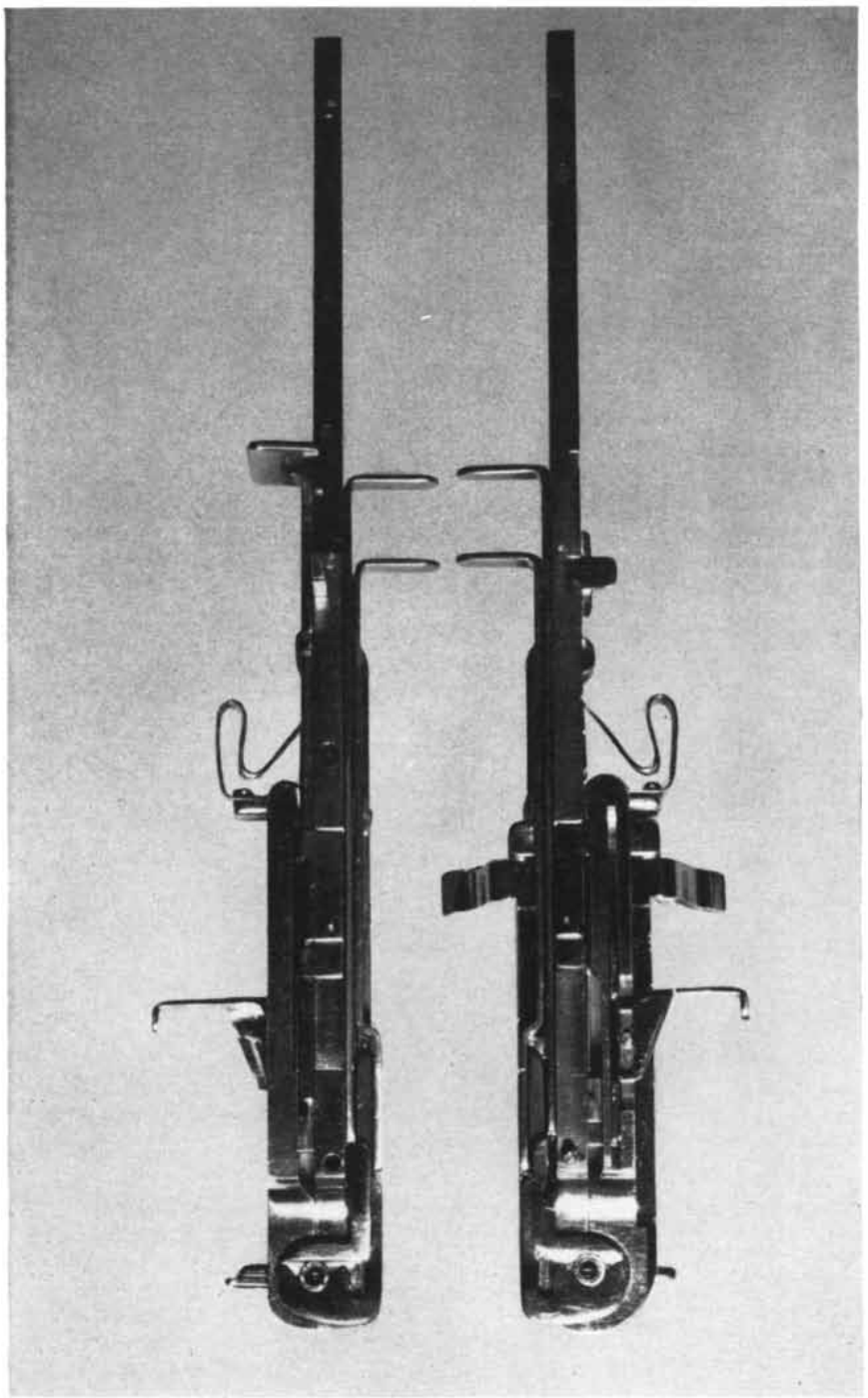


VON PETZ GASTRIC STAPLER, shown at slightly less than one-half actual size, was invented some 30 years ago and is still used in operations for the removal of portions of the stomach and the intestine. The section bearing the inventor's name holds the staples; it is closed against the anvil by means of the screw clamp at left. Turning the wheel forces the staples out against the anvil.



CARDIAC STAPLER, frequently used in heart operations that require the sealing off of an auricular appendage, is shown at about one-half actual size. Knurled knob at right adjusts gap between staple cartridge and anvil; squeezing the handles injects staples.

vessel stapler that has attracted most interest outside of the U.S.S.R. The success of the instrument has stimulated parallel efforts in other countries. I. J. Vogelfanger of the University of Ottawa and W. G. Beattie of the National Research Council of Canada have demonstrated a simplified instrument of their own design for stapling small blood vessels. Kiyoshi Inokuchi of the Kyushu University faculty of medicine, Julian A. Sterling of the Temple University School of Medicine and Timothy Takaro of the Veterans Administration Hospital in Oteen, N.C., have published reports on instruments of a similar kind. The feasibility of blood-vessel stapling may now be regarded as established, although the profession in general has yet to be persuaded of its usefulness. Of the various designs, the Soviet instruments have had the most extensive use, both in the operating room and in the laboratory.

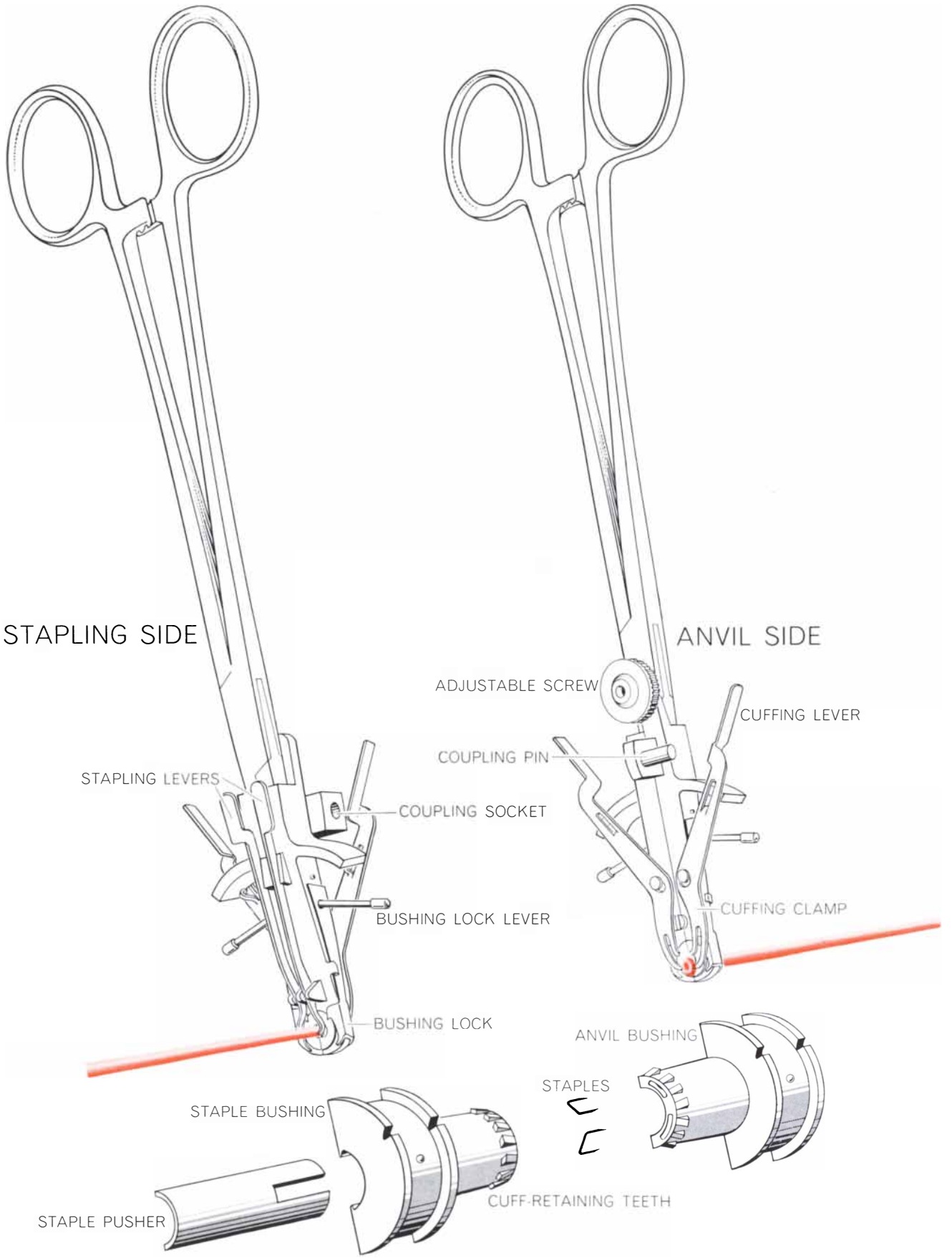


SOVIET VASCULAR STAPLER, like the American stapler designed by Mallina (*see illustration on opposite page*), consists of anvil and staple halves (*left and right respectively*). The Soviet instrument (shown approximately one-fifth larger than actual size), besides being a great deal more complicated, also presents greater maintenance problems.

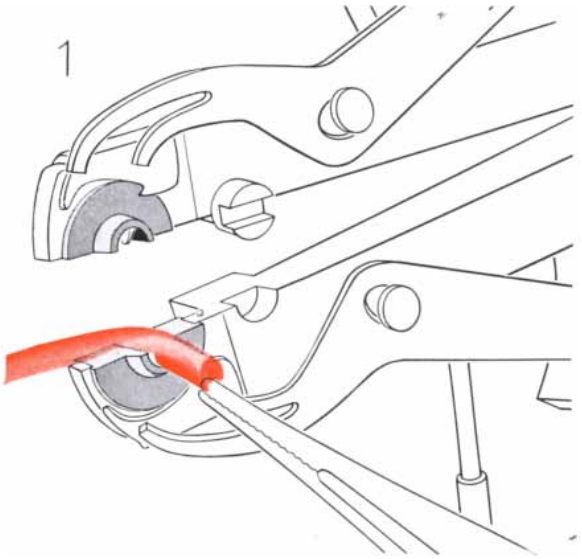
The skilled vascular surgeon can rejoin the ends of larger vessels, four or five millimeters or more in diameter, by hand-sewn sutures. The work is time-consuming. The surgeon may have to insert, one at a time, as many as 30 stitches, and he must tie each stitch before inserting the next one. In most cases, when the surgical technique has been good, the rejoined vessels function adequately. Smaller vessels can also be sewn together by hand, but the stitches almost invariably protrude into the otherwise smooth lining of the vessel and may cause the formation of a blood clot that cuts off circulation. In the absence of a clot a frequent complication is a narrowing of the vessel, which decreases the flow of blood. For the smaller blood vessels only the most exacting techniques, involving the use of a low-power binocular microscope, can prevent such complications. The rejoining of one small artery takes 15 minutes or more. In Boston recently surgeons were able to sew back a boy's arm that had been completely severed at the shoulder. The blood vessels at the shoulder are larger than four millimeters in diameter. A recent attempt in New York to rejoin a severed hand just above the wrist failed because the vital arteries there are only about 1.2 to two millimeters in diameter. The surgeons sewed them together but clotting cut off the flow of blood.

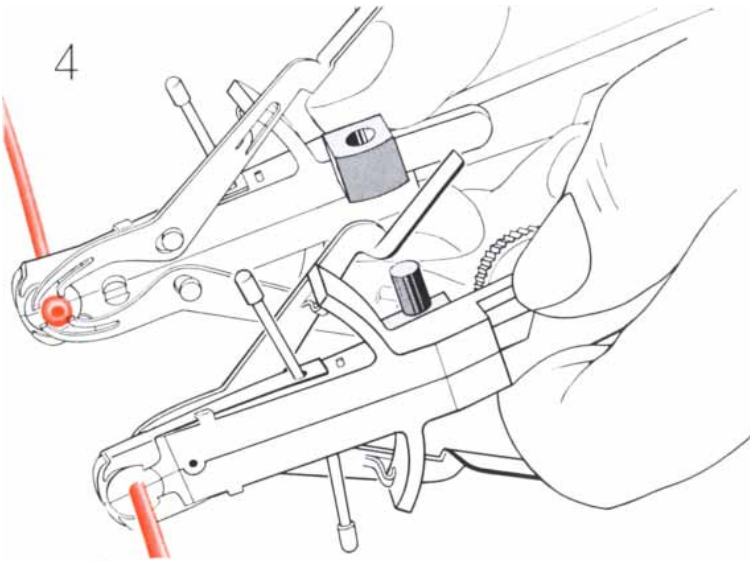
One of the authors (Miller) specializes in surgery for cancer, particularly cancer of the pancreas. He became interested in the Soviet blood-vessel stapler because these operations frequently involve the need to sever and then reconnect important arteries. In removing the pancreas, for example, it is often necessary to take out a section of the artery that supplies blood to the lower small intestine. This artery is only four millimeters in diameter—too small to suture successfully by hand. Malignancies in the neck and elsewhere also often compromise small vital arteries and confront the surgeon with difficult decisions.

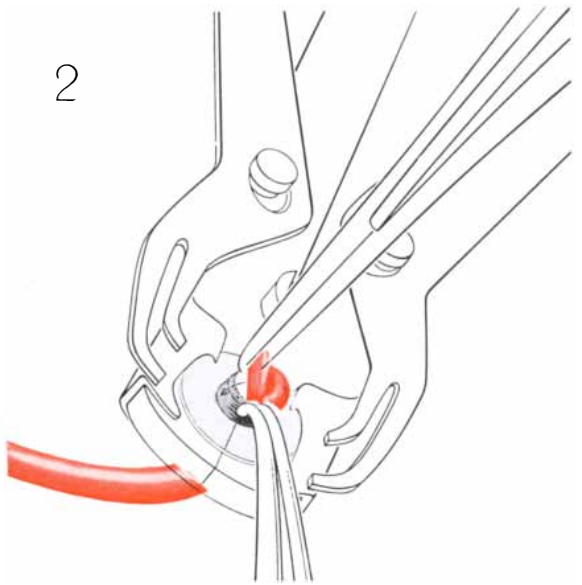
Sometimes it is necessary to remove the esophagus. A rather intricate operation now makes it possible to replace the esophagus with a segment of small intestine taken from the same patient. The small intestine receives its blood from arteries in the mesentery, the sheet of tissue that suspends the intestines from the rear wall of the abdomen. Along with the piece of intestine, the

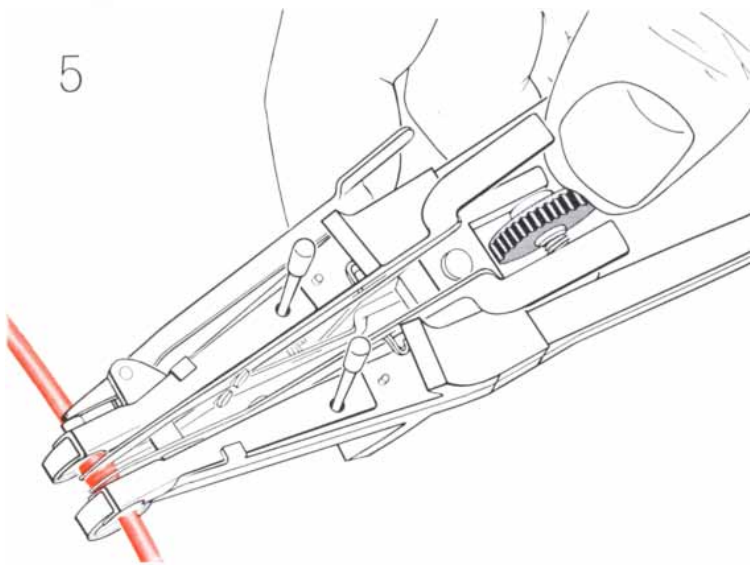


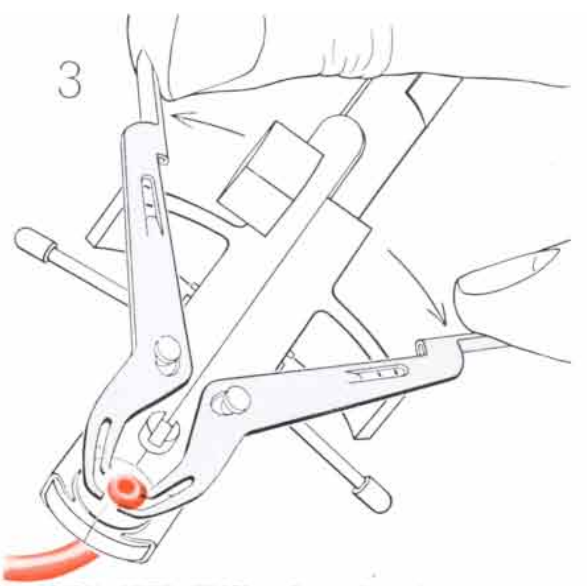
AMERICAN STAPLER consists of stapling and anvil halves. One half of the staple and anvil bushings are shown enlarged at bottom. Each of the two stapling levers controls one half of the staple pusher, which in turn drives the staples against the anvil bushing. Two cuffing clamps on each half help to prevent the blood vessel (*color*) from pulling out of the bushing once it is set in place.

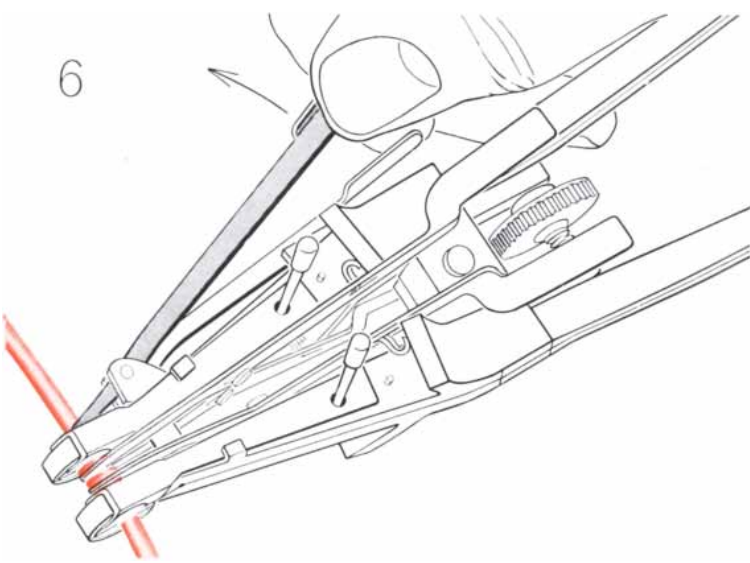




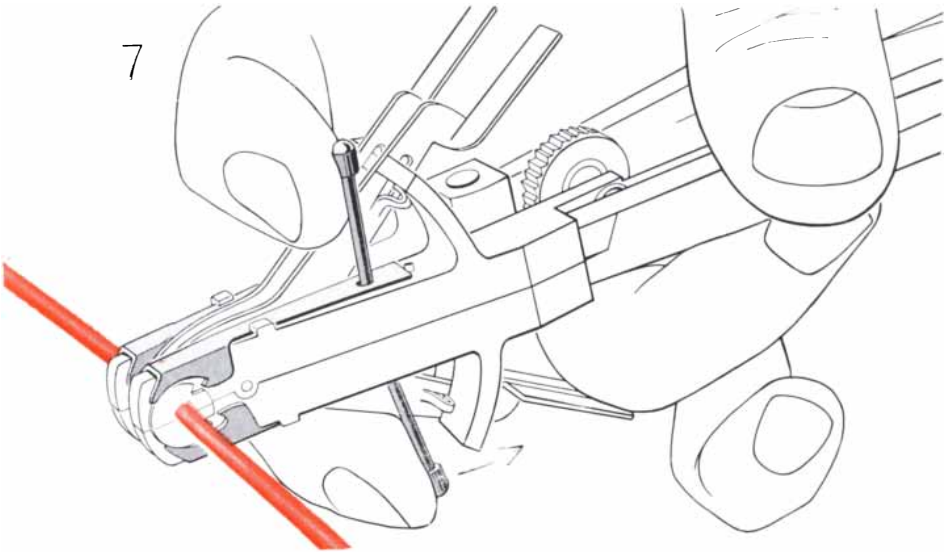


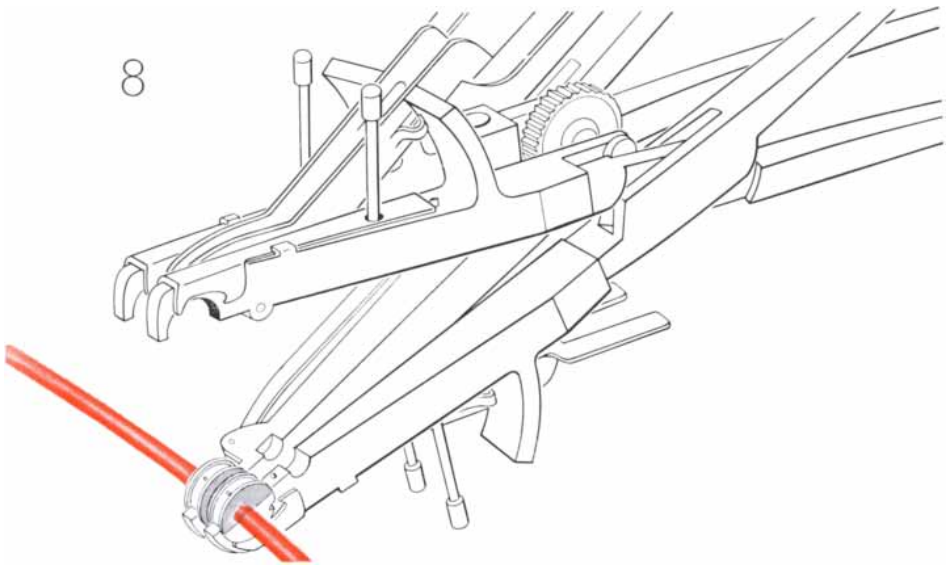


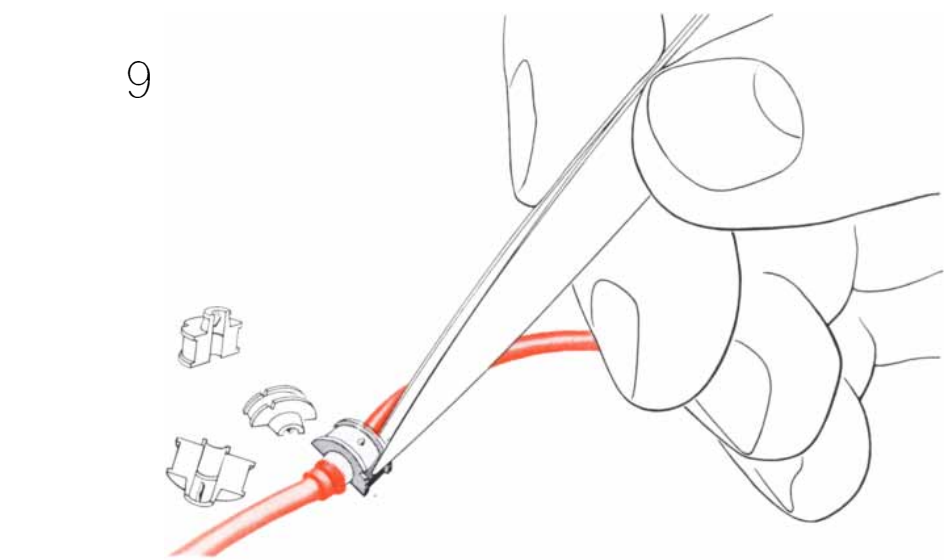




STAPLING OPERATION is depicted in the nine drawings on these two pages. One end of a blood vessel is laid in the groove of one of the bushing halves (*1*); the other bushing half is locked over it and the vessel end is folded over to form a cuff around the bushing tip (*2*); two cuffing clamps are closed on the cuff (*3*). This procedure is repeated with the other end of the vessel, using the other half of the stapler. The two halves of the instrument (*4*) are then joined by setting the coupling pin of one in the coupling







socket of the other. The vessel ends are brought firmly together by means of the adjustable screw (*5*); the surgeon forces the staples through the cuffs by pressing the staple levers (*6*) and releases the bushings by pressing the bushing levers (*7*). The instrument is then opened and removed (*8*) and the bushing halves are picked from under the cuffs (*9*).

surgeon must transplant a part of the mesentery containing blood vessels. It may be necessary for him to join an artery in the mesentery to one from the chest wall or neck. The arteries are about 1.2 millimeters in diameter, and a mechanism for connecting them quickly and smoothly would ensure success in the operation.

After trying for two years without success to obtain a vascular stapler from the U.S.S.R., Miller turned for help to David Rose, a New York builder with an interest in medical matters. Rose made the necessary contacts in Moscow and late in 1959 sent an emissary to pick up two vascular staplers for work on blood vessels in two different size ranges. After gaining experience with these instruments in operations on experimental animals, Miller used them in surgery on four human patients, two with pancreatic cancer and two with cancer of the head and neck. All the operations were successful.

In designing their staplers the Soviet technicians and surgeons decided that stapling must take less time than manual suturing and must provide a suture that causes little damage to adjacent tissues and organs. They decided furthermore that the quality of the suture must not depend on the abilities of the surgeon. The instrument, in other words, had to be virtually foolproof in the hands of any surgeon.

Miller and other U.S. surgeons who have used the vascular staplers (including two other authors of this article, Christie and Cooper) agree that the Soviet instruments meet these requirements. In our opinion, however, they are unnecessarily complicated, consisting as they do of 21 separate pieces that must be taken apart and cleaned after each operation. The parts are machined to such fine tolerances that they all have to be at the same temperature to fit back together. One reason for the complexity of the Soviet staplers is that their various units slide into, over or around each other. More important, the barely visible staples (the wire is about as thick as a human hair) must be loaded under a binocular magnifying glass, a task that requires almost daily practice if it is to be done quickly. Four to eight staples must be loaded for each application. Cleaning, loading and sterilizing a stapler takes several hours. It would be difficult to manufacture such devices in quantity in the U.S., where skilled labor is so costly, and almost impossible to employ them regularly in U.S. hospitals, which suffer from a chronic lack of

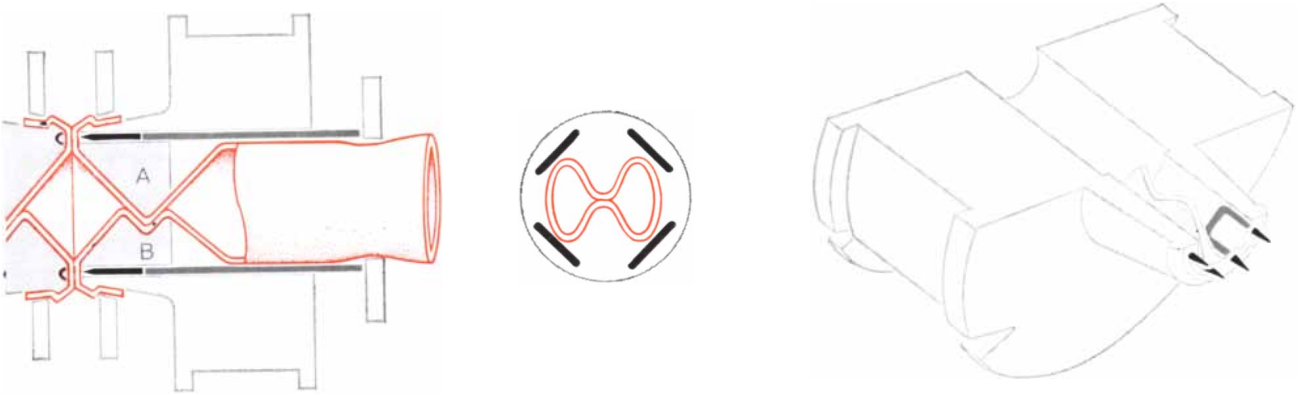
skilled technical personnel. (Visiting Soviet surgeons who demonstrated the staplers on experimental animals in the U.S. in 1961 brought along a graduate engineer to take care of the instruments.) No one in the U.S. knows how widely vascular staplers are being used in the average Soviet hospital.

When it became apparent that the Soviet vascular staplers would not meet U.S. requirements, Rose set up a nonprofit organization, the Foundation for Medical Technology, to design new staplers and to enter other fields in which engineers and physicians should be working together. One of the authors of this article (Mallina) is an engineer, and he joined the group to work on the stapler. After two years he has produced a model that we believe is just as effective as the Soviet device and much simpler. It should be added that the Soviet developments in this field have inspired physicians elsewhere in the U.S., Canada and Japan to undertake similar efforts.

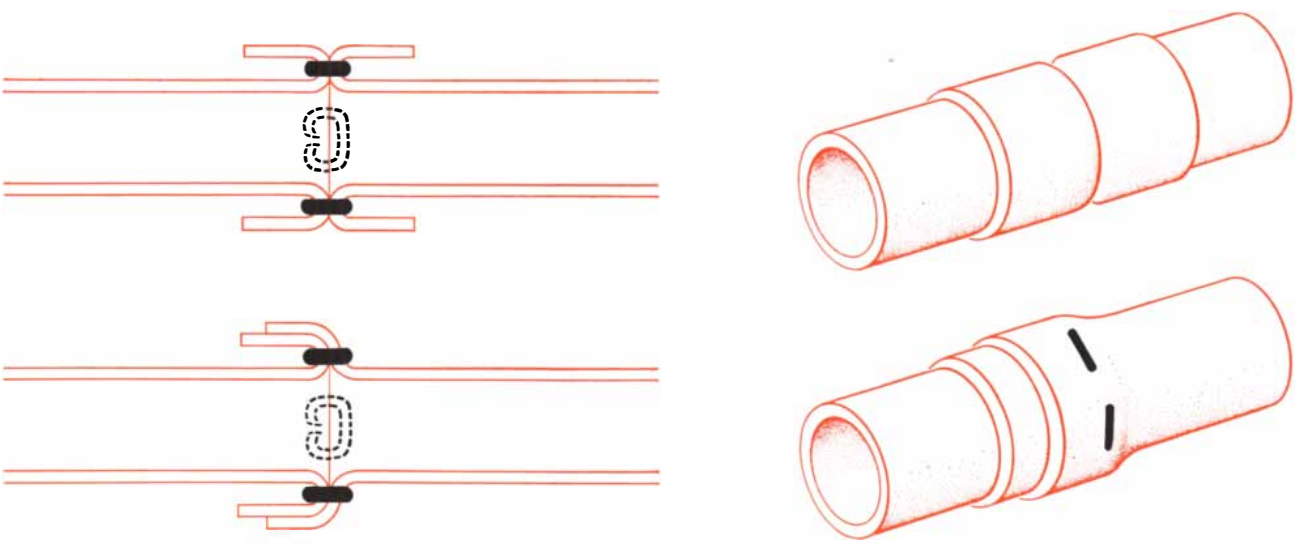
We found that the heart of the problem was the heart of the instrument: the cartridge, or "bushing," that holds the staples and the corresponding anvil against which the staples are pressed. To understand why this is so, it is necessary to consider how the stapler works.

Each vascular stapler has half a dozen different cartridges and corresponding anvils of graduated inside diameters for blood vessels of different sizes. In the Soviet instruments these units are made of stainless steel and are quite expensive to produce. (The slot that holds the staples is not much wider than a human hair.) Foreign users of the Soviet instruments receive only one set of cartridges and anvils for each stapler, and spare units have not yet been made available.

Each cartridge and anvil consists of a ring divided into semicircular halves. The two cartridge half-rings each contain two to four tiny compartments for the staples. An end of the blood vessel is laid in the tiny groove of one of the half-rings; then the second half-ring is brought down and locked in place over the vessel so that the cartridge forms a complete ring, or collar, around the vessel. The end of the vessel projects several millimeters beyond the collar. The surgeon folds this end back, exposing the lining of the vessel and forming a cuff around the tip of the staple cartridge. In the Soviet instrument two clamps are next brought to bear on the cuff to hold the vessel in place. The other vessel end is similarly collared, cuffed and clamped to the anvil unit, the whole procedure taking only a minute or so.

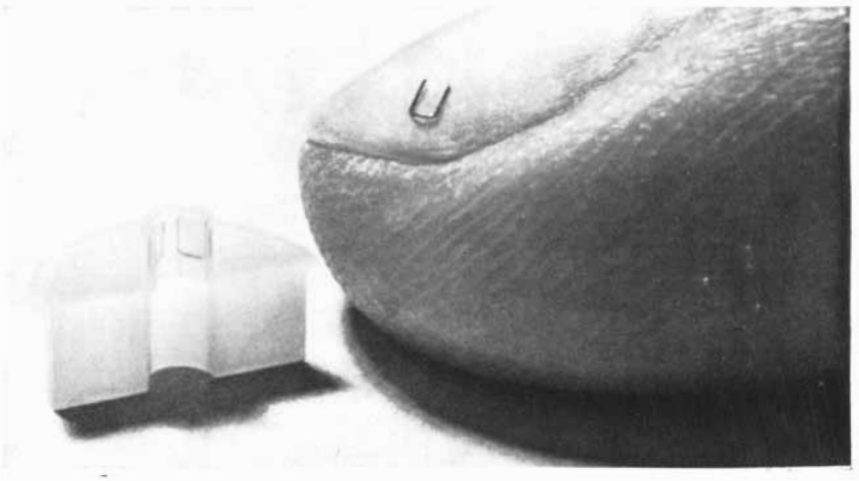


VESSEL IS HELD in the bushing by two vessel teeth (*A and B*) and a pair of cuffing clamps. In the longitudinal section at left the two ends of the vessel, cuffed and clamped, have been brought together. Cross-sectional view in middle shows the configuration of the vessel inside the bushing. The perspective view at right shows the staple bushing half containing the lower vessel tooth.



AFTER CUFFS ARE STAPLED one of them is rolled back over the other. In the longitudinal section at top left the broken black line represents the positions of the third and fourth staples with respect to the other two, which appear in black. The section at bottom left shows one cuff rolled over the other. The two corresponding perspective views are at top and bottom right respectively.

Then the two halves of the stapler are clamped together, with the result that the cuffed ends of the blood vessels meet firmly and exactly [*see illustration on pages 52 and 53*]. The surgeon presses two levers operating two pushers that force the staples through the cuffs formed by the blood-vessel ends and against the anvil, which bends the legs of the staples into a flattened "B." In the American instrument another control releases the cartridge and anvil ring from the rest of the stapler. The stapler is then removed from the surgical field. The surgeon now carefully picks the four half-rings from under the blood-vessel cuffs. He unrolls one cuff so that it forms a tube around the other cuff, and in a matter of minutes the blood vessel has started to heal. No part of any staple enters the sensitive interior region of even the smallest blood vessel; fibrous tissue fills the hairline groove where the two ends have been joined. The interior of the vessel later shows almost no signs of a scar. It would be possible to remove the staples afterward, but since the metal is quite inert there is no point in doing so.



HALF OF BUSHING used in the American stapler has an inside diameter of about 1/16 inch. The object on the finger is a staple. The tip of the bushing holds two more staples.

We decided that for use in the U.S. the cartridge and, if possible, the anvil would have to be inexpensive and disposable. The du Pont plastic Delrin seemed suitable for a cartridge, if anyone could mold it to the fine tolerances needed. Fortunately the Hoffer Plastics Corporation of South Elgin, Ill., proved equal to the task. They have produced experimental molds that in full production can make Delrin cartridges for a few cents apiece. The plastic units are in every way comparable to the Soviet handmade steel units, and they are superior in that the plastic presses on the staples slightly, holding them in place. (Staples sometimes fall out of the steel cartridges.) Since Delrin is translucent, the surgeon can hold the cartridge up to the light to satisfy himself that the staples are all in place.

Mallina has also designed a single machine for clipping off short lengths of stainless-steel or tantalum wire from a spool, bending them into staples, pointing them and inserting the finished staples into the plastic cartridge. This automatic operation completely eliminates tedious handwork under the magnifying glass. In practice the cartridges would come from the factory loaded, sterilized and sealed in packets. Recently it has been found that metal-coated plastic anvils can also be made for a few cents apiece. Thus the surgeon could use one stapler to join as many blood vessels of the same size or different sizes as necessary in one operation, without stopping to reload and sterilize the cartridges.

The stapler itself, which actually serves merely as a holder for the staple cartridge and the blood-vessel ends, is also much simpler in the American model. Mallina tried to eliminate some of the controls of the Soviet device but found that this, with one exception, was impossible. The Soviet engineers had come up against the same problems and had solved them. Mallina simplified the stapler in part by pivoting the controls rather than sliding them. In a system of pivots close tolerances are essential only at the pivot points. By removing one set of controls and combining others, Mallina had produced a machine with 15 instead of 21 separate parts. As with the Soviet instrument, the surgeon needs only a few seconds to carry out each step in the operation. Almost anyone can learn in a few minutes to take apart, clean and reassemble the American apparatus. This is particularly important because in U.S. hospitals nurses, who would prepare the devices, are frequently moved from one job to another. Omitting sterilization time, the apparatus can be cleaned and made ready in a few minutes. In the development of the latest model of the instrument and the staple-loading machine the Central Research Division of Becton, Dickinson & Co. made valuable contributions.

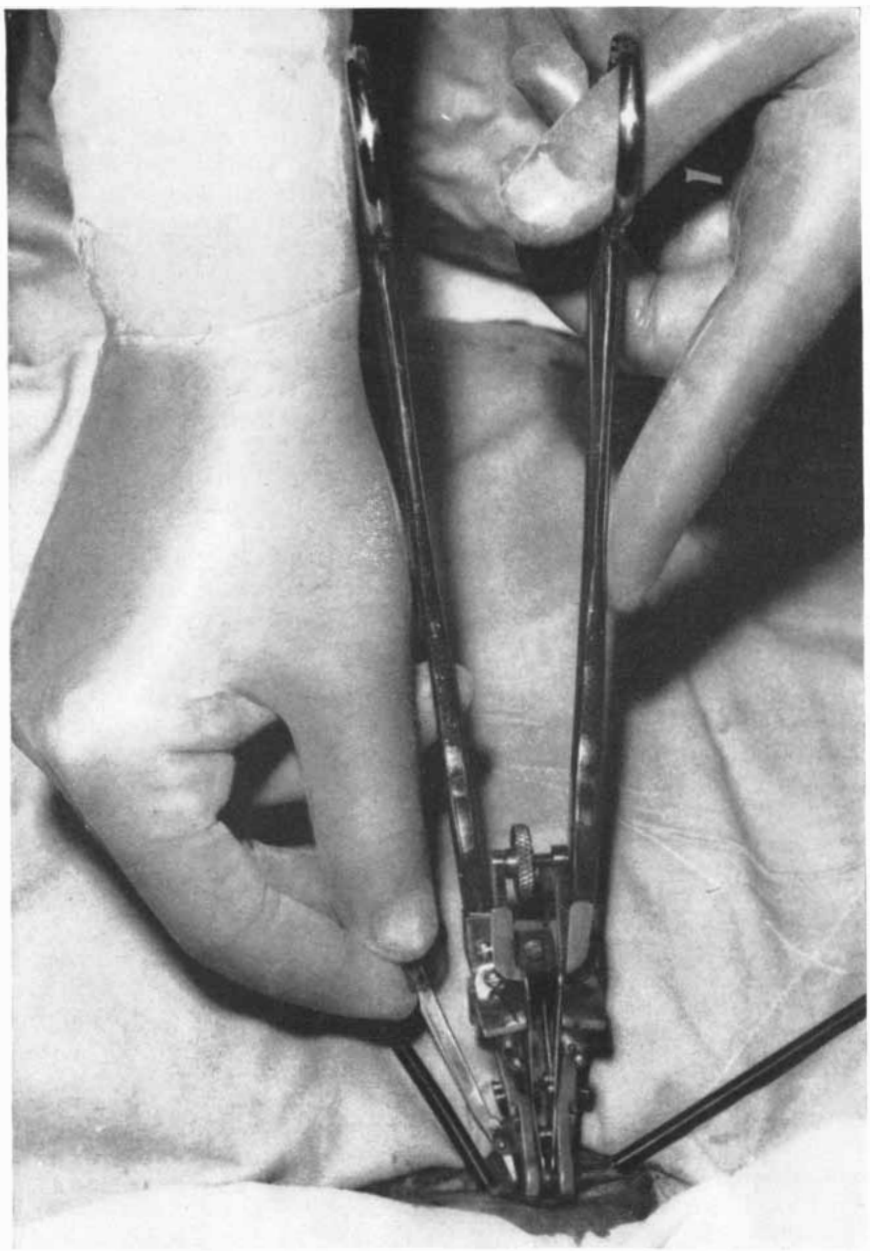
Mallina has managed to moderate the danger of damage to the blood vessel and to reduce the length of the vessel that must be engaged in the stapler by applying a simple physical law to the problem of holding the blood vessel in place. A blood vessel is not only elastic (it contracts to a fraction of its original length when it is cut); it is also one of the most slippery substances one can imagine. The Soviet designers employ clamps to hold the vessel in place before and after cuffing. In addition, bulldog clamps behind the cartridge and anvil squeeze the vessel. Ruled, engraved scales on the Soviet stapler are intended to show the force being applied to the vessel, but the Soviet surgeons who demonstrated the apparatus in the U.S. appeared to ignore the scales and to work by feel. Even with the scales there is always a chance of squeezing the slippery vessel so hard that the sensitive inner lining is damaged, encouraging the formation of a clot.

Instead of relying on squeezing or pinching to hold the blood vessel in place, Mallina placed blunt teeth in the groove of each cartridge half and each anvil half. The teeth in the lower half-rings mesh with the teeth in the upper sections, but with a gap between so that the vessel is bent but in no way crushed. These teeth, and others on the perimeter of the tip of the cartridge and anvil, bring the principle of deflection into play. The principle is familiar to anyone who has ever "snubbed" a large boat to hold it against the dock. The boat can be held with little effort if the rope from it is wrapped several times around even a slippery post. The reason is that the force required to hold it decreases geometrically with the increase in the sum of the angles through which the rope (the wall of the blood vessel in the case of the vascular stapler) is turned. The teeth in the cartridge and in the anvil also made it possible to eliminate two clamping jaws found on each half of the Soviet stapler and so make the tip of the stapler 15 millimeters wide compared with the 20-millimeter width

of the Soviet instrument. As a result our stapler can be used to suture a blood vessel that has been severed quite near a branching vessel.

In the laboratory for experimental surgery at the Bronx Veterans Administration Hospital we have used our new disposable-cartridge stapler in many operations on experimental animals, joining arteries and veins of various sizes as well as ureters and other tubes. We have not observed a single blood-vessel clot or other failure even in vessels as small as 1.5 millimeters in diameter. We have turned the instrument over to visiting surgeons in the midst of such experimental operations, inviting them to use it with little instruction. They have in each case been able to rejoin severed blood vessels successfully.

At present not many U.S. vascular surgeons take kindly to the idea of blood-vessel staplers. Most have not seen or used such instruments but have only heard of them. One has observed that the instruments would be useful for decorating a surgical museum. Another has commented that the staplers reflect a lack of clinical experience with vascular disease. Indeed, it is a fact that staples cannot usually be used on arteries significantly affected by arteriosclerosis or other degenerative diseases; the same is often true of hand-suturing. The comment that vascular staplers are only for amateurs is correct in a sense, since the original Soviet instruments were created for use by surgeons who are not skilled in suturing blood vessels. Nevertheless, by rejoining very small blood vessels quickly and easily the staplers in some cases do a job that only the most skillful hands could duplicate. If vascular staplers were widely available today, they might be used once a week or so in large hospitals for rejoining or rearranging blood vessels damaged by accident or by disease. Some cases now routinely considered inoperable would probably receive the benefit of surgery. Without question, if staplers were generally available they would be used with increasing frequency.



BLOOD VESSEL IS STAPLED by Christie in an experimental operation performed on a dog. Here Christie pushes one of the levers that will inject the staples into the cuffs.

In the future the vascular stapler will play a critical role in the transplantation of organs. Surgeons have transplanted kidneys, hearts, glands, limbs and other body parts in experimental animals, and the success of the surgical procedure has been demonstrated in the attainment of full function by the transplanted organ. The surgery is eventually negated, however, by the immune response of the recipient's body. Unless the donor is an identical twin the transplanted tissue is rejected as foreign material. The immunity mechanism can be suppressed by the use of ionizing radiation, but as yet the procedure is too difficult and too drastic for routine use [see "The Transplantation of the Kidney," by John P. Merrill; SCIENTIFIC AMERICAN, October, 1959].

The stapler already plays a key role in the spectacular organ transplants undertaken by Vladimir P. Demikhov and others at the Sklifosovsky Institute in Moscow. Demikhov has attached a second living head to a dog (the transplant functioned for 29 days) and a second heart in several animals. In the opinion of Jacob J. Matloff, a surgeon at the New England Center Hospital in Boston who spent four months with Demikhov this year, the hundreds of experimental organ transplants performed at the Sklifosovsky Institute would have been impossible without the stapler. Often four or more blood vessels must be joined for one transplant, and hand-suturing would usually take far too long.

It is now generally believed that in the near future the immunity barrier will somehow be overcome or bypassed. When that happens, hospitals throughout the world will need the vascular (and nerve) stapler. Fortunately it will be ready for them.

Kodak **reports on:**

boron-barium-lanthanum-thorium-strontium glass with neodymium . . . what we gave them for the cornerstone . . . utterly simple photomicrography

Laser logic

It was a thrill to see this laser rod commence action at a threshold of only 20 joules at room temperature.

Emission: 1.06μ, by transition of Nd^{3+} from $4F_{3/2}$ to $4I_{11/2}$ (not down to ground state, which is $4I_{9/2}$).

Price: $395 for 2″ x ¼″ cylinder. More for larger sizes, which are available.

Time to technological obsolescence: inevitably short.

Reputation of supplier: decent.

Name of supplier: Eastman Kodak Company, Apparatus and Optical Division, Rochester 4, N. Y.

Delivery: very fast to the first few early birds who would be uncomfortable to let this one whistle by without a close look; stretching out thereafter.

Premises:

In the rare earths the 4f levels are shielded by the 5s electrons and don't depend on the influence of a crystal field to define their energy in the way that Cr^{3+} levels depend on a crystal field. Therefore they can work in glass. Advantages of glass over crystals are 1) optical homogeneity, 2) potentially larger size, 3) potentially lower cost, 4) the 25 years of practical experience we have had from our commercial pioneering of rare-earth glasses for photographic lenses.

While people ultimately interested in machine tools and weapons are still feeling out the ground rules of laser engineering, our neodymium-boron-barium-lanthanum-thorium-strontium glass is a good first choice because 1) it emits at a wavelength convenient to phototubes, phosphors, and photography; 2) neodymium requires no refrigerants, since its fluorescence doesn't return the ion to the ground state; and 3) threshold for laser action comes at 1/3 the energy input that neodymium needs in silicate glass. (Whether low threshold implies high over-all efficiency at converting electrical power to coherent radiation needs to be cleared up.)

Instead of silvered ends, customers will prefer dielectric filters tuned to reflect ~100% of the 1.06μ radiation at one end and 98% at the other end because 1) by interferometric tests in the visible, where the filters are wide open, one can check for homogeneity, end flatness, and end parallelism without removal of the coating; 2) the ends operate solely by interference and don't soak up energy to cook themselves on.

Resist news: thick and fast

An important university recently asked us for a contribution not of money but of a small object suitably symbolic to deposit in the cornerstone of a new building its College of Engineering is putting up. After thinking about it a bit, we sent them three intricately shaped pieces of metal so small that one of them got lost in transit and never found its way into the box that will be opened some day to show our descendants some of the topics that engineers in 1962 regarded as fresh and promising. Is it not true that the engineering mind today is much occupied with working metals and semiconductors in ways to get as much performance as possible from as little bulk as possible?

Doggone right. In addition to making deposits in cornerstones, we have been busy expanding the line of photosensitive resists on which this hot new art so strongly depends. Everybody in it should be delighted to learn of KOR, a new one that's 10 to 15 times as sensitive to arc light and 30 to 100 times as sensitive to tungsten light as Kodak's well-known resist, KPR. This opens up the possibility of exposing KOR by a projected image instead of by contact printing from a master, but the photographic speed is still a little low for an ordinary photographic enlarger. You may wish to fix up some sort of high-intensity projection printer.

KOR is 3 or 4 times as viscous as KPR. As stands to reason, a thick coating requires more exposure than a thin one. Typically, a useful whirled-on KOR coating might require 1100 foot-candle-minutes if applied straight, as compared with 275 when the stuff has been cut 1:1 with KODAK Ortho Resist Thinner before application. When so cut, viscosity about matches that of uncut KPR. By coincidence, the relative prices of the two dopes are such that a quart of the 1:1 diluted KOR costs about as much as a quart of straight KPR.

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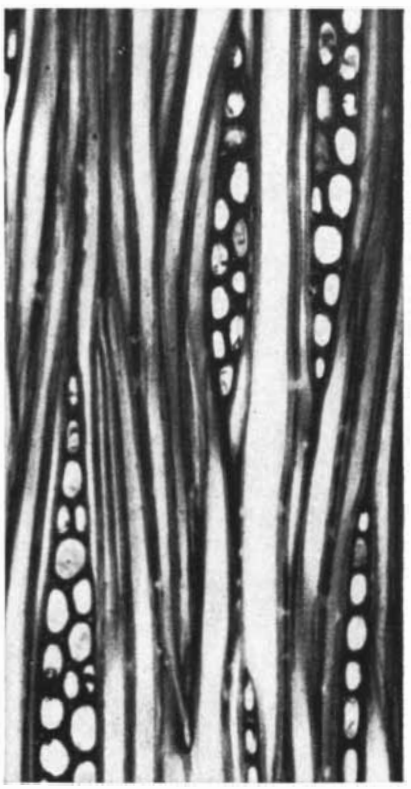
What makes hickory the way it is



This photomicrograph shows the basic structure of hickory wood. It was taken on a plain, ordinary microscope with a BROWNIE Camera. For details on this use of BROWNIE Cameras, request a copy of "Photomicrography with Simple Cameras" from Eastman Kodak Company, Sales Service Division, Rochester 4, N. Y. Everybody knows what a BROWNIE Camera is.

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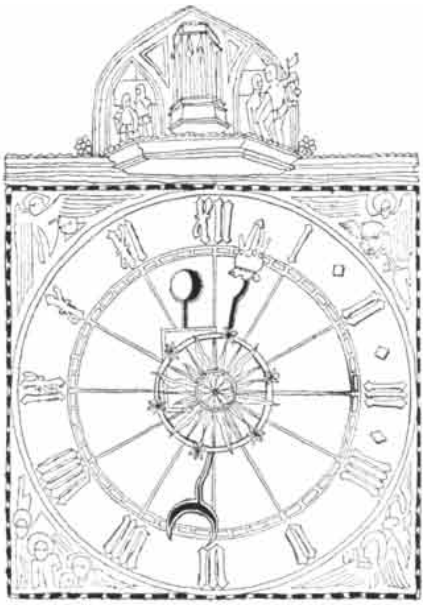

Bombarded Satellites

The hydrogen device exploded 200 miles over Johnston Island in the Pacific Ocean on July 9 has produced "a substantial and greater than anticipated increase in the intensity of radiation at higher altitudes in the region of the natural Van Allen belt," according to the Atomic Energy Commission and the Department of Defense. By causing solar cells to deteriorate, the radiation has silenced three scientific satellites: *Transit IVB*, *Traac* and the British-built and U.S.-launched *Ariel*. The disclosure confirms the fears of British scientists who had urged the U.S. to call off the high-altitude test on the grounds that its effects could not be fully predicted and that it might change the earth's environment for an unknown period.

The new high-intensity belt of radiation consists chiefly of electrons released by the July 9 nuclear explosion and injected into the magnetic field surrounding the earth. The electrons spiral back and forth along lines of magnetic force in a belt about 3,000 miles deep and 3,600 miles wide that circles the earth at the Equator. The lowest part of the belt is about 600 miles above the Pacific and dips to about 200 miles over the South Atlantic. Except where the new artificial belt dips below 600 miles it approximately overlaps the inner Van Allen belt of natural radiation that extends from about 600 to 3,600 miles above the earth. The natural inner belt consists chiefly of protons with energies of between 10 and 100 million electron volts (Mev). The electrons forming the new belt have energies of one Mev and up.

The belt's presence was signaled by *Injun I*, a satellite carrying radiation instruments built in the laboratory of James A. Van Allen at the State University of Iowa. The orbit of *Injun I* lies between 550 and 630 miles above the earth. Soon after the July 9 explosion a small, heavily shielded Geiger tube aboard the satellite, which normally counts about 600 protons per second, suddenly began counting more than 11,000 particles per second in passing over South America. In the course of several weeks, as electrons leaked out of the belt, the peak counting rate dropped to about 5,000 per second. Data received from *Telstar*, the communication satellite, show that the peak intensity of the new belt is at an altitude of about 2,400 miles, where the radiation level has increased about 100 times.

Independent evidence for the belt's formation came from radio observatories in Hawaii and the Philippines. The latter reported a doubling of radiation intensity immediately after the July 9 test. Radio noise from the electrons has interfered with radio-astronomical studies of the galaxy.

The AEC and Van Allen's laboratory do not agree on how long the bomb-injected electrons may persist at altitudes of 500 miles and up. Whereas the AEC says they may persist for five years or more, Van Allen and his associates estimate "many months."

The Test Ban

As disarmament negotiations moved from Geneva to the U.N. General Assembly last month there was a selection of test-ban proposals on the table, but none, apparently, on which the U.S. and the U.S.S.R. could agree. The obstacle was underground testing.

The U.S. and Britain stood on two proposals. One called for prohibition of all tests, with mandatory on-site inspection of underground events certified as "unidentified" by an international commission. The other would ban tests in the atmosphere and space and under water—all of which are readily identifiable—but allow underground tests to continue.

The U.S.S.R., having turned down inspection on the ground that it is a pretext for espionage and the partial ban

on the ground that it would provide a stimulus to the arms race, insisted that any test ban would have to meet one of three conditions. An across-the-board agreement would be acceptable, according to Soviet representative Vasily V. Kuznetsov, only if inspection of underground events were at the invitation of the country concerned. Alternatively, the U.S.S.R. would agree to a formal ban on the readily identifiable tests only if they were accompanied by a moratorium on underground tests until general disarmament is negotiated. In the absence of any formal agreement, said Kuznetsov, the U.S.S.R. would settle for a moratorium on all testing.

Pickle-Barrel Space Shooting

The double satellite flight carried out by the U.S.S.R. in August reflected an extremely high degree of reliability in equipment and of accuracy in launching procedure. Calculations by Martin Summerfield of Princeton University and Robert M. L. Baker, Jr., of the University of California, made at the request of *The New York Times*, make clear the order of accuracy that was required.

To put a satellite close to one already aloft without maneuvering once in orbit, the second one must be launched when the orbital plane of the first slices through the launching site, and when the first satellite is overhead; in other words, the first satellite must be at a certain point on its orbit and the launching site must be under that point. This conjunction should ideally occur when a satellite with a 90-minute orbital period has completed 16 orbits, since in that time the earth—and the launching site—will have made one complete 24-hour revolution. But it is not that simple. A satellite orbit wobbles to the west, so that by the time the satellite arrives at the proper point on its orbit the launching point will have moved 17 minutes to the east. Moreover, the earth actually turns more than 360 degrees in 24 hours; the launching site will therefore be another four minutes too far east by the time the satellite arrives. In other words, the first satellite will be a total of 21 minutes late. If its orbital period is shortened by 1.3 minutes, it will just about make up those 21 minutes in 16 orbits. So the correct period for the first

satellite becomes 88.7 minutes instead of 90, and that is presumably what the Soviet engineers wanted for *Vostok III*. They came close: 88.32 minutes. But the .4-minute error meant that *Vostok III* would be at the right point for an intercept 6.4 minutes (.4 minute multiplied by 16 orbits) before the launching site got there and 2,000 miles downrange by the time *Vostok IV* could be launched in the same orbit. The two satellites could not be both in the same orbit and close to each other. But *Vostok IV* could be put alongside *Vostok III* in a parallel and nearby orbit if it were fired another 6.4 minutes ahead of time. That would call for launching *Vostok IV* a total of 28 minutes less than 24 hours after *Vostok III:* 17 minutes for *Vostok III*'s orbital wobble, four minutes for the earth's extra rotation, 6.4 minutes for the error in *Vostok III*'s period and a little more to give the second satellite time to climb to altitude.

Vostok III's launching time was reported as 11:30 a.m. on August 11 and *Vostok IV*'s as 11:02 the next morning—exactly 28 minutes less than 24 hours later. Summerfield's comment: "Real pickle-barrel shooting!"

Antarctic Summer

The approach of the Antarctic summer finds some 80 U.S. scientists heading south this month for a new season of research and exploration. This is the fourth year in which the National Science Foundation, through its U.S. Antarctic Research Program, is organizing, administering and supplying financial support for investigations in the world's first international scientific preserve. NSF grants this season will total about $6,240,000. Logistic support is provided by the Navy.

Increased emphasis on upper-atmosphere research has led to the establishment of a new year-round scientific station (named for James Eights, who was the first U.S. scientist to visit Antarctica) at a site near the base of the Antarctic Peninsula that is magnetically conjugate to a station near the city of Quebec. Ionospheric and cosmic ray research will also be carried out aboard the Antarctic Research Program vessel *Eltanin*. Investigators will take advantage of the *Eltanin*'s mobility by operating a mobile low-frequency radio laboratory on a truck that will cruise through the northern U.S. and southern Canada along a course conjugate to the ship's course in Antarctic waters. The vessel, available now for its first full Antarctic summer, will also make possible an expanded program in oceanography and marine biology.

An effort will be made to clarify the geological history of the continent and to relate its various geological provinces to one another. Investigations will be carried out in the largely unexplored Pensacola Mountains, in the Queen Maud Range and Ellsworth Mountains and near the Shackleton Glacier in the Antarctic Horst. A major over-snow traverse will cover 1,270 miles of the central polar plateau, gathering seismic and other data on ice thickness and rock-surface elevations. Its findings may resolve some bothersome conflicts in reports from earlier expeditions that covered some of the same territory. And glaciologists will try to develop a new aerial technique for measuring ice-surface movement in an effort to answer the basic question of whether the volume of ice in Antarctica is increasing, decreasing or is in a state of equilibrium.

New Step in Photosynthesis

A substance called ferredoxin, recently found to exist in green plants, is apparently an important link in the primary, energy-carrying chain of events in photosynthesis. So report Kunio Tagawa and Daniel I. Arnon of the University of California in an article in *Nature*. An iron-containing protein, ferredoxin is the most strongly electronegative (that is, electron-donating) electron carrier known to participate in the oxidation-reduction reactions of the living cell. Its role in photosynthesis is to accept electrons released from chlorophyll by light and to transfer them to a material known as pyridine nucleotide. This in turn serves as the electron donor, or reducing agent, for the conversion of carbon dioxide to carbohydrates.

Ferredoxin was first isolated earlier this year by L. E. Mortenson, R. C. Valentine and J. E. Carnahan of the E. I. du Pont de Nemours laboratories, who extracted it from soil bacteria of the genus *Clostridium*. The discovery had special significance for Arnon and his co-workers because they had been using extracts of the same bacteria in some experiments in photosynthesis.

They were trying to find out if chloroplasts—the functional units of photosynthesis in green plants—can be made to produce hydrogen gas under the action of light. Certain photosynthetic bacteria were already known to do so. This meant that in the bacteria, light must release electrons to highly electronegative carriers, since a large reducing potential is required to convert hydrogen ions to hydrogen gas. According to a theory put

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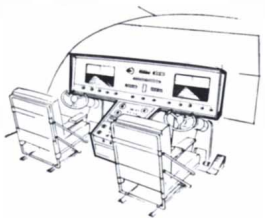

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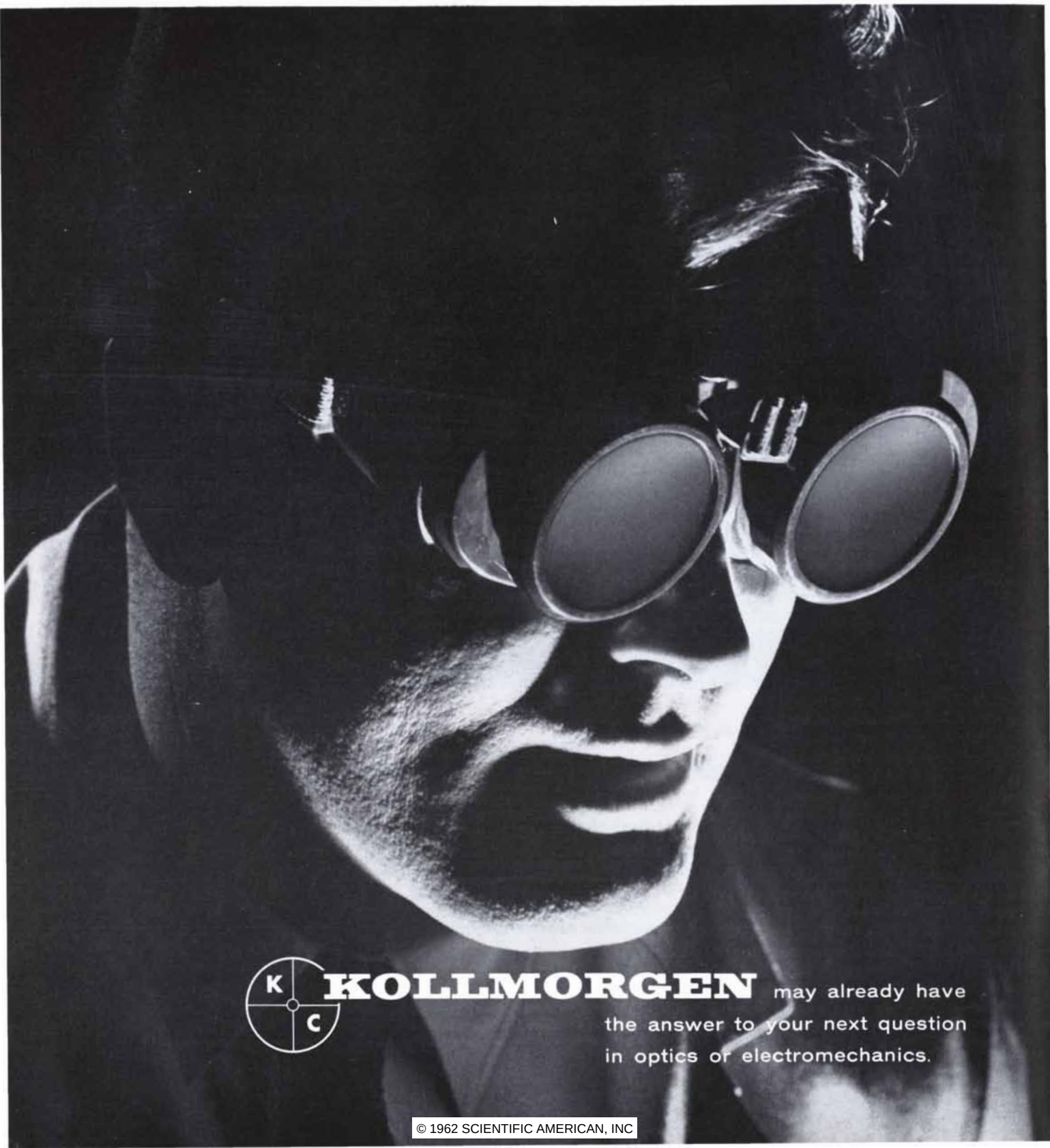


forward by Arnon's group, the "primary photochemical act" should be the same in plants and in bacteria. Therefore plant photosynthesis should also involve electrons on carriers that are electronegative enough to reduce hydrogen. Under normal conditions plants would not actually produce hydrogen because they lack an enzyme called hydrogenase, which is also required.

The experimenters therefore tried adding to chloroplasts hydrogenase obtained from various bacteria. They found that the illuminated chloroplasts would then evolve hydrogen. In most cases they also had to add an electron-carrying compound, but not when they used an extract of *Clostridium*. The bacteria contained their own electron carrier, which turned out to be ferredoxin.

Once they knew that bacterial ferredoxin could participate in the electron-transfer reactions of photosynthesis in green plants, they suspected that the plants themselves might contain a similar material. They applied the extraction procedure of the du Pont chemists to a preparation of spinach chloroplasts and obtained a substance closely resembling the ferredoxin of *Clostridium*. In subsequent investigations they have found that ferredoxins from spinach, *Clostridium* and other bacteria all have the same effect. In particular the ferredoxin enables chloroplasts to take electrons from hydrogen gas and transfer them to pyridine nucleotide in the absence of light. In other words, hydrogen can perform the function of light in chloroplasts that are enriched in ferredoxin.

Hot, Wet Moon

The moon may have a hot interior and it may harbor substantial quantities of subsurface water, two investigators have suggested in separate studies. This runs counter to the prevailing view that the moon is cold to its core and devoid of water. Zdeněk Kopal of the University of Manchester has estimated that tidal friction, operating for billions of years, may have heated the moon's interior to 1,000 or 2,000 degrees centigrade. It is known that the earth's gravitational attraction has created a permanent bulge of about 165 feet on the side of the moon that faces the earth. Kopal has computed that this bulge is increased about 10 per cent when the moon is closest to the earth and is reduced an equal amount when the moon is most distant. It is this tidal oscillation, Kopal believes, that has heated the moon's interior.

The speculation that the moon may have important resources of water is discussed in a recent issue of *Nature* by John W. Salisbury of the Air Force Cambridge Research Laboratories. Salisbury argues that none of the minerals regarded as valuable on earth could be mined economically on the moon, even if rich deposits happened to exist and could be located. Water, on the other hand, would have considerable value. In addition to its usual physiological applications, it could be decomposed by hydrolysis to provide oxygen for breathing and hydrogen and oxygen for use as fuel.

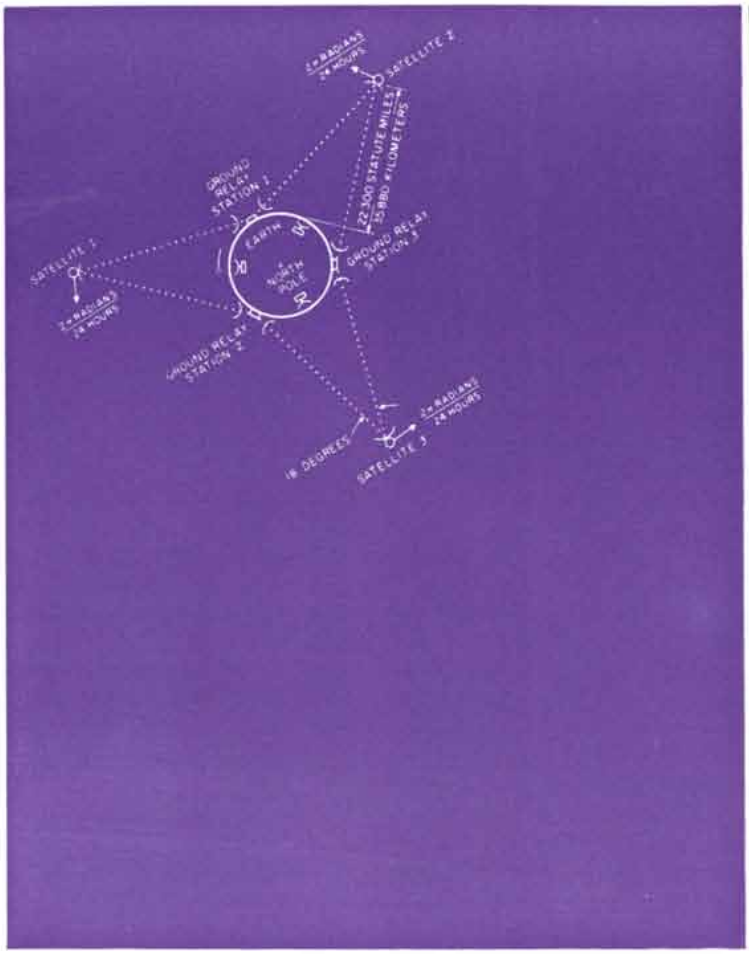
Salisbury considers various lines of evidence suggesting that large water deposits may exist beneath the lunar surface. Three years ago, for example, the Soviet astronomer N. Kozyrev recorded the spectrum of a gas escaping in a large crater. The gas contained a two-carbon molecule that may have been acetylene formed by the action of water on calcium carbide. Salisbury also discusses how water may have played a role in the formation of certain topographical features, such as chains of small craters and "wrinkly ridges." He urges that advanced lunar probes be designed to prospect for water in likely regions.

Sterilized Mosquitoes

A chemical-sterilization method that shows practical promise for exterminating mosquitoes is reported in *Nature* by Donald E. Weidhaas of the U.S. Department of Agriculture. Unlike insecticides, which may harm many different organisms and are of limited effectiveness, sterilization can be confined to specific organisms and, more important, can lead to total extermination of the species. Sterilization produced by X-ray treatment of male insects has already been applied with great success against the screw-worm fly in the southeastern U.S. [see "The Eradication of the Screw-Worm Fly," by Edward F. Knipling; SCIENTIFIC AMERICAN, October, 1960].

The substances used by Weidhaas are complex phosphorus-containing organic compounds known as tepa and apholate. They had previously been found to sterilize both sexes of the housefly. Weidhaas and his associates discovered that the chemicals would also sterilize two species of mosquito, *Anopheles quadrimaculatus* Say and *Aëdes aegypti* (L.).

In one experiment Weidhaas collected 88 wild *Anopheles* females and exposed 57 of them for four hours on panels treated with 500 milligrams of tepa per square foot. The other 31 females were kept as controls. Two-thirds of the unexposed controls laid eggs that developed normally. Two-thirds of the ex-



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posed females also laid eggs, but not a single egg developed.

Two-Phase Bone

The evolutionary success of vertebrate animals may rest in large part on the same principle that has made Fiberglas a commercial success, according to a University of Oxford zoologist. In a letter to *Nature* J. D. Currey points out that bone, like Fiberglas, is a "two phase" material, stronger than either of its components and superior in mechanical properties to other types of skeleton.

Bone consists of tiny crystals of a mineral called apatite, dispersed through a matrix of the protein collagen. If it could be tested in pure bulk form, bone apatite would presumably exhibit the typical properties of ceramic materials—high elasticity and compressive strength and low tensile strength. Collagen, on the other hand, has low elasticity and high tensile strength. As with any two-phase material, the strength of the combination is due to the fact that small cracks in the elastic material—apatite—do not spread to become big ones because the apatite crystals are themselves small and are separated by the soft and yielding collagen. The combination gives bone a high elasticity in tensile strength of about 15,000 pounds per square inch and a compressive strength of about 25,000 pounds per square inch.

Invertebrate skeletons usually consist of large crystals of calcium carbonate, in which cracks can easily spread. "The superiority of bone over most other skeletal materials," Curry concludes, "is probably one of the main foundations of the success of the vertebrates."

Coming In on a Wing and Two Feet

The ability of the housefly to land upside down on a ceiling has long fascinated entomologists, aeronautical engineers and armchair naturalists, and there has been much speculation on how the insect does it. A leading theory has been that the fly executes a half-roll as it approaches the ceiling and then makes a six-point landing on all feet at once.

Not so, says William G. Hyzer in a paper published in *Science*. He has photographed the maneuver with a high-speed motion picture camera operating at the rate of 9,500 frames per second. His pictures show the fly executing the start of an inside loop that carries it vertically upward and plants its forefeet on the ceiling. It then pivots around the point of attachment and puts down its other four feet.

THE GENETIC CODE

How does the order of bases in a nucleic acid determine the order of amino acids in a protein? It seems that each amino acid is specified by a triplet of bases, and that triplets are read in simple sequence

by F. H. C. Crick

Within the past year important progress has been made in solving the "coding problem." To the biologist this is the problem of how the information carried in the genes of an organism determines the structure of proteins.

Proteins are made from 20 different kinds of small molecule—the amino acids—strung together into long polypeptide chains. Proteins often contain several hundred amino acid units linked together, and in each protein the links are arranged in a specific order that is genetically determined. A protein is therefore like a long sentence in a written language that has 20 letters.

Genes are made of quite different long-chain molecules: the nucleic acids DNA (deoxyribonucleic acid) and, in some small viruses, the closely related RNA (ribonucleic acid). It has recently been found that a special form of RNA, called messenger RNA, carries the genetic message from the gene, which is located in the nucleus of the cell, to the surrounding cytoplasm, where many of the proteins are synthesized [see "Messenger RNA," by Jerard Hurwitz and J. J. Furth; SCIENTIFIC AMERICAN, February].

The nucleic acids are made by joining up four kinds of nucleotide to form a polynucleotide chain. The chain provides a backbone from which four kinds of side group, known as bases, jut at regular intervals. The order of the bases, however, is not regular, and it is their precise sequence that is believed to carry the genetic message. The coding problem can thus be stated more explicitly as the problem of how the sequence of the four bases in the nucleic acid determines the sequence of the 20 amino acids in the protein.

The problem has two major aspects, one general and one specific. Specifically one would like to know just what sequence of bases codes for each amino acid. Remarkable progress toward this goal was reported early this year by Marshall W. Nirenberg and J. Heinrich Matthaei of the National Institutes of Health and by Severo Ochoa and his colleagues at the New York University School of Medicine. [Editor's note: Brief accounts of this work appeared in "Science and the Citizen" for February and March. This article was planned as a companion to one by Nirenberg, now in preparation, which will deal with the biochemical aspects of the genetic code.]

The more general aspect of the coding problem, which will be my subject, has to do with the length of the genetic coding units, the way they are arranged in the DNA molecule and the way in which the message is read out. The experiments I shall report were performed at the Medical Research Council Laboratory of Molecular Biology in Cambridge, England. My colleagues were Mrs. Leslie Barnett, Sydney Brenner, Richard J. Watts-Tobin and, more recently, Robert Shulman.

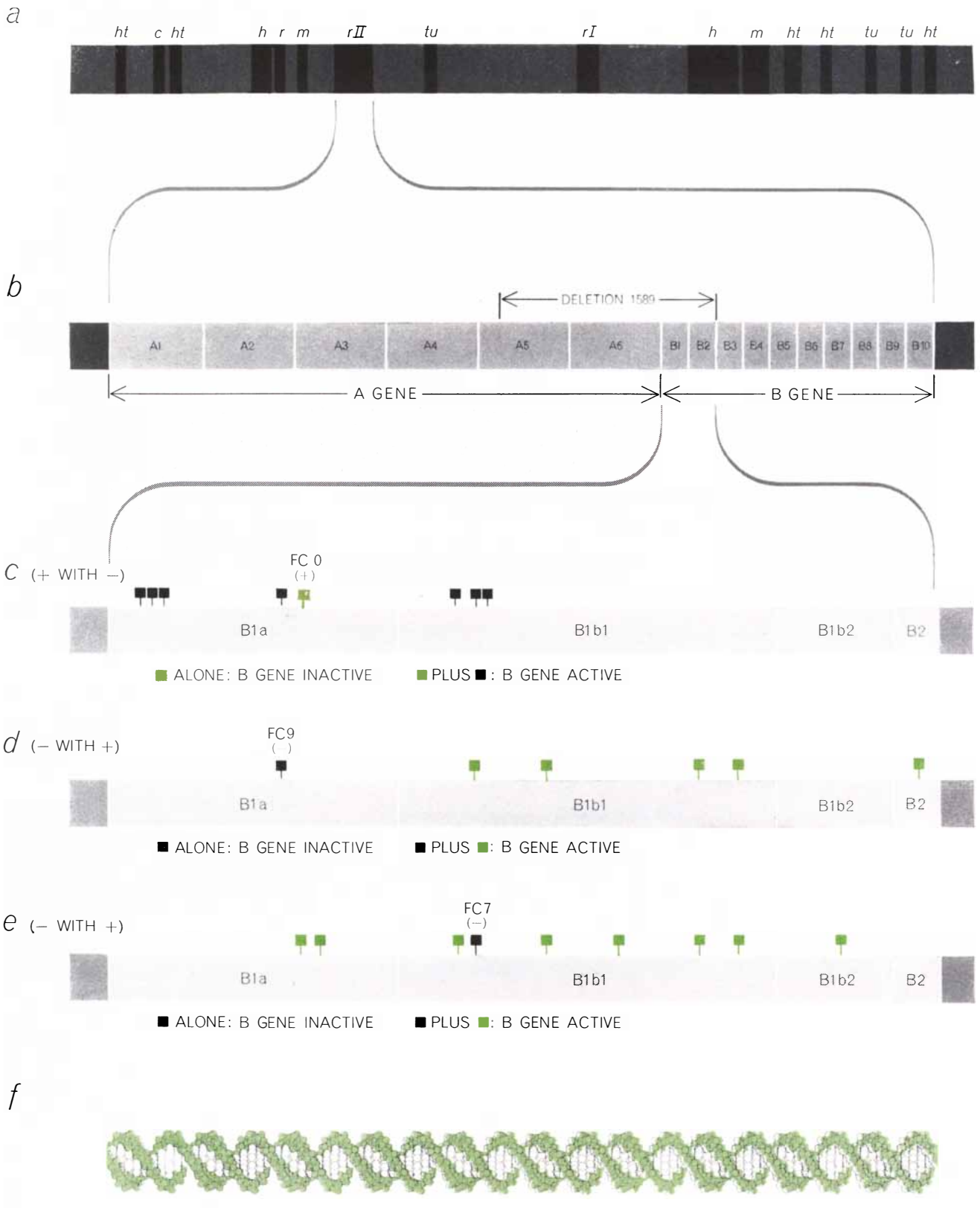
The organism used in our work is the bacteriophage T4, a virus that infects the colon bacillus and subverts the biochemical machinery of the bacillus to make multiple copies of itself. The infective process starts when T4 injects its genetic core, consisting of a long strand of DNA, into the bacillus. In less than 20 minutes the virus DNA causes the manufacture of 100 or so copies of the complete virus particle, consisting of a DNA core and a shell containing at least six distinct protein components. In the process the bacillus is killed and the virus particles spill out. The great value of the T4 virus for genetic experiments is that many generations and billions of individuals can be produced in a short time. Colonies containing mutant individuals can be detected by the appearance of the small circular "plaques" they form on culture plates. Moreover, by the use of suitable cultures it is possible to select a single individual of interest from a population of a billion.

Using the same general technique, Seymour Benzer of Purdue University was able to explore the fine structure of the A and B genes (or cistrons, as he prefers to call them) found at the "*r*II" locus of the DNA molecule of T4 [see "The Fine Structure of the Gene," by Seymour Benzer; SCIENTIFIC AMERICAN, January]. He showed that the A and B genes, which are next to each other on the virus chromosome, each consist of some hundreds of distinct sites arranged in linear order. This is exactly what one would expect if each gene is a segment, say 500 or 1,000 bases long, of the very long DNA molecule that forms the virus chromosome [*see illustration on opposite page*]. The entire DNA molecule in T4 contains about 200,000 base pairs.

The Usefulness of Mutations

From the work of Benzer and others we know that certain mutations in the A and B region made one or both genes inactive, whereas other mutations were only partially inactivating. It had also been observed that certain mutations were able to suppress the effect of harmful mutations, thereby restoring the function of one or both genes. We suspected that the various—and often puzzling—consequences of different kinds of mutation might provide a key to the nature of the genetic code.

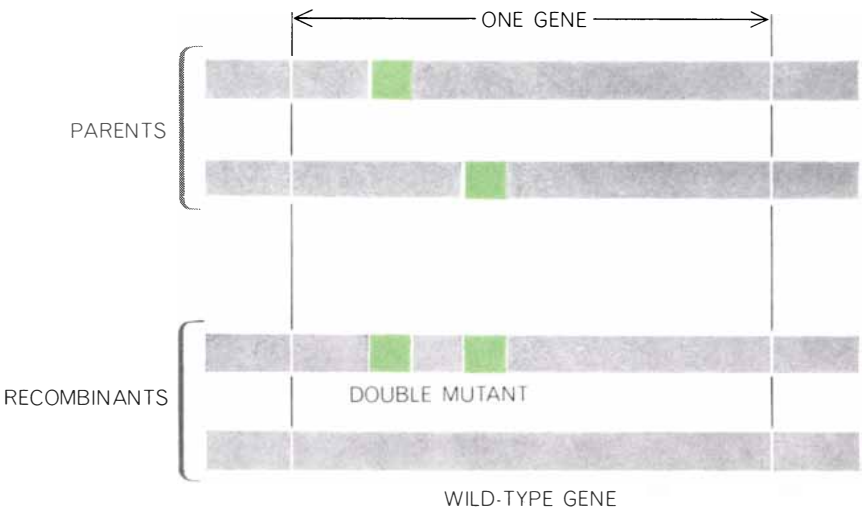
We therefore set out to re-examine the effects of crossing T4 viruses bearing mutations at various sites. By growing two different viruses together in a common culture one can obtain "recombinants" that have some of the properties



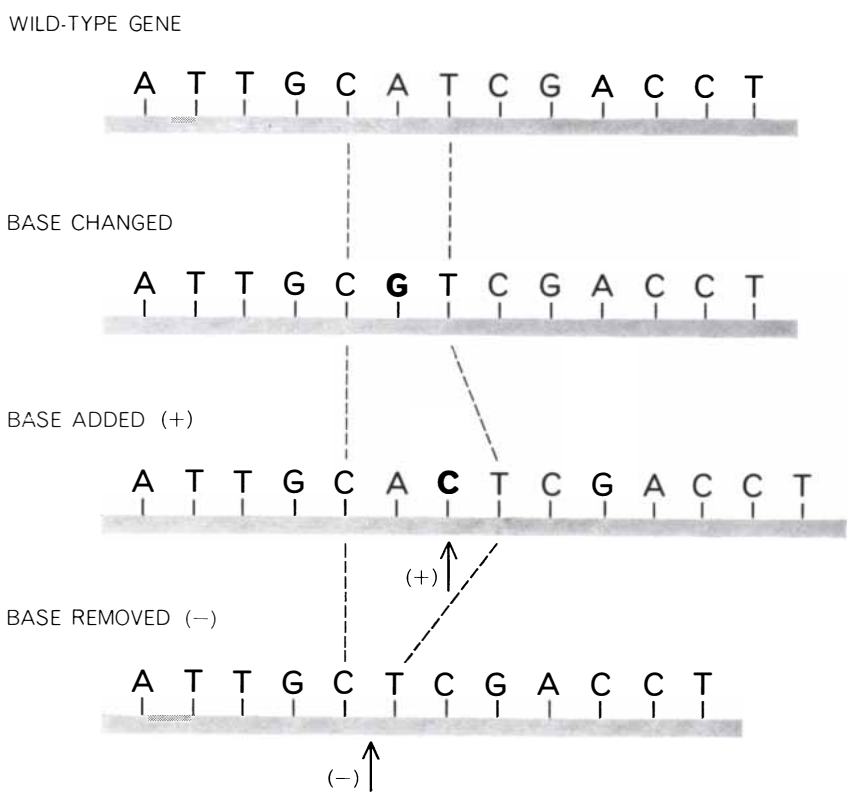
rII REGION OF THE T4 VIRUS represents only a few per cent of the DNA (deoxyribonucleic acid) molecule that carries full instructions for creating the virus. The region consists of two genes, here called A and B. The A gene has been mapped into six major segments, the B gene into 10 (*b*). The experiments reported in this article involve mutations in the first and second segments of the B gene. The B gene is inactivated by any mutation that adds a molecular subunit called a base (*colored square*) or removes one (*black square*). But activity is restored by simultaneous addition and removal of a base, as shown in *c*, *d* and *e*. An explanation for this recovery of activity is illustrated on page 70. The molecular representation of DNA (*f*) is estimated to be approximately in scale with the length of the B1 and B2 segments of the B gene. The two segments contain about 100 base pairs.

of one parent and some of the other. Thus one defect, such as the alteration of a base at a particular point, can be combined with a defect at another point to produce a phage with both defects [*see upper illustration below*]. Alternatively, if a phage has several defects, they can be separated by being crossed with the "wild" type, which by definition has none. In short, by genetic methods one can either combine or separate different mutations, provided that they do not overlap.

Most of the defects we shall be considering are evidently the result of adding or deleting one base or a small group of bases in the DNA molecule and not merely the result of altering one of the bases [*see lower illustration on this page*]. Such additions and deletions can be produced in a random manner with the compounds called acridines, by a process that is not clearly understood. We think they are very small additions or deletions, because the altered gene seems to have lost its function completely; mutations produced by reagents capable of changing one base into another are often partly functional. Moreover, the acridine mutations cannot be reversed by such reagents (and vice versa). But our strongest reason for believing they are additions or deletions is that they can be combined in a way that suggests they have this character.



GENETIC RECOMBINATION provides the means for studying mutations. Colored squares represent mutations in the chromosome (DNA molecule) of the T4 virus. Through genetic recombination, the progeny can inherit the defects of both parents or of neither.

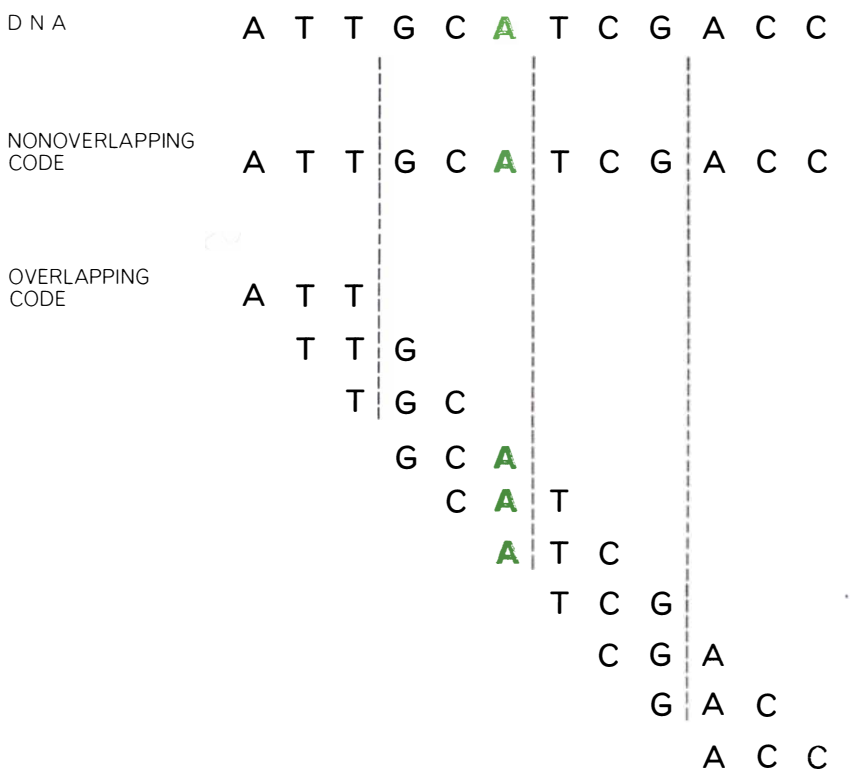


TWO CLASSES OF MUTATION result from introducing defects in the sequence of bases (A, T, G, C) that are attached to the backbone of the DNA molecule. In one class a base is simply changed from one into another, as A into G. In the second class a base is added or removed. Four bases are adenine (A), thymine (T), guanine (G) and cytosine (C).

To understand this we shall have to go back to the genetic code. The simplest sort of code would be one in which a small group of bases stands for one particular acid. This group can scarcely be a pair, since this would yield only 4×4, or 16, possibilities, and at least 20 are needed. More likely the shortest code group is a triplet, which would provide $4 \times 4 \times 4$, or 64, possibilities. A small group of bases that codes one amino acid has recently been named a codon.

The first definite coding scheme to be proposed was put forward eight years ago by the physicist George Gamow, now at the University of Colorado. In this code adjacent codons overlap as illustrated on the opposite page. One consequence of such a code is that only certain amino acids can follow others. Another consequence is that a change in a single base leads to a change in three adjacent amino acids. Evidence gathered since Gamow advanced his ideas makes an overlapping code appear unlikely. In the first place there seems to be no restriction of amino acid sequence in any of the proteins so far examined. It has also been shown that typical mutations change only a single amino acid in the polypeptide chain of a protein. Although it is theoretically possible that the genetic code may be partly overlapping, it is more likely that adjacent codons do not overlap at all.

Since the backbone of the DNA molecule is completely regular, there is nothing to mark the code off into groups of three bases, or into groups of any other size. To solve this difficulty various ingenious solutions have been proposed. It was thought, for example, that the code might be designed in such a way that if the wrong set of triplets were chosen, the message would always be complete nonsense and no protein would



PROPOSED CODING SCHEMES show how the sequence of bases in DNA can be read. In a nonoverlapping code, which is favored by the author, code groups are read in simple sequence. In one type of overlapping code each base appears in three successive groups.

be produced. But it now looks as if the most obvious solution is the correct one. That is, the message begins at a fixed starting point, probably one end of the gene, and is simply read three bases at a time. Notice that if the reading started at the wrong point, the message would fall into the wrong sets of three and would then be hopelessly incorrect. In fact, it is easy to see that while there is only one correct reading for a triplet code, there are two incorrect ones.

If this idea were right, it would immediately explain why the addition or the deletion of a base in most parts of the gene would make the gene completely nonfunctional, since the reading of the genetic message from that point onward would be totally wrong. Now, although our single mutations were always without function, we found that if we put certain pairs of them together, the gene would work. (In point of fact we picked up many of our functioning double mutations by starting with a nonfunctioning mutation and selecting for the rare second mutation that restored gene activity, but this does not affect our argument.) This enabled us to classify all our mutations as being either plus or minus. We found that by using the following rules we could always predict the behavior of any pair we put together in the same gene. First, if plus is combined with plus, the combination is nonfunctional. Second, if minus is combined with minus, the result is nonfunctional. Third, if plus is combined with minus, the combination is nonfunctional if the pair is too widely separated and functional if the pair is close together.

The interesting case is the last one. We could produce a gene that functioned, at least to some extent, if we combined a plus mutation with a minus mutation, provided that they were not too far apart.

To make it easier to follow, let us assume that the mutations we called plus really had an extra base at some point and that those we called minus had lost a base. (Proving this to be the case is rather difficult.) One can see that, starting from one end, the message would be read correctly until the extra base was reached; then the reading would get out of phase and the message would be wrong until the missing base was reached, after which the message would come back into phase again. Thus the genetic message would not be wrong over a long stretch but only over the short distance between the plus and the minus. By the same sort of argument one can see that for a triplet code the combination plus with plus or minus with minus should never work [*see illustration on next page*].

We were fortunate to do most of our work with mutations at the left-hand end of the B gene of the *r*II region. It appears that the function of this part of the gene may not be too important, so that it may not matter if part of the genetic message in the region is incorrect. Even so, if the plus and minus are too far apart, the combination will not work.

Nonsense Triplets

To understand this we must go back once again to the code. There are 64 possible triplets but only 20 amino acids to be coded. Conceivably two or more triplets may stand for each amino acid. On the other hand, it is reasonable to expect that at least one or two triplets may not represent an amino acid at all but have some other meaning, such as "Begin here" or "End here." Although such hypothetical triplets may have a meaning of some sort, they have been named nonsense triplets. We surmised that sometimes the misreading produced in the region lying between a plus and a minus mutation might by chance give rise to a nonsense triplet, in which case the gene might not work.

We investigated a number of plus-with-minus combinations in which the distance between plus and minus was relatively short and found that certain combinations were indeed inactive when we might have expected them to function. Presumably an intervening nonsense triplet was to blame. We also found cases in which a plus followed by a minus worked but a minus followed by a plus did not, even though the two mutations appeared to be at the same sites, although in reverse sequence. As I have indicated, there are two wrong ways to read a message; one arises if the plus is to the left of the minus, the other if the plus is to the right of the minus. In cases where plus with minus gave rise to an active gene but minus with plus did not, even when the mutations evidently occupied the same pairs of sites, we concluded that the intervening misreading produced a nonsense triplet in one case but not in the other. In confirmation of this hypothesis we have been able to modify such nonsense triplets by mutagens that turn one base into another, and we have thereby restored the gene's activity. At the same time we have been able to locate the position of the nonsense triplet.

Recently we have undertaken one

other rather amusing experiment. If a single base were changed in the left-hand end of the B gene, we would expect the gene to remain active, both because this end of the gene seems to be unessential and because the reading of the rest of the message is not shifted. In fact, if the B gene remained active, we would have no way of knowing that a base had been changed. In a few cases, however, we have been able to destroy the activity of the B gene by a base change traceable to the left-hand end of the gene. Presumably the change creates a nonsense triplet. We reasoned that if we could shift the reading so that the message was read in different groups of three, the new reading might not yield a nonsense triplet. We therefore selected a minus and a plus that together allowed the B gene to function, and that were on each side of the presumed nonsense mutation. Sure enough, this combination of three mutants allowed the gene to function [*see top illustration on page 74*]. In other words, we could abolish the effect of a nonsense triplet by shifting its reading.

All this suggests that the message is read from a fixed point, probably from one end. Here the question arises of how one gene ends and another begins, since in our picture there is nothing on the backbone of the long DNA molecule to separate them. Yet the two genes A and B are quite distinct. It is possible to measure their function separately, and Benzer has shown that no matter what mutation is put into the A gene, the B function is not affected, provided that the mutation is wholly within the A gene. In the same way changes in the B gene do not affect the function of the A gene.

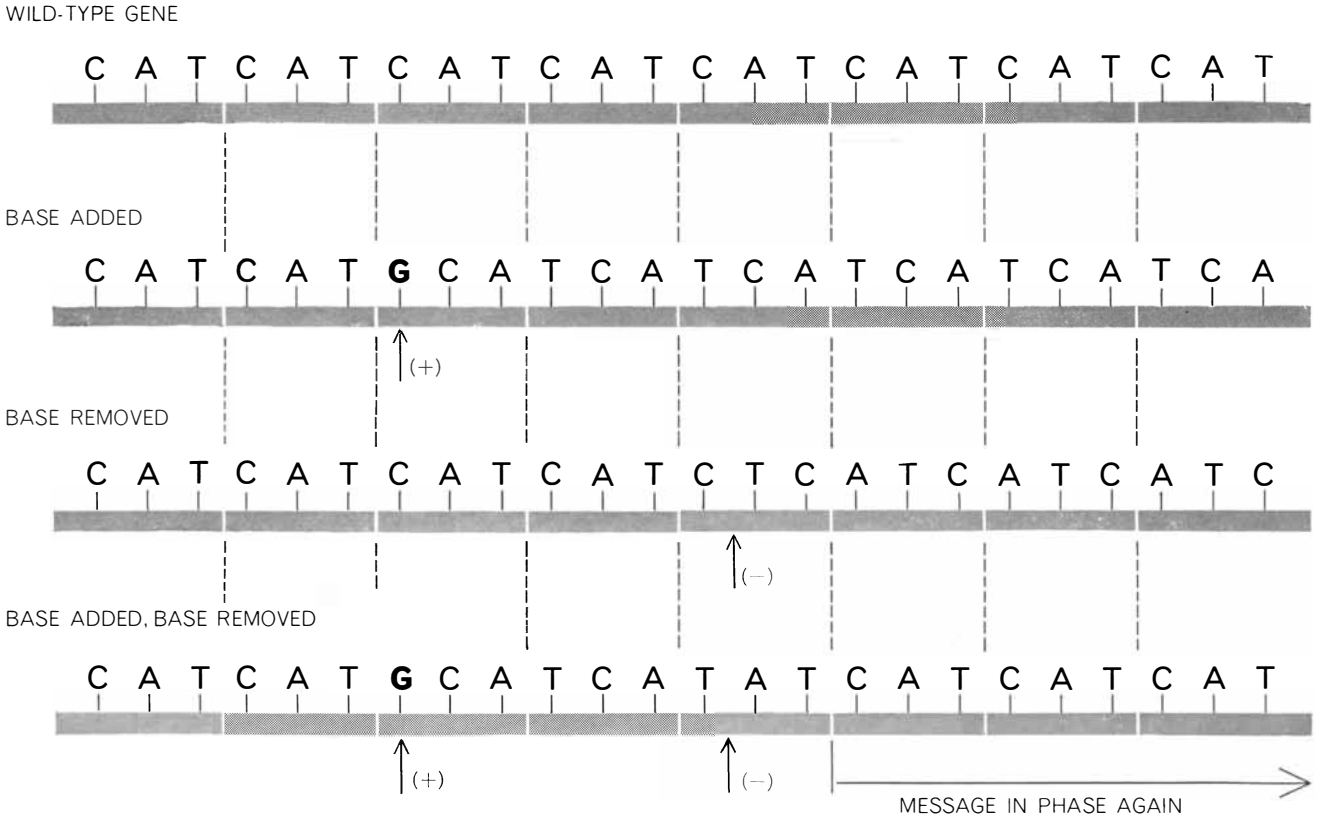
The Space between the Genes

It therefore seems reasonable to imagine that there is something about the DNA between the two genes that isolates them from each other. This idea can be tested by experiments with a mutant T4 in which part of the *r*II region is deleted. The mutant, known as T4 1589, has lost a large part of the right end of the A gene and a smaller part of the left end of the B gene. Surprisingly the B gene still shows some function; in fact this is why we believe this part of the B gene is not too important.

Although we describe this mutation as a deletion, since genetic mapping shows that a large piece of the genetic information in the region is missing, it does not mean that physically there is a gap. It seems more likely that DNA is all one piece but that a stretch of it has been left out. It is only by comparing it with the complete version—the wild type—that one can see a piece of the message is missing.

We have argued that there must be a small region between the genes that separates them. Consequently one would predict that if this segment of the DNA were missing, the two genes would necessarily be joined. It turns out that it is quite easy to test this prediction, since by genetic methods one can construct double mutants. We therefore combined one of our acridine mutations, which in this case was near the beginning of the A gene, with the deletion 1589. Without the deletion present the acridine mutation had no effect on the B function, which showed that the genes were indeed separate. But when 1589 was there as well, the B function was completely destroyed [*see top illustration on page 72*]. When the genes were joined, a change far away in the A gene knocked out the B gene completely. This strongly suggests that the reading proceeds from one end.

We tried other mutations in the A



EFFECT OF MUTATIONS that add or remove a base is to shift the reading of the genetic message, assuming that the reading begins at the left-hand end of the gene. The hypothetical message in the wild-type gene is CAT, CAT... Adding a base shifts the reading to TCA, TCA... Removing a base makes it ATC, ATC... Addition and removal of a base puts the message in phase again.

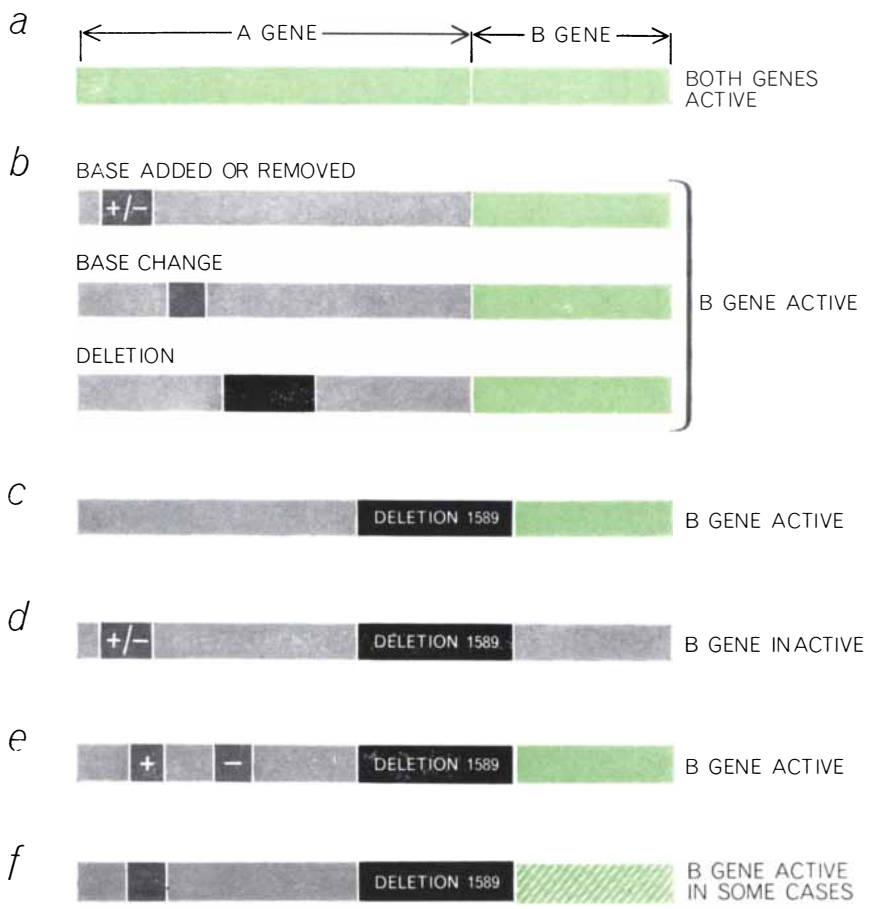
gene combined with 1589. All the acridine mutations we tried knocked out the B function, whether they were plus or minus, but a pair of them (plus with minus) still allowed the B gene to work. On the other hand, in the case of the other type of mutation (which we believe is due to the change of a base and not to one being added or subtracted) about half of the mutations allowed the B gene to work and the other half did not. We surmise that the latter are nonsense mutations, and in fact Benzer has recently been using this test as a definition of nonsense.

Of course, we do not know exactly what is happening in biochemical terms. What we suspect is that the two genes, instead of producing two separate pieces of messenger RNA, produce a single piece, and that this in turn produces a protein with a long polypeptide chain, one end of which has the amino acid sequence of part of the presumed A protein and the other end of which has most of the B protein sequence—enough to give some B function to the combined molecule although the A function has been lost. The concept is illustrated schematically at the bottom of the next page. Eventually it should be possible to check the prediction experimentally.

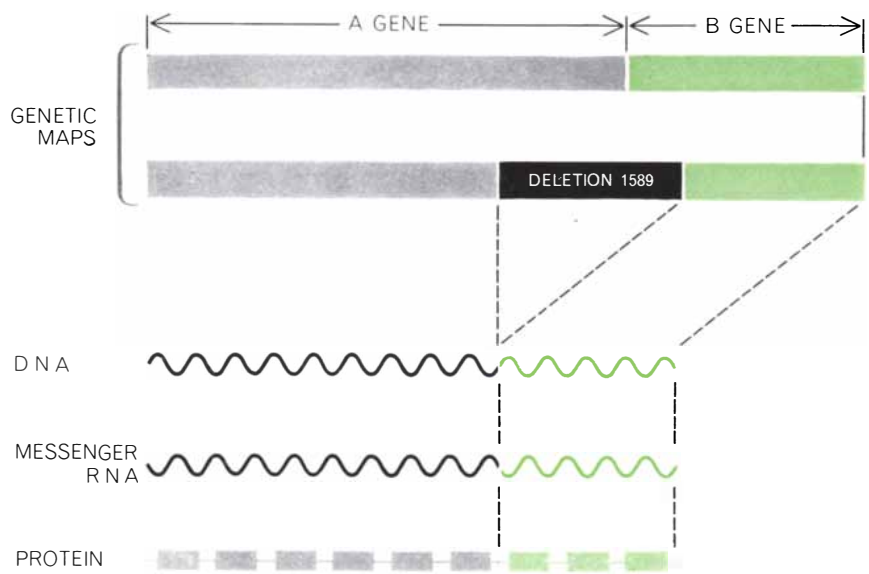
How the Message Is Read

So far all the evidence has fitted very well into the general idea that the message is read off in groups of three, starting at one end. We should have got the same results, however, if the message had been read off in groups of four, or indeed in groups of any larger size. To test this we put not just two of our acridine mutations into one gene but three of them. In particular we put in three with the same sign, such as plus with plus with plus, and we put them fairly close together. Taken either singly or in pairs, these mutations will destroy the function of the B gene. But when all three are placed in the same gene, the B function reappears. This is clearly a remarkable result: two blacks will not make a white but three will. Moreover, we have obtained the same result with several different combinations of this type and with several of the type minus with minus with minus.

The explanation, in terms of the ideas described here, is obvious. One plus will put the reading out of phase. A second plus will give the other wrong reading. But if the code is a triplet code, a third plus will bring the message back into phase again, and from then on to the end it will be read correctly. Only between



DELETION JOINING TWO GENES makes the B gene vulnerable to mutations in the A gene. The messages in two wild-type genes (*a*) are read independently, beginning at the left end of each gene. Regardless of the kind of mutation in A, the B gene remains active (*b*). The deletion known as 1589 inactivates the A gene but leaves the B gene active (*c*). But now alterations in the A gene will often inactivate the B gene, showing that the two genes have been joined in some way and are read as if they were a single gene (*d*, *e*, *f*).



PROBABLE EFFECT OF DELETION 1589 is to produce a mixed protein with little or no A-gene activity but substantial B activity. Although the conventional genetic map shows the deletion as a gap, the DNA molecule itself is presumably continuous but shortened. In virus replication the genetic message in DNA is transcribed into a molecule of ribonucleic acid, called messenger RNA. This molecule carries the message to cellular particles known as ribosomes, where protein is synthesized, following instructions coded in the DNA.

the pluses will the message be wrong [*see bottom illustration on page 74*].

Notice that it does not matter if plus is really one extra base and minus is one fewer; the conclusions would be the same if they were the other way around. In fact, even if some of the plus mutations were indeed a single extra base, others might be two fewer bases; in other words, a plus might really be minus minus. Similarly, some of the minus mutations might actually be plus plus. Even so they would still fit into our scheme.

Although the most likely explanation is that the message is read three bases at a time, this is not completely certain. The reading could be in multiples of three. Suppose, for example, that the message is actually read six bases at a time. In that case the only change needed in our interpretation of the facts is to assume that all our mutants have been changed by an even number of bases. We have some weak experimental evidence that this is unlikely. For instance, we can combine the mutant 1589 (which joins the genes) with medium-sized deletions in the A cistron. Now, if deletions were random in length, we should expect about a third of them to allow the B function to be expressed if the message is indeed read three bases at a time, since those deletions that had lost an exact multiple of three bases should allow the B gene to function. By the same reasoning only a sixth of them should work (when combined with 1589) if the reading proceeds six at a time. Actually we find that the B gene is active in a little more than a third. Taking all the evidence together, however, we find that although three is the most likely coding unit, we cannot completely rule out multiples of three.

There is one other general conclusion we can draw about the genetic code. If we make a rough guess as to the actual size of the B gene (by comparing it with another gene whose size is known approximately), we can estimate how many bases can lie between a plus with minus combination and still allow the B gene to function. Knowing also the frequency with which nonsense triplets are created in the misread region between the plus and minus, we can get some idea whether there are many such triplets or only a few. Our calculation suggests that nonsense triplets are not too common. It seems, in other words, that most of the 64 possible triplets, or codons, are not nonsense, and therefore they stand for amino acids. This implies that probably more than one codon can stand for one amino acid. In the jargon

minus one for paper

	S	P	R
S	0	1	-1
P	-1	0	1
R	1	-1	0

The payoffs are known. The Scissors-Paper-Rock game matrix* provides a mathematical abstraction of the conflict situation. Now a Game Theory analysis can be performed. Its objective is to answer the question of how best to play the game. Strategy options in real-life conflicts are exceedingly more complex. To select the optimal course of action is the major move in our global game. To this end do our engineers design command and control systems today for tomorrow's offensive and defensive moves. If you seek to devote your scientific skills to determining long-range strategies and their associated tactical systems, you will find us genuinely receptive to your original thinking. Engineers, mathematicians, and scientists are cordially invited to apply. A good first move would be to send your résumé to Mr. Harry F. Laur at 6700 Eton Avenue, Canoga Park, California. He will counter with an immediate response. Litton Systems, Inc. is an equal opportunity employer.

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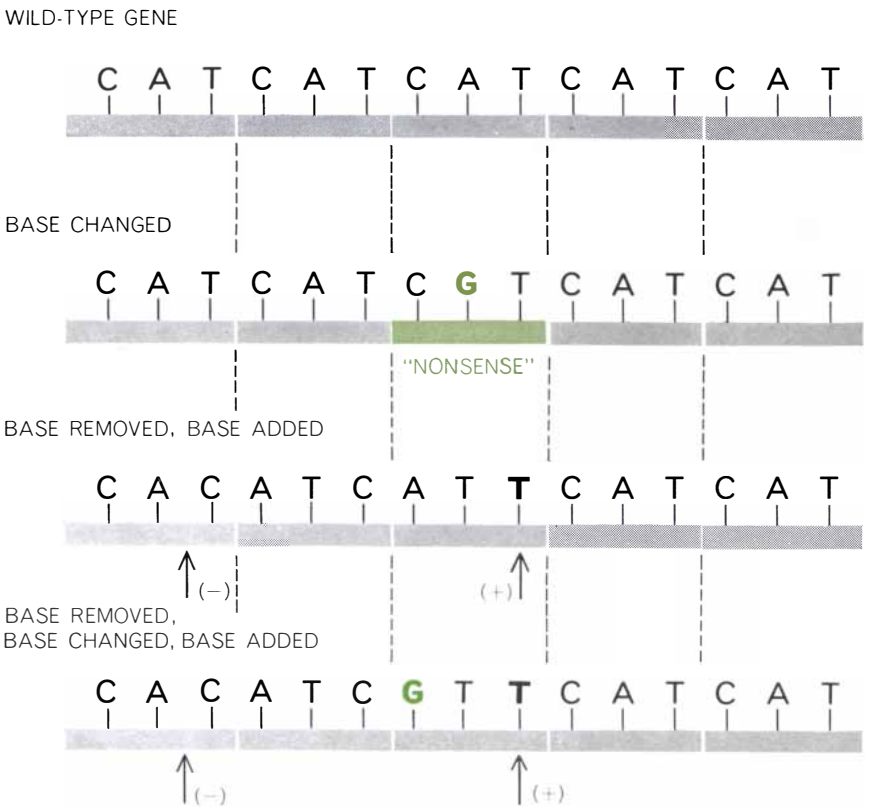
*Williams, J. D., *The Compleat Strategyst*



NONSENSE MUTATION is one creating a code group that evidently does not represent any of the 20 amino acids found in proteins. Thus it makes the gene inactive. In this hypothetical case a nonsense triplet, CGT, results when an A in the wild-type gene is changed to G. The nonsense triplet can be eliminated if the reading is shifted to put the G in a different triplet. This is done by recombining the inactive gene with one containing a minus-with-plus combination. In spite of three mutations, the resulting gene is active.

of the trade, a code in which this is true is "degenerate."

In summary, then, we have arrived at three general conclusions about the genetic code:

1. The message is read in nonoverlapping groups from a fixed point, probably from one end. The starting point determines that the message is read correctly into groups.

2. The message is read in groups of a fixed size that is probably three, although multiples of three are not completely ruled out.

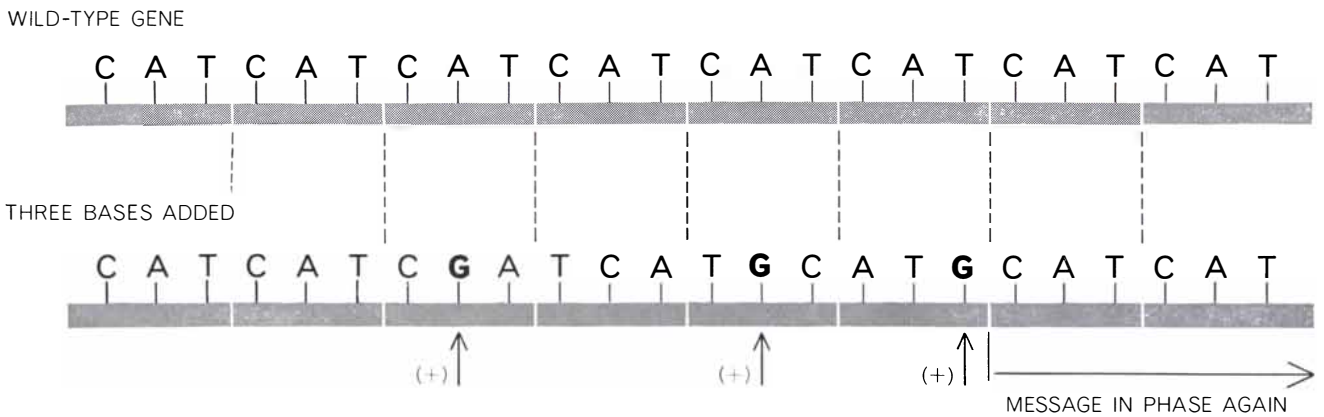
3. There is very little nonsense in the code. Most triplets appear to allow the gene to function and therefore probably represent an amino acid. Thus in general more than one triplet will stand for each amino acid.

It is difficult to see how to get around our first conclusion, provided that the B gene really does code a polypeptide chain, as we have assumed. The second conclusion is also difficult to avoid. The third conclusion, however, is much more indirect and could be wrong.

Finally, we must ask what further evidence would really clinch the theory we have presented here. We are continuing to collect genetic data, but I doubt that this will make the story much more convincing. What we need is to obtain a protein, for example one produced by a double mutation of the form plus with minus, and then examine its amino acid sequence. According to conventional theory, because the gene is altered in only two places the amino acid sequences also should differ only in the two corresponding places. According to our theory it should be altered not only at these two places but also at all places in between. In other words, a whole string of amino acids should be changed. There is one protein, the lysozyme of the T4 phage, that is favorable for such an approach, and we hope that before long workers in the U.S. who have been studying phage lysozyme will confirm our theory in this way.

The same experiment should also be useful for checking the particular code schemes worked out by Nirenberg and Matthaei and by Ochoa and his colleagues. The phage lysozyme made by the wild-type gene should differ over only a short stretch from that made by the plus-with-minus mutant. Over this stretch the amino acid sequence of the two lysozyme variants should correspond to the same sequence of bases on the DNA but should be read in different groups of three.

If this part of the amino acid sequence of both the wild-type and the altered lysozyme could be established, one could check whether or not the codons assigned to the various amino acids did indeed predict similar sequences for that part of the DNA between the base added and the base removed.



TRIPLE MUTATION in which three bases are added fairly close together spoils the genetic message over a short stretch of the gene but leaves the rest of the message unaffected. The same result can be achieved by the deletion of three neighboring bases.

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STARLIGHT!

NO. 6 IN A SERIES OF SCIENCE-FICTION ORIGINALS CREATED EXPRESSLY FOR HOFFMAN ELECTRONICS CORPORATION

Isaac Asimov

Arthur Trent heard them quite clearly. The tense, angry words shot out of his receiver.

"Trent! You can't get away. We will intersect your orbit in two hours and if you try to resist we will blow you out of space."

Trent smiled and said nothing. He had no weapons and no need to fight. In far less than two hours, the ship would make its Jump through hyperspace and they would never find him. He would have with him nearly a kilogram of Krillium, enough for the construction of the brain-paths of thousands of robots and worth some ten million credits on any world in the Galaxy—and no questions asked.

Old Brennmeyer had planned the whole thing. He had planned it for thirty years and more. It had been his life's work.

"It's the getaway, young man," he had said. "That's why I need you. You can lift a ship off the ground and out into space. I can't."

"Getting it into space is no good, Mr. Brennmeyer," Trent said, "we'll be caught in half a day."

"Not," said Brennmeyer, craftily, "if we make the Jump; not if we flash through hyperspace and end up light-years away."

"It would take half a day to plot the Jump and even if we could take the time, the police would alert all stellar systems."

"No, Trent, no." The old man's hand fell on his, clutching it in trembling excitement. "Not *all* stellar systems; only the dozen in our neighborhood. The Galaxy is big and the colonists of the last fifty thousand years have lost touch with each other."

He talked avidly, painting the picture. The Galaxy now was like the surface of man's original planet (Earth, they had called it) in prehistoric times. Man had been scattered over all the continents but each group had known only the area immediately surrounding itself.

"If we make the Jump at random,"

Brennmeyer said, "we would be anywhere, even fifty thousand light-years away, and there would be no more chance of finding us than of finding a pebble in a meteor swarm."

Trent shook his head, "And we don't find ourselves, either. We wouldn't have the foggiest way of getting to an inhabited planet."

Brennmeyer's quick-moving eyes inspected the surroundings. No one was near him, but his voice sank to a whisper anyway. "I've spent thirty years collecting data on every habitable planet in the Galaxy. I've searched all the old records. I've travelled thousand of light-years, farther than any space-pilot. And the location of every habitable planet is now in the memory store of the best computer in the world."

Trent lifted his eyebrows politely.

Brennmeyer said, "I design computers and I have the best.

"I've also plotted the exact location of every luminous star in the Galaxy, every star of spectral class F, B, A and O, and put that into the memory store. Once we've made the Jump the computer will scan the heavens spectroscopically and compare the results with the map of the Galaxy it contains. Once it finds the proper match, and sooner or later it will, the ship is located in space and it is then automatically guided through a second Jump to the neighborhood of the nearest inhabited planet."

"Sounds too complicated."

"It can't miss. All these years I've worked on it and it can't miss. I'll have ten years left yet to be a millionaire. But you're young; you'll be a millionaire much longer."

"When you Jump at random, you can end inside a star."

"Not one chance in a hundred trillion, Trent. We might also land so far from any luminous star that the computer can't find anything to match up against its program. We might find we've jumped only a light year or two and the police are still on our trail. The chances of that are smaller still. If you want to worry, worry that you might die of a heart attack at the moment of take-off. The chances for that are much higher."

"*You* might, Mr. Brennmeyer. You're older."

The old man shrugged. "I don't count. The computer will do everything automatically."

Trent nodded and remembered that. One midnight, when the ship was ready and Brennmeyer arrived with the Krillium in a briefcase (he had no difficulty for he was a greatly trusted man) Trent took the briefcase with one hand while his other moved quickly and surely.

A knife was still the best, just as quick as a molecular depolarizer, just as fatal, and much more quiet. Trent left the knife there with the body, complete with fingerprints. What was the difference? They wouldn't get him.

Deep in space now, with the police-cruisers in pursuit, he felt the gathering tension that always preceded a Jump. No physiologist could explain it, but every space-wise pilot knew what it felt like.

There was a momentary inside-out feeling as his ship and himself, for one moment of non-space and non-time, became non-matter and non-energy, then reassembled themselves instantaneously in another part of the Galaxy.

Trent smiled. He was still alive. No star was too close and there were thousands that were close enough. The sky was alive with stars and the pattern was so different that he knew the Jump had gone far. Some of those stars had to be spectral class F and better. The computer would have a nice rich pattern to match against its memory. It shouldn't take long.

He leaned back in comfort and watched the bright pattern of starlight move as the ship rotated slowly. A bright star came into view, a really bright one. It didn't seem more than a couple of light-years away and his pilot's sense told him it was a hot one; good and hot. The computer would use that as its base and match the pattern centered about it. Once again, he thought: It shouldn't take long.

But it did. The minutes passed. Then an hour. And still the computer clicked busily and its lights flashed.

Trent frowned. Why didn't it find the pattern? The pattern had to be there. Brennmeyer had showed him his long years of work. He *couldn't* have left out a star or recorded it in the wrong place.

Surely stars were born and died and moved through space while in being, but these changes were slow, slow. In a million years, the patterns that Brennmeyer had recorded couldn't—

A sudden panic clutched at Trent. NO! It *couldn't* be. The chances for it were even smaller than Jumping into a star's interior.

He waited for the bright star to come into view again and, with trembling hands, brought it into telescopic focus. He put in all the magnification he could, and around the bright speck of light was the tell-tale fog of turbulent gases caught, as it were, in mid-flight.

It was a nova!

From dim obscurity, the star had raised itself to bright luminosity,—perhaps only a month ago. It had graduated from a spectral class low enough to be ignored by the computer, to one that would be most certainly taken into account.

But the nova that existed in space didn't exist in the computer's memory store because Brennmeyer had not put it there. It had not existed when Brennmeyer was collecting his data—at least not as a luminous star.

"Don't count it," shrieked Trent. "Ignore it."

But he was shouting at automatic machinery that would match the nova-centered pattern against the Galactic pattern and find it nowhere and continue, nevertheless, to match and match and match for as long as its energy supply held out.

The air supply would run out much sooner. Trent's life would ebb away much sooner.

Helplessly, Trent slumped in his chair, watching the mocking pattern of star light and beginning the long and agonized wait for death.

—If he had only kept the knife.

Semiconductor Particle-Detectors

This new type of counter is supplanting all others in the field of low-energy nuclear physics. Among its advantages are rapid response and the ability to distinguish particles close in energy

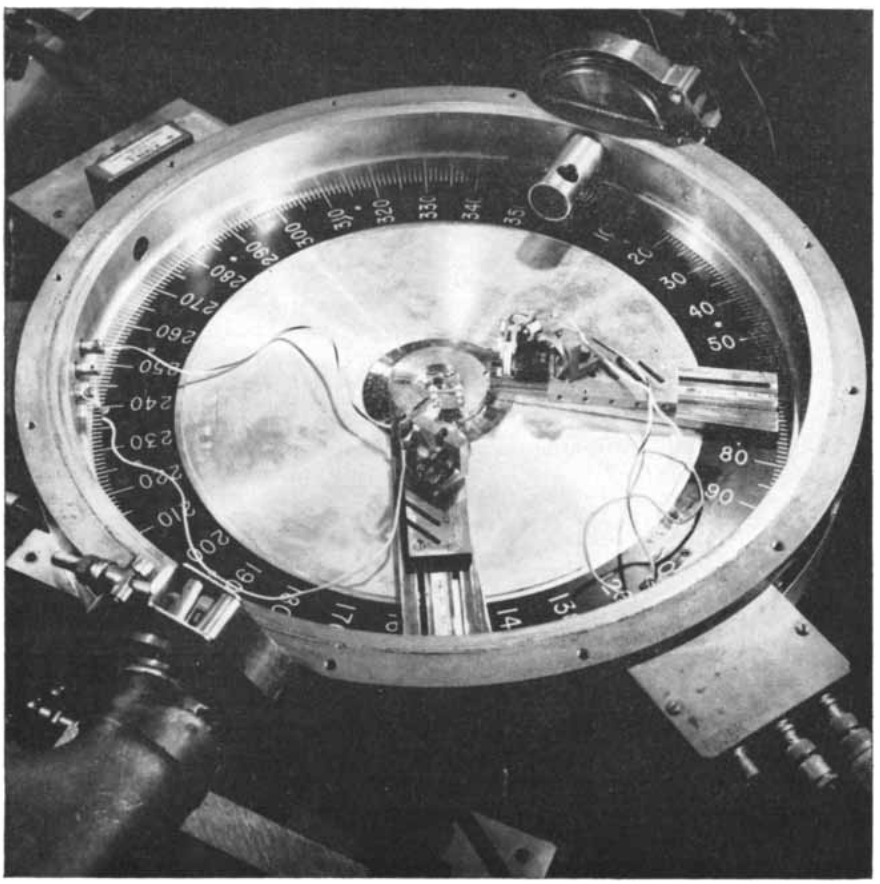
by Olexa-Myron Bilaniuk

Nuclear physics became possible when experimenters first learned how to detect the particles emitted by radioactive materials. Today the study of nuclear structure is still largely a matter of counting and measuring the fragments that excited atomic nuclei eject to rid themselves of excess energy. Recently the measurements have been made both easier to perform and more precise through the application of semiconductors. Just as the transistor has all but pushed the vacuum tube out of the electronics shop, so are semiconductor detectors fast supplanting bulkier and less efficient counters in the nuclear laboratory.

By current multibillion-electron-volt standards the particle energies in nuclear radiation are modest indeed: they are measured in millions of electron volts (Mev) or, at most, a few tens of Mev. As it happens, it is precisely in this low-energy region that semiconductor counters are best suited to function. Not only can they detect low-energy particles efficiently, they can also differentiate between tiny differences in energy.

The classical detector in low-energy physics has been the ionization chamber. A brief consideration of its operation will help to make clear the advantages offered by the new devices. The chamber is filled with an inert gas and contains a pair of electrodes, which are maintained at a potential difference of about 1,000 volts. A nuclear fragment entering the chamber through a thin window ionizes some of the gas atoms. The electrons and positive ions are swept out of the gas and onto the electrodes, giving rise to an electric pulse proportional in amplitude to the number of ion pairs produced. This in turn is proportional to the energy lost by the fragment in the chamber. The duration of the pulse depends on the time required to sweep up the liberated charge. (In contrast to its well-known relative, the Geiger counter, the ionization chamber does not employ a strong electric field to multiply the charges produced by the incoming particle. In order to measure energy, the chamber must respond with pulses of different sizes to different quantities of liberated charge.)

The quality of the counter is determined principally by its ability to distinguish between fragments of nearly equal energy; or, more strictly, between fragments losing nearly equal quantities of energy in the chamber. Because many nuclear measurements require a distinction among almost simultaneous events, a counter should produce brief signals to achieve good time resolution. Brief signals provide the additional bonus of



SEMICONDUCTOR COUNTERS are photographed in an experiment on neutron-neutron interaction at the Brookhaven National Laboratory. View at left shows vacuum chamber in which a target material, placed at the center, is bombarded by cyclotron beam emerging from tube at top. Counters are mounted on two arms. In close-up view at right the circular

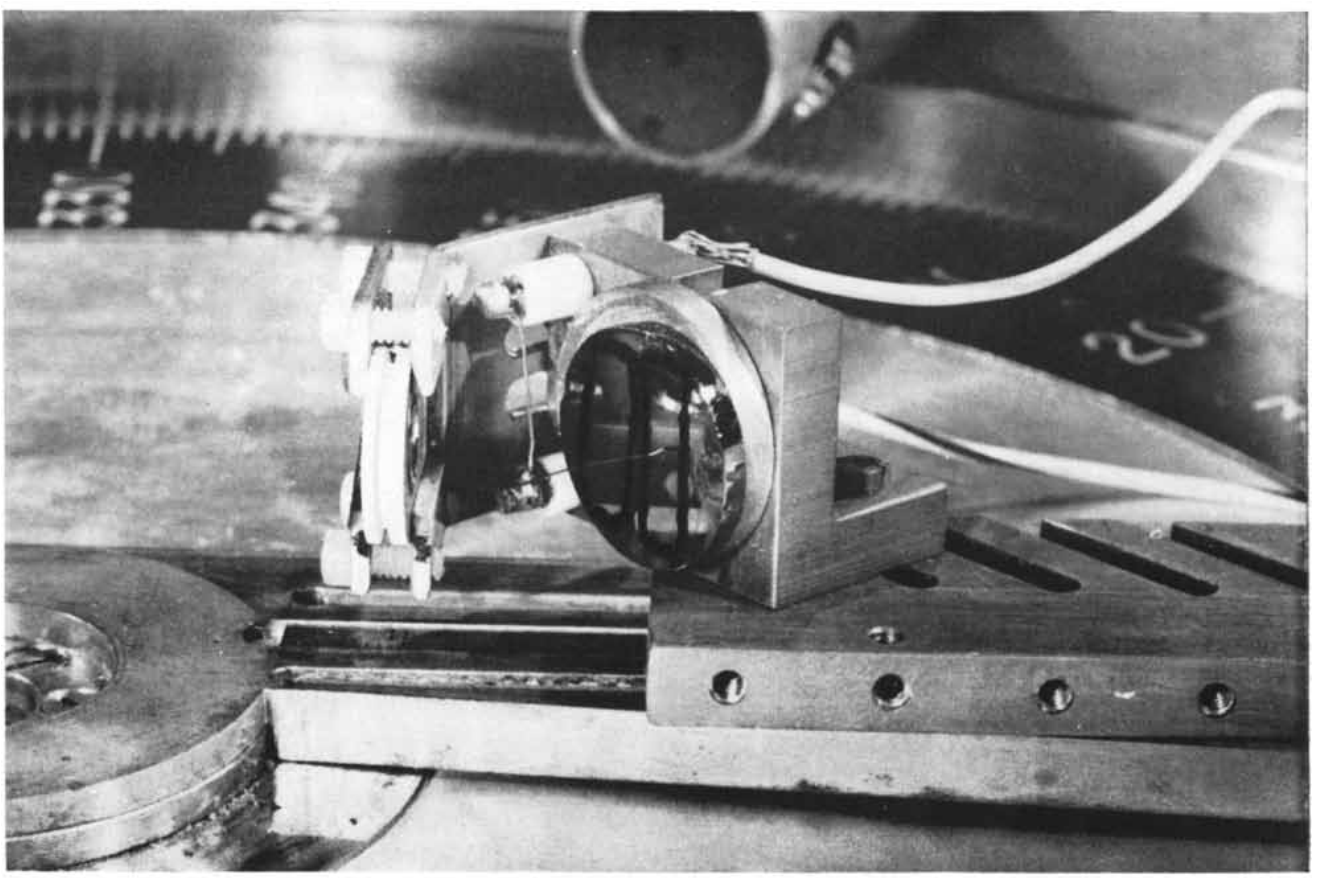
short recovery time, enabling the counter to respond to a rapid succession of particles.

Both the energy resolution and the time resolution of an ionization chamber are easy to estimate. The theoretical limit for energy resolution is set by the fact that it takes, on the average, 27 electron volts of energy to ionize one gas atom. If a nuclear fragment loses one Mev in the gas, it produces some 1,000,000 ÷ 27, or 37,000 ions. This average figure is subject to an uncertainty arising from the chance element in the process of collision and ionization. On the assumption of a "Poisson distribution," or a bell-shaped probability curve, the uncertainty is measured by the square root of 37,000, or 192. A detailed analysis shows that the curve is not exactly bell-shaped and that the uncertainty is somewhat smaller, but the simpler computation correctly reflects the dependence of the uncertainty on the amount of energy required to produce an ion pair. In the present example this uncertainty sets a theoretical limit of 192 ÷ 37,000, or .52 per cent, on the energy resolution of the ionization chamber.

Time resolution is simply a question of the speed with which the electric field clears out at least the majority of the liberated charges. It is determined primarily by the distance the charges have to travel and by the intensity of the electric field. In a practical ionization chamber it is hard to resolve pulses separated by less than 10 microseconds (millionths of a second). In terms of counting rate this means that if the number of accidental coincidences is to be less than 1 per cent of the registered counts, the rate must be limited to fewer than 1,000 counts per second.

An ionization chamber must be fairly large because to lose a measurable amount of its energy a nuclear fragment must cover a considerable distance in a gas. Here the advantage of a solid-state device is most clearly apparent. The great stopping power of scintillation crystals has made them the most popular detectors for low-energy nuclear research [see "Scintillation Counters," by George B. Collins; SCIENTIFIC AMERICAN, November, 1953]. Their energy resolution is limited, however, to about 3 per cent at best, and they are inseparable from the intricate photomultiplier tube. On both counts the semiconductor counter is superior, and it is displacing not only the gas-filled ionization chamber but also its own solid-state kin, the scintillation crystal.

In their physical appearance semiconductor counters resemble scintillation crystals, but in operation they are more closely related to ionization chambers. Charges created by incoming particles are collected by electrodes at the surface and converted to electric pulses. The first devices to be designed on this principle did not make use of the peculiar properties of semiconductors but were made simply of nonmetallic crystals, such as diamond or silicon. The carbon atoms in a diamond crystal are bound to one another in such a way as to tie all the atomic electrons to their respective lattice points. No charges are available to carry a current even if a high electric field is applied across the crystal. In solid-state parlance we say that the valence band, where the electrons are tied to their lattice sites, is separated by a wide, forbidden energy



disk facing 45 degrees from the axis of the arm is an "n-p junction" counter (see text), which counts the particles from target and measures their energy. The rectangles on one-inch silicon disk outline two separate counting areas. To the left of disk, seen edge on, is a "surface barrier" counter, which measures the rate of energy loss of the particles. The information from both counters serves to identify particles. The experiment is a joint project of the Bell Telephone Laboratories and Brookhaven National Laboratory.

gap from the conduction band, in which the charges are free to move through the crystal. When a nuclear fragment enters the crystal, it knocks electrons from the valence band into the conduction band, thus creating mobile charge carriers. These consist of both the liberated electrons and the positive "holes" they vacate. An external electric field can now sweep out the charge carriers, giving rise to a pulse of current.

In addition to its much higher stopping power compared with gas, the crystal counter surpasses the ionization chamber in energy resolution and recovery time. To activate one charge pair in the diamond crystal requires only nine electron volts, on the average, as against 27 for argon. Repeating the earlier calculation shows that the loss of one Mev of energy by a fragment activates 111,000 electron-hole pairs, with an uncertainty of the square root of 111,000, or 333. This gives an efficiency limit of .3 per cent. Even more significant is the improvement in time resolution. Principally because much shorter distances are involved, the activated charges are swept out from the crystal in a few hundredths of a microsecond instead of a few microseconds.

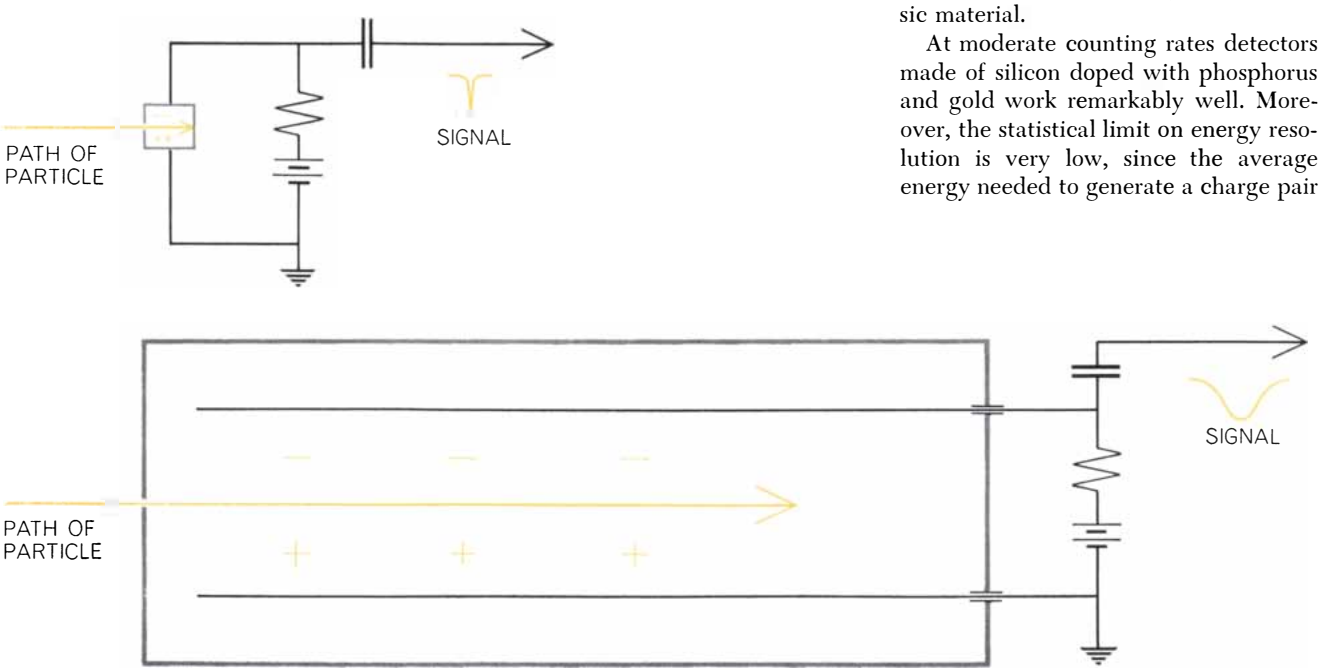
In spite of its great advantages, the crystal counter has not been a success. Two drawbacks are responsible: dark current and polarization. Random thermal motions continually activate charge carriers in the crystal, even in the absence of an ionizing nuclear projectile (that is, even in the "dark"). Under the influence of the external electric field, they give rise to an ever present fluctuating current that constitutes electrical noise above which the useful signals must be detected.

The dark current is insignificant in diamond because of the large width of the forbidden gap and the presence of so-called trapping centers arising from localized crystal imperfections. Depending on the type of imperfection, a trapping center may catch electrons or holes. Both types of center exist in every crystal, and they waylay a substantial fraction of the charge carriers activated by the bombarding particles. These trapped charges build up an electric field inside the crystal, which opposes the externally applied field. Even at moderate counting rates polarization considerably reduces the effective field strength. Not only does this lower the detection efficiency, it also destroys the proportionality between particle energy and collected charge, which is essential for good energy resolution.

By choosing a crystal such as silicon, which is similar to diamond but has a smaller forbidden gap, the effects of polarization can be considerably decreased. The bombarding particles release enough charge carriers to fill the traps and still produce substantial current. But the gain is offset by a prohibitively large dark current. A slab of high-purity silicon a quarter of a centimeter thick and one square centimeter in area has a resistance of approximately 2,500 ohms. Applying 250 volts across the slab gives rise to a dark current of a tenth of an ampere. Merely to dissipate the resulting 25 watts of heat becomes a problem, to say nothing of the difficulty of detecting the pulses that are caused by radiation.

What is wanted is a crystal with high resistance, to minimize dark current, and with minimum tendency to polarization. A fairly effective compromise that has been developed recently makes use of a silicon crystal judiciously doped with phosphorus and gold. Phosphorus atoms have five outer, or valence, electrons, one more than can fit into the interatomic bonds in the silicon crystal. The extra electrons are easily detached from their atoms to become mobile charge carriers. Because the majority of carriers are then negative, phosphorus-doped silicon is called an n-type semiconductor. The availability of electrons from the donor phosphorus atoms means that n-type silicon has much lower resistance than pure, or "intrinsic," material. Adding the right number of gold atoms just offsets the decrease in resistance by providing deep trapping centers to capture the mobile electrons. The net effect is that a crystal of ordinary silicon achieves the resistance of extremely pure, intrinsic material.

At moderate counting rates detectors made of silicon doped with phosphorus and gold work remarkably well. Moreover, the statistical limit on energy resolution is very low, since the average energy needed to generate a charge pair



CRYSTAL COUNTER (*top*), which was forerunner of semiconductor counters, is compared schematically with classic ionization chamber (*bottom*). Both are shown in approximately actual size. In both an incoming particle releases mobile charges, which are swept away by an externally applied voltage and which produce a brief output voltage pulse. Crystal gives much sharper pulses.

in silicon is only 3.5 Mev. In the case of a particle losing one Mev of energy the limit is only .2 per cent. At higher counting rates, however, gold-doped silicon crystals are still prone to polarization. In addition, they must be operated at liquid nitrogen temperatures so that thermal motions do not lift too many charge carriers across the narrow forbidden gap.

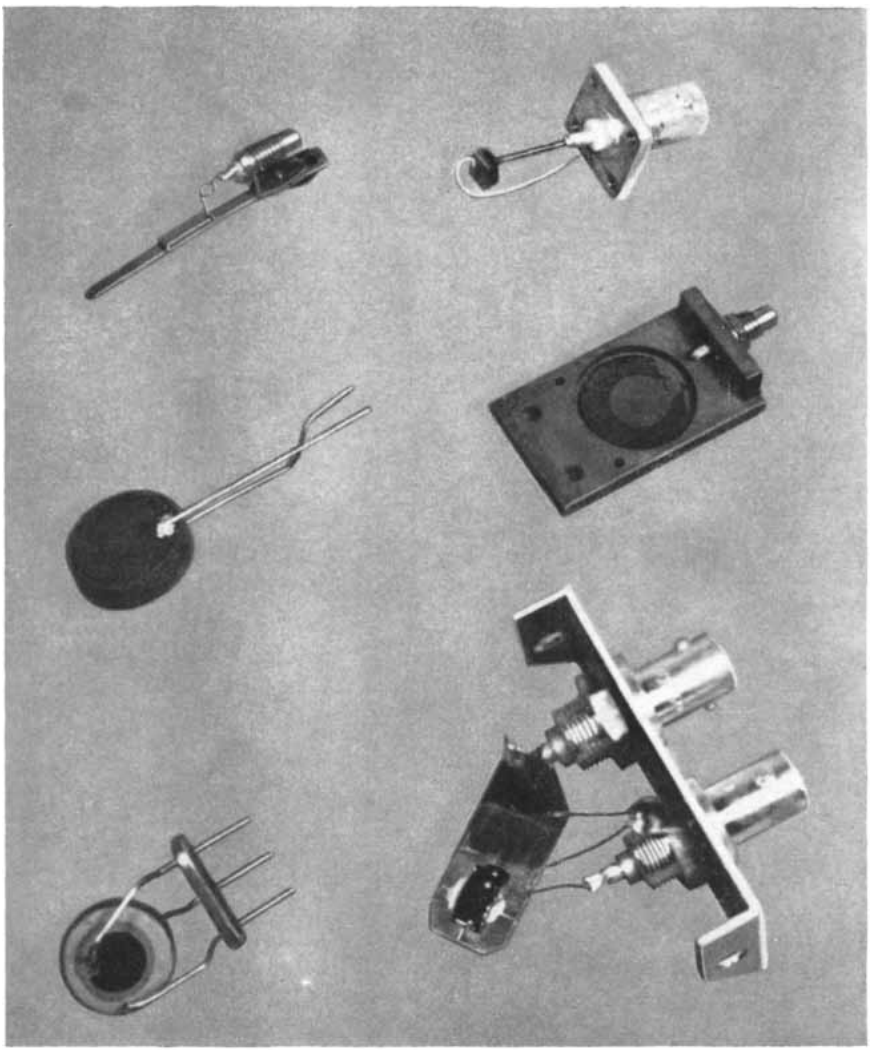
The chief stumbling block for the homogeneous crystal counter, at least in the present state of technology, is the apparent impossibility of achieving high resistivity without recourse to trapping. An elegant resolution of this problem has been found in the surface-junction counter.

Consider a silicon crystal in the interior of which one lattice atom in every million million or so is replaced by a boron atom. Boron has three valence electrons—one fewer than are required to satisfy the bonds to all neighboring atoms in the crystal. Therefore every boron atom constitutes an acceptor site, where electrons can easily lodge. Electrons moving into the sites leave behind positive holes that can move through the crystal and carry electric current. For this reason the material is called p-type. Suppose that one surface of the p-type crystal is doped with phosphorus to make it n-type. Then some of the extra donor electrons from the surface will lodge themselves in acceptor sites underneath, creating a narrow polarized region that is positive on one side and negative on the other [*see illustration on page 84*]. This dipole layer of bound positive and negative charge gives rise to an internal electric field that maintains the "depletion" region free of charge carriers and gives it very high resistivity. An external electric field applied in the direction of the internal field serves to widen the depletion region. In contrast to gold-doped silicon, the junction has no deep trapping centers to cause polarization.

When an ionizing nuclear fragment passes through the junction, it leaves a plasma of conduction electrons and holes in its wake that is swept out by the electric field within a few nanoseconds (thousands of a millionth of a second). This is the fastest detector recovery time known. The energy resolution, determined by the low energy needed for creation of an electron-hole pair in silicon, is still at its record low. (If germanium, with a narrower forbidden gap, is used instead of silicon, the limit to the energy resolution lies even lower. But germanium junction counters have to be cooled, whereas silicon works perfectly well at room temperature.)

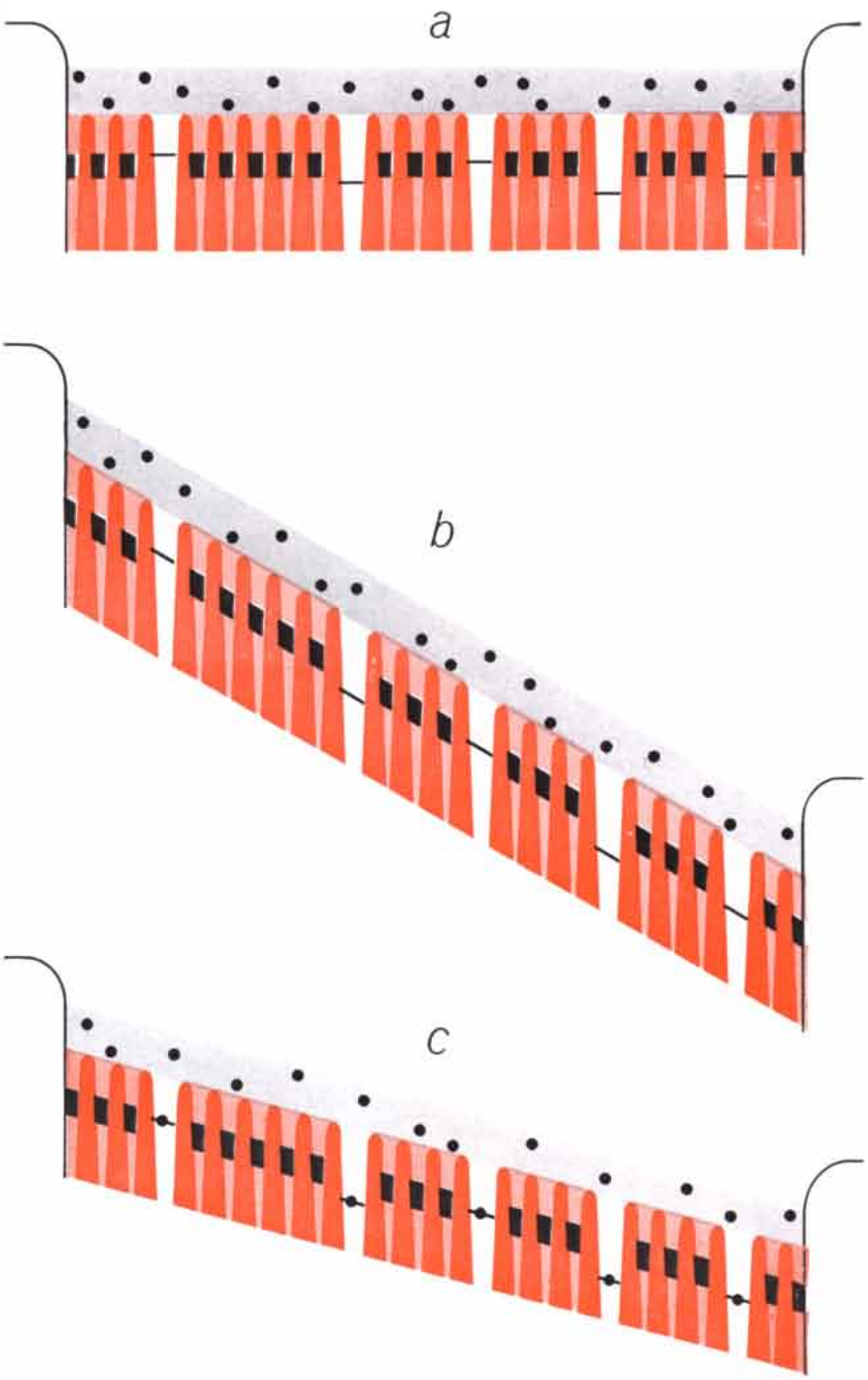
Similar to the surface-junction detector, both in quality and operation, is the silicon (or germanium) surface-barrier detector. It is designed to take advantage of the fact that the undamaged surface of a crystal can play the role of acceptor. Donor electrons from the interior of a phosphorus-doped, n-type silicon crystal collect on the surface, establishing a high-resistivity depletion region near the crystal surface, exactly as in the junction counter. A thin film of gold evaporated onto the surface makes it possible to widen the depletion layer by applying an additional voltage between the surface and the interior of the crystal. An ionizing particle entering the depletion region gives rise to a current pulse that can be collected at the gold film.

Although surface-junction and surface-barrier counters are unexcelled in their energy resolution and speed of signal, the limited depth of their depletion layer constitutes a serious weakness. To distinguish among particles of different energy the detector must stop all the particles within its sensitive region so that all the energy of each one contributes to the output pulse. The depth of the sensitive depletion layer increases as the square root of the applied voltage times the resistivity (determined by the purity) of the crystal. Even with externally applied fields as high as 400 volts and the purest available silicon, the



VARIOUS TYPES OF COUNTER discussed in the text were built in the author's laboratory at the University of Rochester. Raised rectangle in middle of strip at top left is a surface-barrier counter. Entire assembly is about two inches long. The other devices are: a surface-junction counter (*top right*), an n-i-p counter (*middle left*), a thin transmission counter (*middle right*), a p-n-i-p counter (*bottom left*), in which transmission counter is incorporated in the n-i-p device, and a combined transistor-counter (*bottom right*), which amplifies its own signals. Commercial firms have begun to make some of the devices.

depth of the sensitive region is only one millimeter. Therefore at present depletion-layer counters can be used to detect only particles that lose all their energy before they traverse one millimeter of silicon. Since the rate at which the particles lose energy is proportional to the square of their charge, the shallowness of the sensitive region is no handicap in working with multiply charged fragments. In most cases they are completely stopped in silicon after traveling only a fraction of a millimeter. For this reason these counters are admirably suited to the detection of nuclear fission fragments and have recently made



CONDUCTION IN CRYSTAL can take place only if charge carriers (*black dots*) are raised from valence energy band (*lower gray segments*) to conduction band (*upper gray band*), where they are above the potential energy barriers (*dark-colored shapes*) separating the atoms of the crystal. Applying an outside voltage provides a potential "hill" (*b*) down which the carriers can move. Imperfections in the crystal are traps (*black lines*) for carriers. When the traps are filled (*c*), an internal voltage partly offsets the applied voltage.

possible fission measurements of unequalled precision.

Even alpha particles and helium 3 ions, with their charge of two units, are easily detected, and their energy measured, within the sensitive region, as long as their energy does not exceed some 40 Mev. Most investigations of nuclear structure involve energies below this value, so that surface-junction and surface-barrier counters are now used almost exclusively for alpha spectroscopy and similar experiments. The trouble begins as soon as protons or deuterons (nuclei containing one proton and one neutron) are involved. The rate of energy loss for protons is only about a quarter of that for alpha particles, so that a detector with a sensitive region wide enough to stop 40-Mev alphas will be good for protons only up to 10 Mev. Tilting the crystal at an angle to the incoming particles extends the range to somewhat higher energies, but the basic limitation remains. Of course this limitation makes depletion-layer counters completely unsuitable for high-energy nuclear physics, where particle energies reach billions of electron volts.

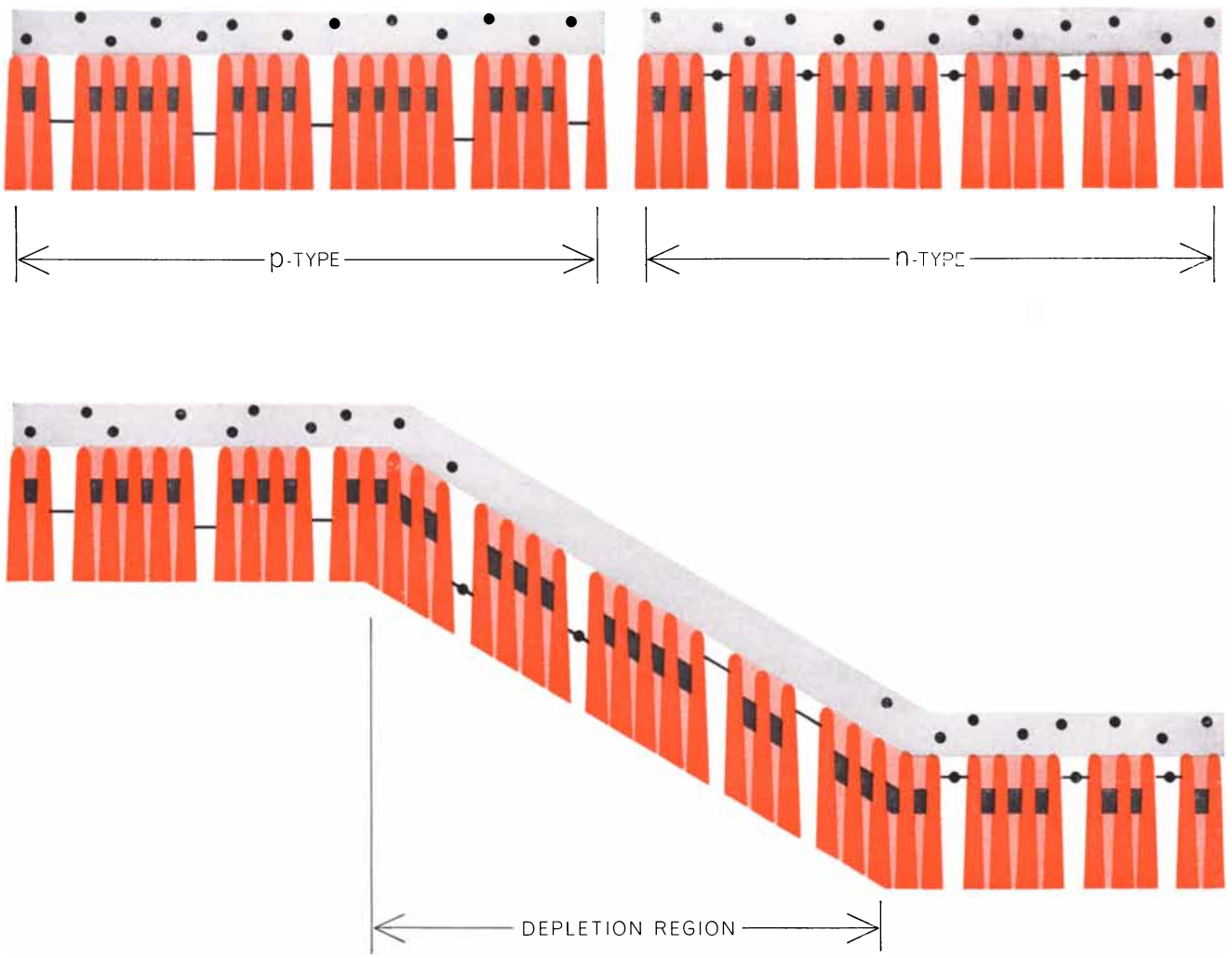
A considerable widening of the sensitive depletion region is achieved in the n-i-p (n-intrinsic-p) version of the junction counter. This device can be envisaged as a cross between an n-p junction and a crystal counter. It was first made in France by diffusing phosphorus and boron into the opposite faces of an ultrapure silicon slab. The result was a crystal with three distinct zones: a thin n-type surface layer, an intrinsic (undoped) interior and a p-type surface layer. As in the case of the n-p junction, some of the donor electrons drift over to occupy some of the acceptor sites, thereby depleting portions of the n and p layers of charge carriers. Moreover, the electric field thereby created bridges the intrinsic region, and so it too is kept free of carriers. Therefore practically the entire crystal becomes sensitive to ionizing rays. The counter works well, but it is difficult to make. Even extremely minute quantities of impurities in the silicon supply so many charge carriers that the central region can no longer be maintained in a depleted state.

An ingenious substitute for ultrapure silicon has been developed at the General Electric Research Laboratory by E. M. Pell. He begins with p-type silicon and diffuses lithium atoms into one face of the crystal. Lithium, with its single outer-shell electron, acts as a donor impurity and creates an n-p surface junction. Unlike the donors mentioned previously, however, lithium atoms do

not fit themselves into the crystal lattice proper but remain "interstitial." They are small enough to wander through the lattice. If a voltage is applied to the crystal in the right direction, lithium atoms that have given up their valence electrons will be forced into the p-type interior. There each ion eventually encounters an acceptor site occupied by an electron and hence negatively charged. The positive lithium ion neutralizes, or "compensates," the acceptor ion. In the process it becomes neutral itself and is no longer acted on by the outside voltage. The result is that all the acceptor sites within a rather wide zone are eventually compensated, and the material here exhibits properties of intrinsic silicon of very high resistivity. In effect the crystal now has an n-i-p configuration. Many laboratories today are fabricating n-i-p counters by the lithium drift method. Sensitive depths up to two millimeters are achieved more or less routinely. A few experimenters have made high-quality n-i-p counters twice as thick, and Jack H. Elliott at the Radiation Laboratory of the University of California has succeeded in extending the compensation to a depth of six millimeters, which appears to be a record. Although the manufacture of thick semiconductor counters is still largely an occult art, it will undoubtedly be reduced soon to a standardized procedure.

Interestingly enough, at the same time that physicists are straining to make thicker semiconductor counters, they are also trying to produce extremely thin ones. The latter are useful in distinguishing different types of particles of the same energy. Suppose that 20-Mev alpha particles are to be counted in the presence of 20-Mev deuterons. Alpha particles at this energy have a range of .2 millimeter in silicon; the deuterons penetrate to 1.5 millimeters. A counter with a depletion region only .2 millimeter thick will completely stop the 20-Mev alpha particles within its sensitive region, while absorbing less than two Mev of energy from the deuterons. Consequently the alpha signals are about 10 times larger than deuteron signals and can easily be selected electronically. It should be noted that although the experiment requires a narrow sensitive zone, the crystal need not be thin.

Now consider the problem of counting the deuterons rather than the alphas in the mixed beam. As long as the 20-Mev deuterons do not have to be further distinguished from, say, 19.7-Mev deuterons, the solution is straightforward. The alphas can be absorbed away by covering the counter with a thin foil. The more penetrating deuterons pass through the foil, leaving only two Mev of energy behind, and can then be detected without interference. But in traversing the foil deuterons undergo a



P-N JUNCTION COUNTER is made, in effect, by joining p-type and n-type semiconductors. P-type contains empty "acceptor sites" (*black lines*); n-type contains "donor sites," each with an easily lost electron (*black dot*). At junction electrons from donor sites drift into acceptor sites, producing a voltage that keeps the "depletion" region (*slanted section*) free of mobile carriers.

STAINLESS STEEL LIFELINE TO THE HEART

There are a growing number of people in America today who are going quietly and confidently about their business. They look normal. They act normal.

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Each carries, securely locked beneath the muscles of his chest or abdomen, a tiny transistorized battery box called a pacemaker. This box transmits pulsing electrical current along a stainless steel suture to the patient's heart wall. These gentle, timed electrical impulses shock the heart muscle into action.

The evolution of the pacemaker has returned many serious and possibly fatal heart cases to normal life.

However, pacemakers were not always as portable as they are today. The first ones were large, bedside units, which are in common use today. Further development produced a pacemaker small enough to be carried by the patient. One of several ways the steel suture entered his body was through a vein in his neck. He could move about, yes, but the unit was somewhat cumbersome and he lived a restricted life. Now, doctors and scientists have developed a miniature pacemaker, completely internal. It provides vital stimulus to the heart without interfering with the patient's normal activity.

Cyanamid's role in the evolution of the pacemaker? A relatively small one...about as important as the cord that plugs into the wall and brings your electrical appliances to life.

Cyanamid's Davis & Geck Division manufactures the stainless steel conductive suture that transmits electrical current from the pacemaker to the heart. This, however, is not quite as simple as it sounds. The wire *must* be strong, it must be non-corrosive. It must be chemically inert. It must be able to withstand continuous bending and straightening with every beat of the heart. This steel wire is implanted inside a patient's body. It is his lifeline.

But this is not a new type of assignment for Cyanamid's Davis & Geck Division. It has, for many years, been engaged in the manufacture of sutures...the fine tough strands and filaments that hold wounded muscles and skin together until they heal.

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Development of this link in the lifesaving chain is typical of the work being done by twelve Cyanamid divisions. From man-made fibers to industrial chemicals to stainless steel lifelines there is one common denominator. Man's need. If the need exists now or is likely to exist, there are Cyanamid scientists at work on it today.

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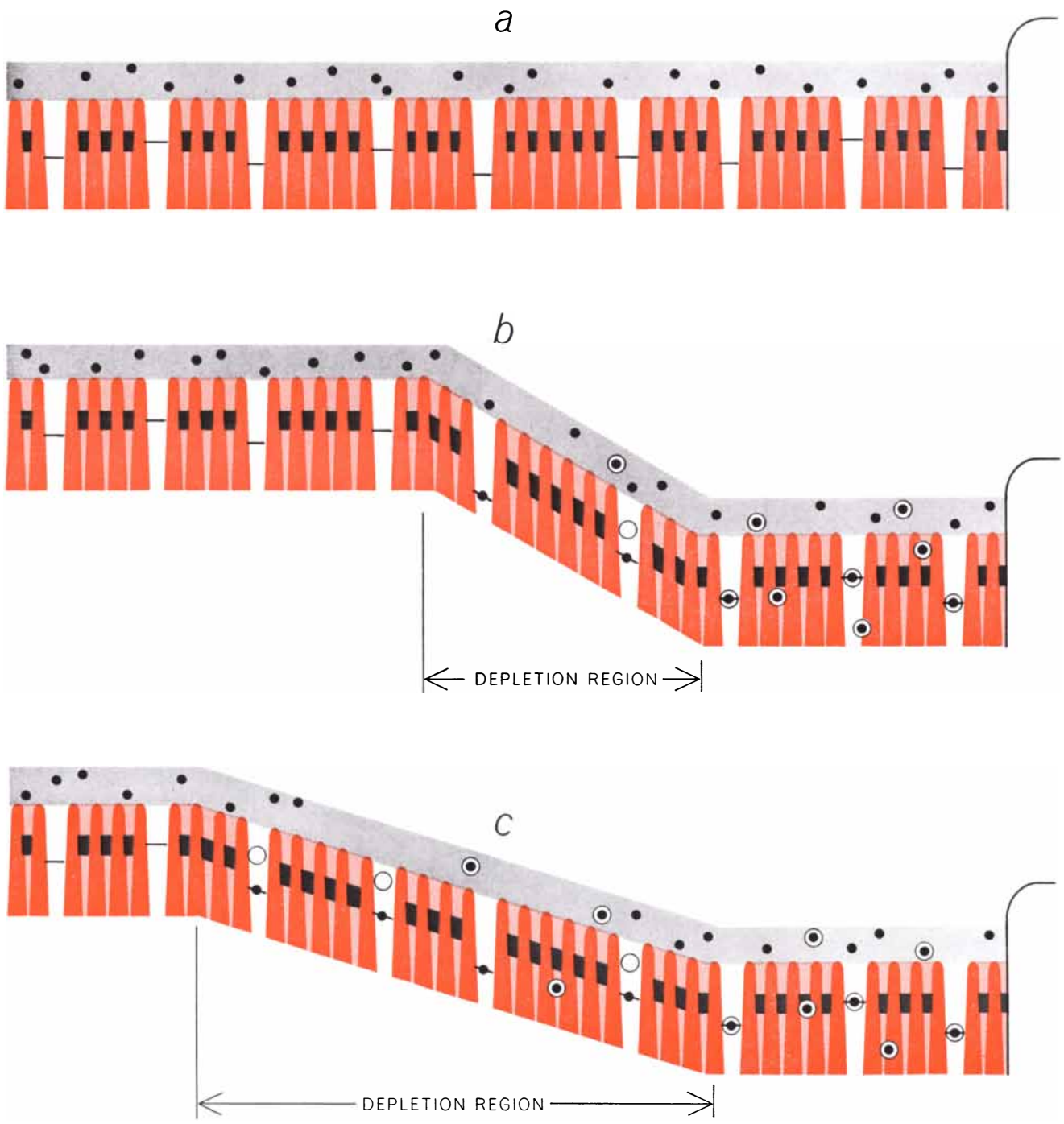
process called straggling, which spreads their energies. If the 20-Mev deuterons are accompanied by 19.7-Mev deuterons, the two groups become indistinguishable.

This is where the extremely thin transmission counter comes in. Harvey E. Wegner of the Los Alamos Scientific Laboratory has demonstrated that in traversing a thin crystal different particles give rise to pulses proportional to the rates at which they lose their energy. Therefore alphas produce much larger pulses than deuterons. The smaller deuteron signals from a thin sampling counter can be used to "gate" a second, ordinary counter so that it will respond only to the deuteron and ignore all the pulses arising from the alphas. Since the sampling counter is very thin, straggling is not significant and the high resolution of the main counter can be fully realized.

Making extremely thin transmission counters involves as much magic as does fabricating thick depletion layers. The main bugbear is the fragility of thin silicon wafers. Workers at the Bell Telephone Laboratories have recently produced a transmission counter a hundredth of a millimeter thick—a remark-



N-I-P COUNTER is made by diffusing lithium atoms (*open circles*) into one surface of p-type semiconductor. Lithium can donate its single outer electron (*black dot in circle*) to acceptor sites, converting surface to n-type ("*b*" *right*) and forming an n-p junction depletion region ("*b*" *center*). Lithium ions pushed into crystal by an outside voltage "compensate" acceptor levels in the p-type material, creating an "intrinsic" region with high resistivity and correspondingly increasing the thickness of the sensitive layer (*c*).

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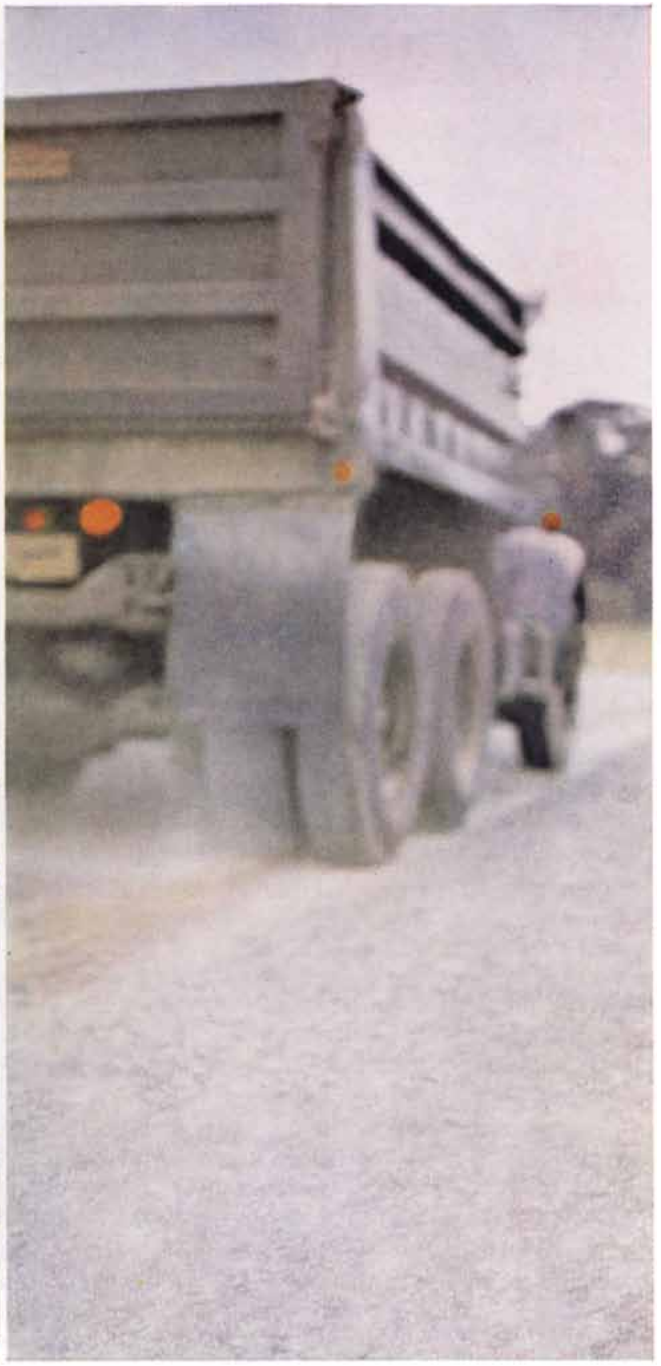
able accomplishment. At the University of Rochester my colleagues and I are trying to employ the undepleted portion of the n layer in a thick n-i-p counter as the base for a thin gold-silicon surface-barrier counter. We hope in this way to dispense with the separate fragile wafer and at the same time convert the insensitive "window" layer of the n-i-p detector into a useful component of a combination counter.

Some nuclear radiations contain separate groups of particles so nearly equal in energy that even the best semiconductor counters cannot resolve them. In that case the groups must be sorted out spatially, by passing the beam through the field of a strong magnet. Each particle trajectory bends at a different angle, depending on the charge and momentum. The separated beams are normally detected by sending them through special photographic emulsions, where they produce a visible track. But nuclear emulsions leave a great deal to be desired as particle detectors. Often the success or failure of a measurement hinges on some minor adjustment of the apparatus while the experiment is in progress. No such control is possible when working with nuclear emulsions because the experimenter cannot tell what is happening until the emulsions have been developed and scanned. Furthermore, scanning of the developed emulsions is in itself an onerous task.

A number of workers have tried replacing nuclear emulsions with banks of gas-filled or scintillation counters. To preserve the high resolution that the magnetic spectrograph provides, the individual counters must be quite narrow—on the order of two millimeters or less in thickness. Gas counters do not function well in such small dimensions. Scintillation counters can be cut to any size, but the need for individual photomultiplier tubes makes the array impossibly unwieldy. The semiconductor counter, on the other hand, being compact and self-contained, is eminently suited for assembly into arrays. Banks of 20 counters each have already been constructed and used successfully at the University of Rochester and at the University of Michigan.

The semiconductor counter has barely emerged from infancy. Many of its potentialities remain to be explored; some undoubtedly are yet to be thought of. As with so many technological aids to basic science, its development is a two-way street: while serving as a detector of nuclear radiation, it furnishes valuable information on the properties of semiconductors.



Enjay tests at 20 below to keep diesel fuel flowing

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Here's How A-L Research is Enlarging the Horizons

Out of the A-L Research Center have come such steels and alloys as S-816, a super-alloy for jet turbine blades; A-286, the most widely used of the super-alloys; AM-350 and AM-355, versatile new precipitation-hardening stainless steels; MF-1, the special muffler steel; electrical steels with improved orientation; and many more.

This new R&D Center concentrates within its five stainless steel buildings the equipment and people that contribute so much to both the usual and unusual in special metals. These attractive, efficient structures, on a 13½ acre plot, provide more than 120,000 square feet of space.

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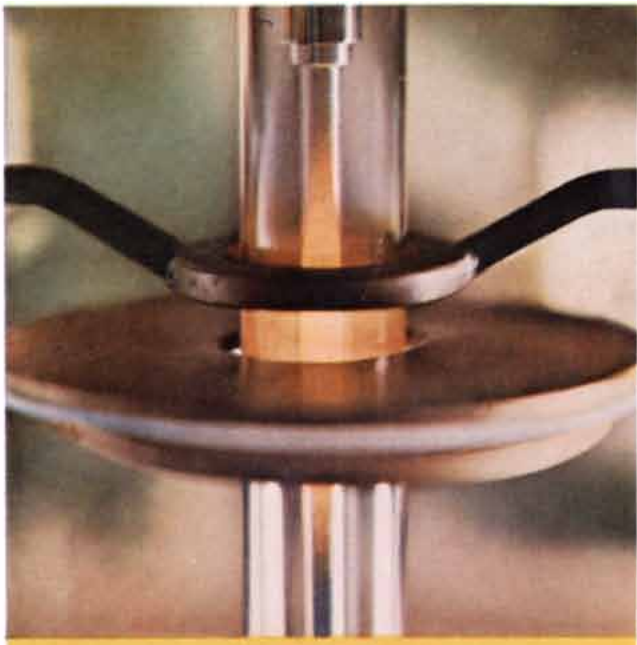
PIONEERING on the Horizons of Steel

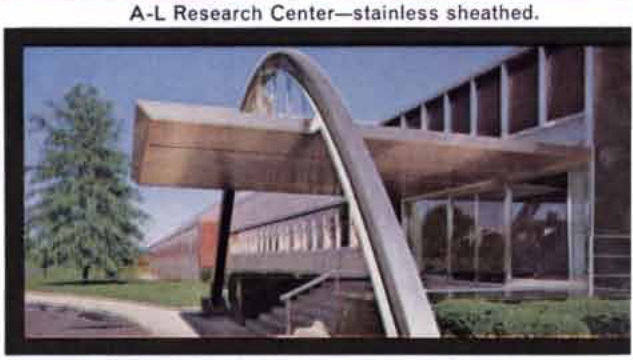


Zone melting furnace.

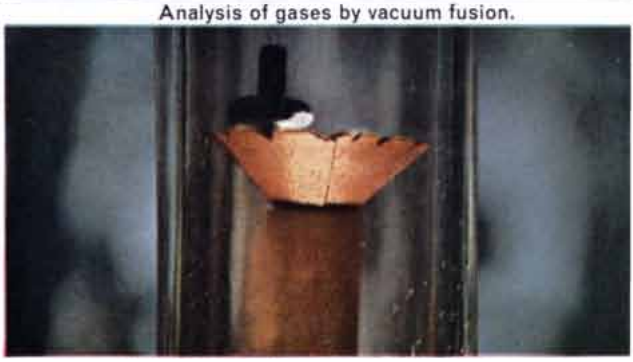
Levitation induction melting.

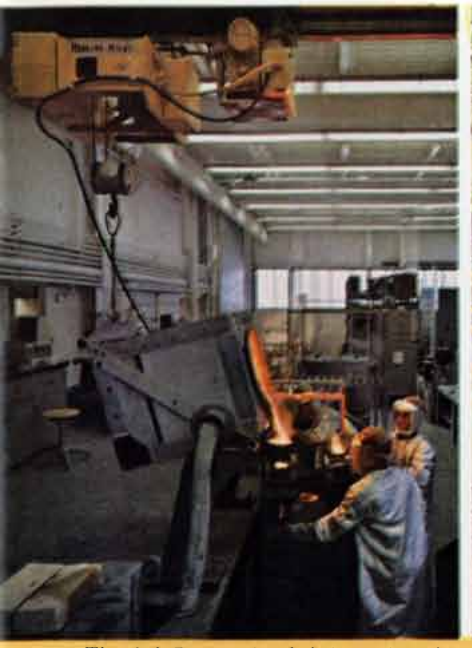
Electron microscope.

A-L Research Center—stainless sheathed.



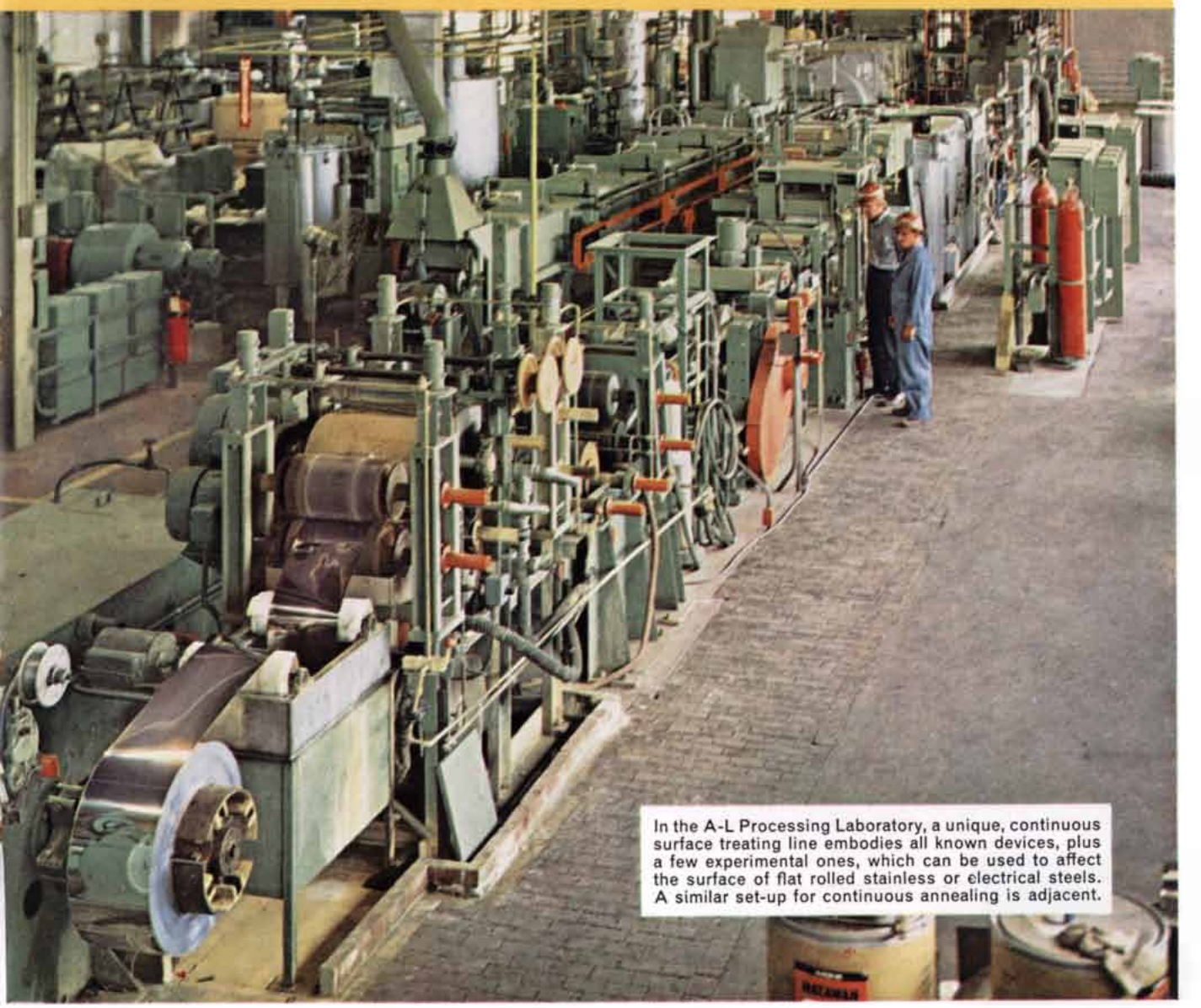
Analysis of gases by vacuum fusion.



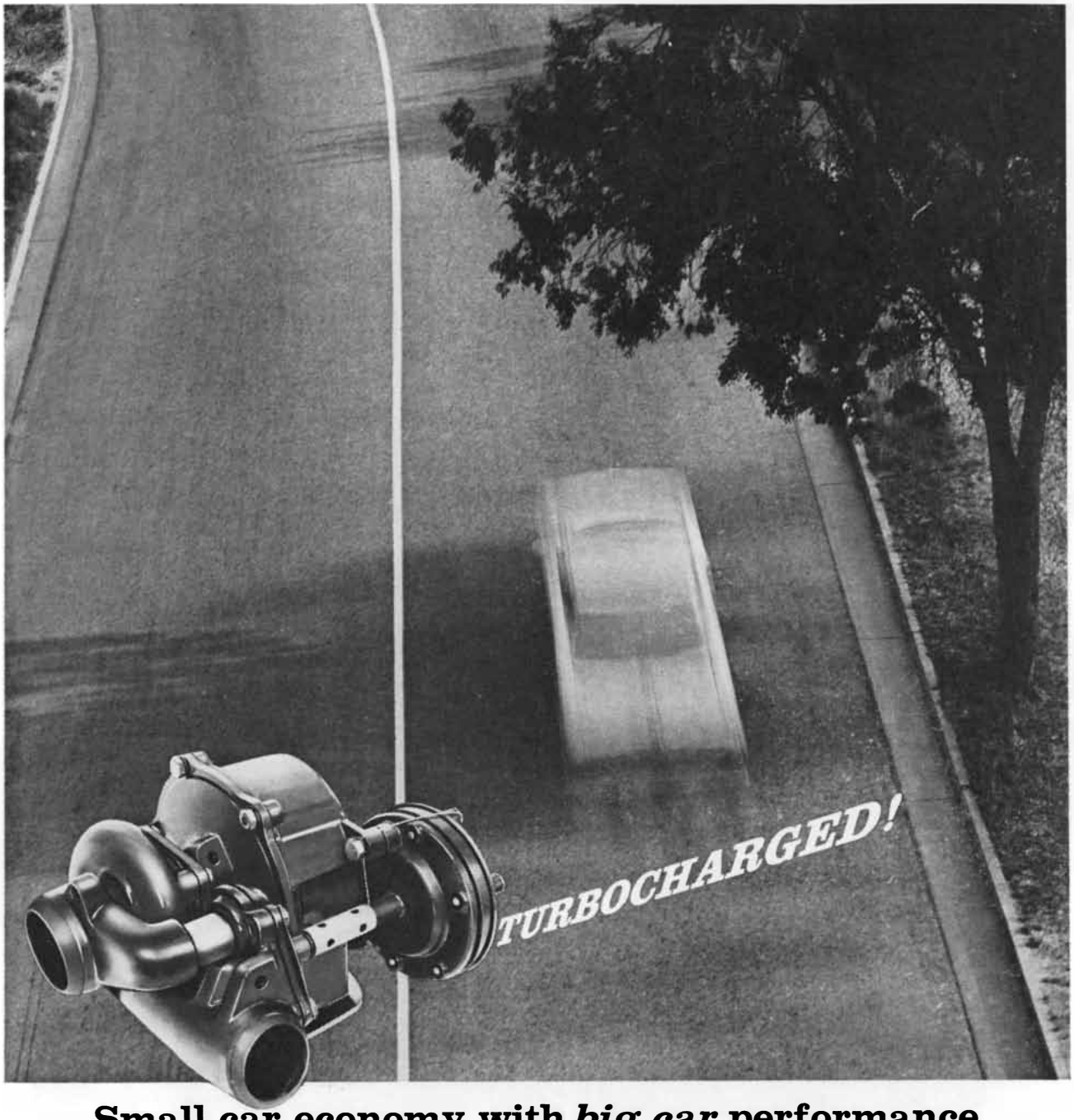


The A-L Processing Lab is equipped to melt by four different processes—air arc, air induction, vacuum arc and vacuum induction—and produces ingots from ½ to 500 lbs.

Research rolls in hot and cold mills under carefully controlled and monitored conditions.



In the A-L Processing Laboratory, a unique, continuous surface treating line embodies all known devices, plus a few experimental ones, which can be used to affect the surface of flat rolled stainless or electrical steels. A similar set-up for continuous annealing is adjacent.



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Garrett's AiResearch Industrial Division has been a leading manufacturer of lightweight turbochargers for more than a decade on everything from earth-moving equipment and trucks to pumping stations and small aircraft. And now AiResearch turbochargers are providing the most dramatic passenger automobile improvement in a decade.

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Cognitive Dissonance

It is the subject of a new theory based on experiments showing that the grass is usually not greener on the other side of the fence and that grapes are sourest when they are in easy reach

by Leon Festinger

There is an experiment in psychology that you can perform easily in your own home if you have a child three or four years old. Buy two toys that you are fairly sure will be equally attractive to the child. Show them both to him and say: "Here are two nice toys. This one is for you to keep. The other I must give back to the store." You then hand the child the toy that is his to keep and ask: "Which of the two toys do you like better?" Studies have shown that in such a situation most children will tell you they prefer the toy they are to keep.

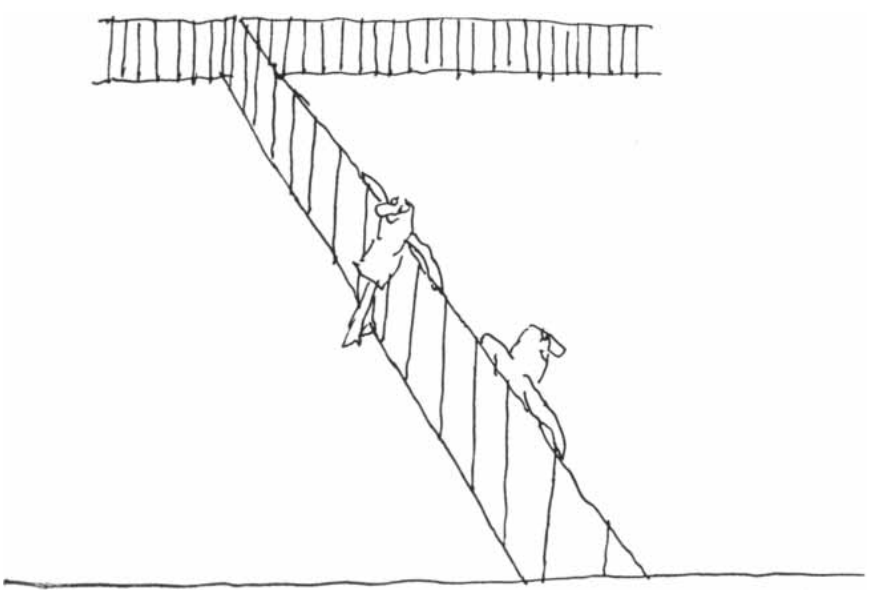
This response of children seems to conflict with the old saying that the grass is always greener on the other side of the fence. Do adults respond in the same way under similar circumstances or does the adage indeed become true as we grow older? The question is of considerable interest because the adult world is filled with choices and alternative courses of action that are often about equally attractive. When they make a choice of a college or a car or a spouse or a home or a political candidate, do most people remain satisfied with their choice or do they tend to wish they had made a different one? Naturally any choice may turn out to be a bad one on the basis of some objective measurement, but the question is: Does some psychological process come into play immediately after the making of a choice that colors one's attitude, either favorably or unfavorably, toward the decision?

To illuminate this question there is another experiment one can do at home, this time using an adult as a subject rather than a child. Buy two presents for your wife, again choosing things you are reasonably sure she will find about equally attractive. Find some plausible excuse for having both of them in your possession, show them to your wife and ask her to tell you how attractive each one is to her. After you have obtained a good measurement of attractiveness, tell her that she can have one of them, whichever she chooses. The other you will return to the store. After she has made her choice, ask her once more to evaluate the attractiveness of each of them. If you compare the evaluations of attractiveness before and after the choice, you will probably find that the chosen present has increased in attractiveness and the rejected one decreased.

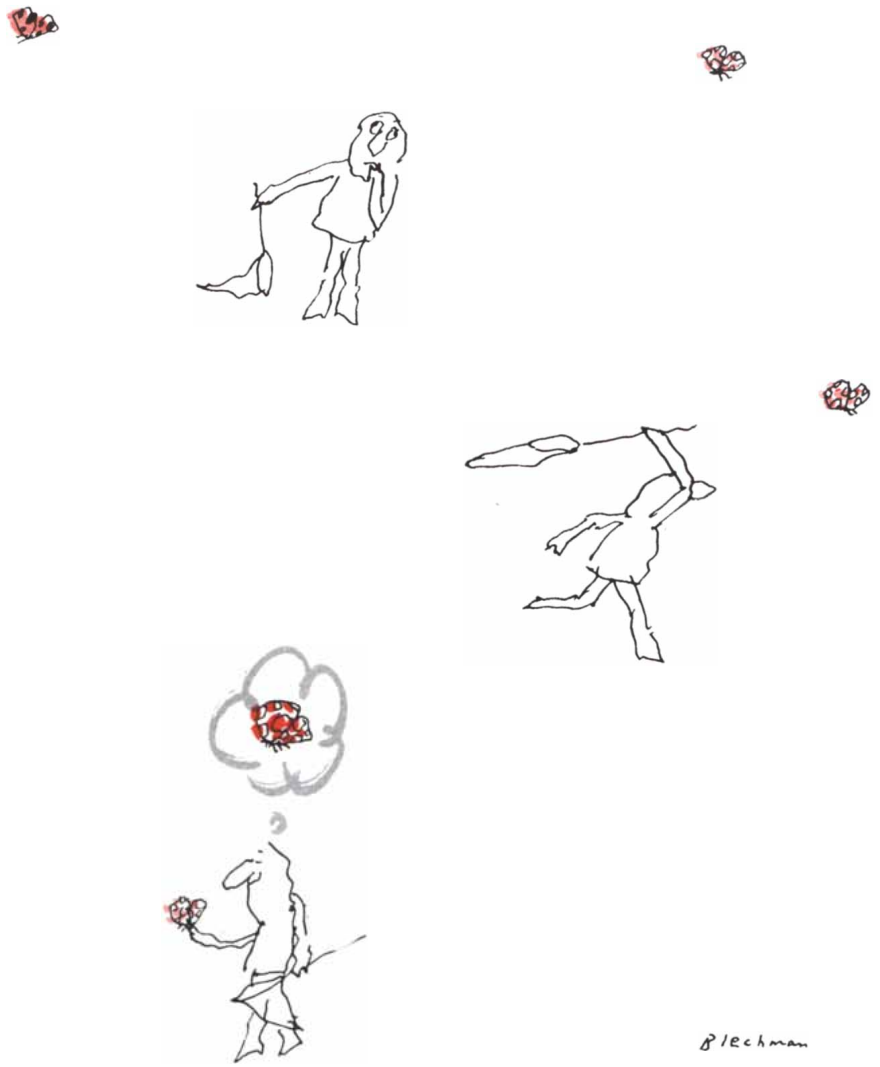
Such behavior can be explained by a new theory concerning "cognitive dissonance." This theory centers around the idea that if a person knows various things that are not psychologically consistent with one another, he will, in a variety of ways, try to make them more consistent. Two items of information that psychologically do not fit together are said to be in a dissonant relation to each other. The items of information may be about behavior, feelings, opinions, things in the environment and so on. The word "cognitive" simply emphasizes that the theory deals with relations among items of information.

Such items can of course be changed. A person can change his opinion; he can change his behavior, thereby changing the information he has about it; he can even distort his perception and his information about the world around him. Changes in items of information that produce or restore consistency are referred to as dissonance-reducing changes.

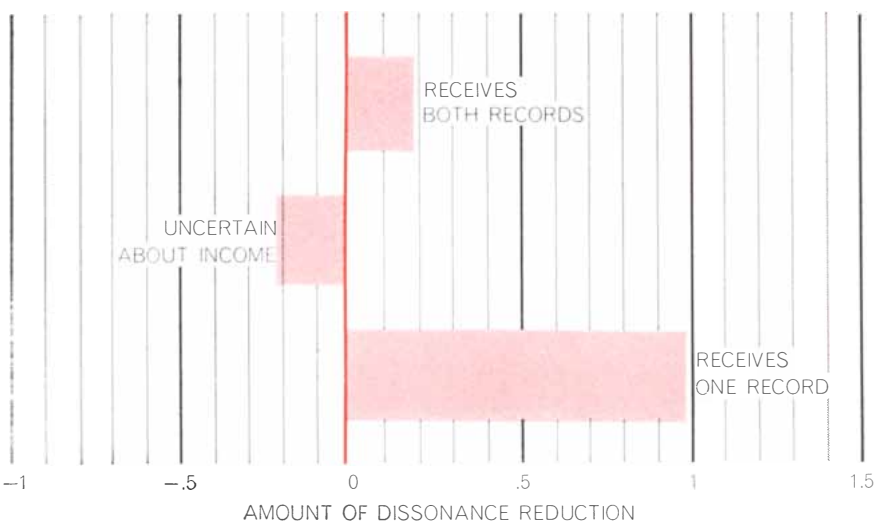
Cognitive dissonance is a motivating state of affairs. Just as hunger impels a person to eat, so does dissonance impel a person to change his opinions or his behavior. The world, however, is much



The grass is not always greener on the other side of the fence



Consequences of making a decision between two reasonably attractive alternatives



DISSONANCE REDUCTION is a psychological phenomenon found to occur after a person has made a choice between two approximately equal alternatives. The effect of the phenomenon is to enhance the attractiveness of the chosen object or chosen course of action. The chart summarizes the results of an experiment in which high school girls rated the attractiveness of 12 "hit" records before and after choosing one of them as a gift. Substantial dissonance reduction occurred under only one of three experimental conditions described in the text. Under two other conditions no systematic reduction was observed.

more effectively arranged for hunger reduction than it is for dissonance reduction. It is almost always possible to find something to eat. It is not always easy to reduce dissonance. Sometimes it may be very difficult or even impossible to change behavior or opinions that are involved in dissonant relations. Consequently there are circumstances in which appreciable dissonance may persist for long periods.

To understand cognitive dissonance as a motivating state, it is necessary to have a clearer conception of the conditions that produce it. The simplest definition of dissonance can, perhaps, be given in terms of a person's expectations. In the course of our lives we have all accumulated a large number of expectations about what things go together and what things do not. When such an expectation is not fulfilled, dissonance occurs.

For example, a person standing unprotected in the rain would expect to get wet. If he found himself in the rain and he was not getting wet, there would exist dissonance between these two pieces of information. This unlikely example is one where the expectations of different people would all be uniform. There are obviously many instances where different people would not share the same expectations. Someone who is very self-confident might expect to succeed at whatever he tried, whereas someone who had a low opinion of himself might normally expect to fail. Under these circumstances what would produce dissonance for one person might produce consonance for another. In experimental investigations, of course, an effort is made to provide situations in which expectations are rather uniform.

Perhaps the best way to explain the theory of cognitive dissonance is to show its application to specific situations. The rest of this article, therefore, will be devoted to a discussion of three examples of cognitive dissonance. I shall discuss the effects of making a decision, of lying and of temptation. These three examples by no means cover all the situations in which dissonance can be created. Indeed, it seldom happens that everything a person knows about an action he has taken is perfectly consistent with his having taken it. The three examples, however, may serve to illustrate the range of situations in which dissonance can be expected to occur. They will also serve to show the kinds of dissonance-reduction effects that are obtained under a special circumstance: when dissonance involves the person's behavior

and the action in question is difficult to change.

Let us consider first the consequences of making a decision. Imagine the situation of a person who has carefully weighed two reasonably attractive alternatives and then chosen one of them—a decision that, for our purposes, can be regarded as irrevocable. All the information this person has concerning the attractive features of the rejected alternative (and the possible unattractive features of the chosen alternative) are now inconsistent, or dissonant, with the knowledge that he has made the given choice. It is true that the person also knows many things that are consistent or consonant with the choice he has made, which is to say all the attractive features of the chosen alternative and unattractive features of the rejected one. Nevertheless, some dissonance exists and after the decision the individual will try to reduce the dissonance.

There are two major ways in which the individual can reduce dissonance in this situation. He can persuade himself that the attractive features of the rejected alternative are not really so attractive as he had originally thought, and that the unattractive features of the chosen alternative are not really unattractive. He can also provide additional justification for his choice by exaggerating the attractive features of the chosen alternative and the unattractive features of the rejected alternative. In other words, according to the theory the process of dissonance reduction should lead, after the decision, to an increase in the desirability of the chosen alternative and a decrease in the desirability of the rejected alternative.

This phenomenon has been demonstrated in a variety of experiments. A brief description of one of these will suffice to illustrate the precise nature of the effect. In an experiment performed by Jon Jecker of Stanford University, high school girls were asked to rate the attractiveness of each of 12 "hit" records. For each girl two records that she had rated as being only moderately attractive were selected and she was asked which of the two she would like as a gift. After having made her choice, the girl again rated the attractiveness of all the records. The dissonance created by the decision could be reduced by increasing the attractiveness of the chosen record and decreasing the attractiveness of the rejected record. Consequently a measurement of dissonance reduction could be obtained by summing both of these kinds of changes in ratings made before and after the decision.

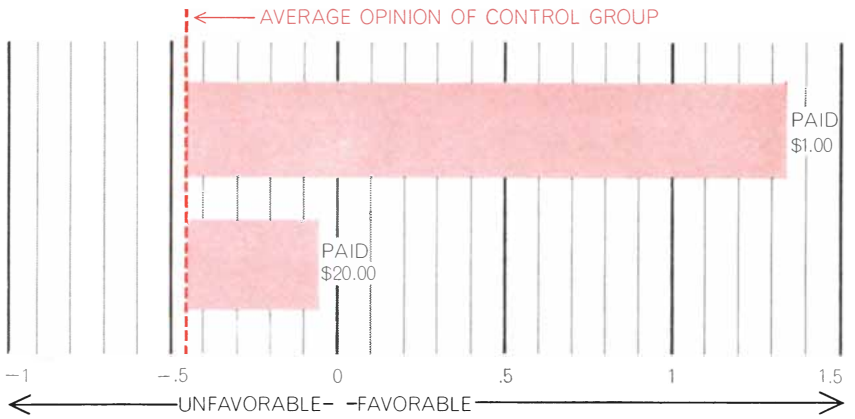
Different experimental variations were employed in this experiment in order to examine the dynamics of the process of dissonance reduction. Let us look at three of these experimental variations. In all three conditions the girls, when they were making their choice, were given to understand there was a slight possibility that they might actually be given both records. In one condition they were asked to rerate the records after they had made their choice but before they knew definitely whether they would receive both records or only the one they chose. The results for this condition should indicate whether dissonance reduction begins with having made the choice or whether it is suspended until the uncertainty is resolved. In a second condition the girls were actually given both records after their choice and were then asked to rerate

Further consequences of making a difficult decision

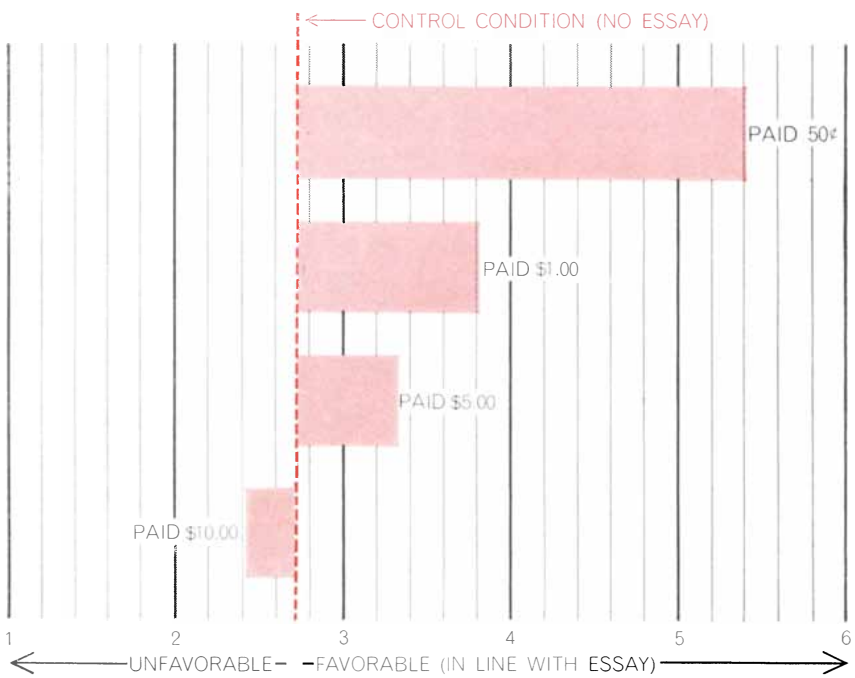
all the records. Since they had received both records and therefore no dissonance existed following the decision, there should be no evidence of dissonance reduction in this condition. In a third condition the girls were given only the record they chose and were then asked to do the rerating. This, of course, resembles the normal outcome of a decision and the usual dissonance reduction should occur.

The chart on page 94 shows the results for these three conditions. When the girls are uncertain as to the outcome, or when they receive both records, there is no dissonance reduction—that is, no systematic change in attractiveness of the chosen and rejected records. The results in both conditions are very close to zero—one slightly positive, the other slightly negative. When they receive only the record they chose, however, there is a large systematic change in rating to reduce dissonance. Since dissonance reduction is only observed in this last experimental condition, it is evident that dissonance reduction does not occur during the process of making a decision but only after the decision is made and the outcome is clear.

Let us turn now to the consequences of lying. There are many circumstances in which, for one reason or another, an individual publicly states something that is at variance with his private belief. Here again one can expect dissonance to arise. There is an inconsistency between knowing that one really believes one thing and knowing that one has publicly stated something quite different. Again, to be sure, the individual knows things that are consonant with his overt, public behavior. All the reasons that induced him to make the public statement are consonant with his having made it and provide him with some justification for his behavior. Nevertheless, some dissonance exists and, according to the theory, there will be attempts to reduce it. The degree to which the dissonance is bothersome for the individual will depend on two things. The more deviant his public statement is from his private belief, the greater will be the dissonance. The greater the amount of justification the person has for having made the public statement, the less bothersome the dissonance will be.



CONSEQUENCES OF LYING are found to vary, depending on whether the justification for the lie is large or small. In this experiment students were persuaded to tell others that a boring experience was really fun. Those in one group were paid only $1 for their cooperation; in a second group, $20. The low-paid students, having least justification for lying, experienced most dissonance and reduced it by coming to regard the experience favorably.



GRADED CHANGE OF OPINION was produced by paying subjects various sums for writing essays advocating opinions contrary to their beliefs. When examined later, students paid the least had changed their opinion the most to agree with what they had written. Only the highest paid group held to their original opinion more strongly than did a control group.

How can the dissonance be reduced? One method is obvious. The individual can remove the dissonance by retracting his public statement. But let us consider only those instances in which the public statement, once made, cannot be changed or withdrawn; in other words, in which the behavior is irrevocable. Under such circumstances the major avenue for reduction of the dissonance is change of private opinion. That is, if the private opinion were changed so that it agreed with what was publicly stated, obviously the dissonance would be gone. The theory thus leads us to expect that after having made an irrevocable public statement at variance with his private belief, a person will tend to change his private belief to bring it into line with his public statement. Furthermore, the degree to which he changes his private belief will depend on the amount of justification or the amount of pressure for making the public statement initially. The less the original justification or pressure, the greater the dissonance and the more the person's private belief can be expected to change.

An experiment recently conducted at Stanford University by James M. Carlsmith and me illustrates the nature of this effect. In the experiment, college students were induced to make a statement at variance with their own belief. It was done by using students who had

volunteered to participate in an experiment to measure "motor performance." The purported experiment lasted an hour and was a boring and fatiguing session. At the end of the hour the experimenter thanked the subject for his participation, indicating that the experiment was over. The real purpose of the hour-long session, however, was to provide each subject with an identical experience about which he would have an unfavorable opinion.

At the end of the fatiguing hour the experimenter enlisted the subject's aid in preparing the next person for the experiment. The subject was led to believe that, for experimental purposes, the next person was supposed to be given the impression that the hour's session was going to be very interesting and lots of fun. The subject was persuaded to help in this deception by telling the next subject, who was waiting in an adjoining room, that he himself had just finished the hour and that it had indeed been very interesting and lots of fun. The first subject was then interviewed by someone else to determine his actual private opinion of the experiment.

Two experimental conditions were run that differed only in the amount of pressure, or justification given the subject for stating a public opinion at variance with his private belief. All subjects, of course, had the justification of helping to conduct a scientific experiment. In addition to this, half of the subjects were paid $1 for their help—a relatively small amount of money; the other subjects were paid $20—a rather large sum for the work involved. From the theory we would expect that the subjects who were paid only $1, having less justification for their action, would have more dissonance and would change their private beliefs more in order to reduce the dissonance. In other words, we would expect the greatest change in private opinion among the subjects given the least tangible incentive for changing.

The upper illustration on the opposite page shows the results of the experiment. The broken line in the chart shows the results for a control group of subjects. These subjects participated in the hour-long session and then were asked to give their private opinion of it. Their generally unfavorable views are to be expected when no dissonance is induced between private belief and public statement. It is clear from the chart that introducing such dissonance produced a change of opinion so that the subjects who were asked to take part in a deception finally came to think better of the session than did the control subjects. It is also clear that only in the condition where they were paid a dollar is this opinion change appreciable. When they were paid a lot of money, the justification for misrepresenting private belief is high and there is correspondingly less change of opinion to reduce dissonance.

The effect of rewards on lying

Another way to summarize the result is to say that those who are highly rewarded for doing something that involves dissonance change their opinion less in the direction of agreeing with what they did than those who are given very little reward. This result may seem surprising, since we are used to thinking that reward is effective in creating change. It must be remembered, however, that the critical factor here is that the reward is being used to induce a behavior that is dissonant with private opinion.

To show that this result is valid and not just a function of the particular situation or the particular sums of money used for reward, Arthur R. Cohen of New York University conducted a similar experiment in a different context. Cohen paid subjects to write essays advocating an opinion contrary to what they really believed. Subjects were paid either $10, $5, $1 or 50 cents to do this. To measure the extent to which dissonance was reduced by their changing their opinion, each subject was then given a questionnaire, which he left unsigned, to determine his private opinion on the issue. The extent to which the subjects reduced dissonance by changing their opinion to agree with what they wrote in the essay is shown in the lower illustration on the opposite page. Once again it is clear that the smaller the original justification for engaging in the dissonance-producing action, the greater the subsequent change in private opinion to bring it into line with the action.

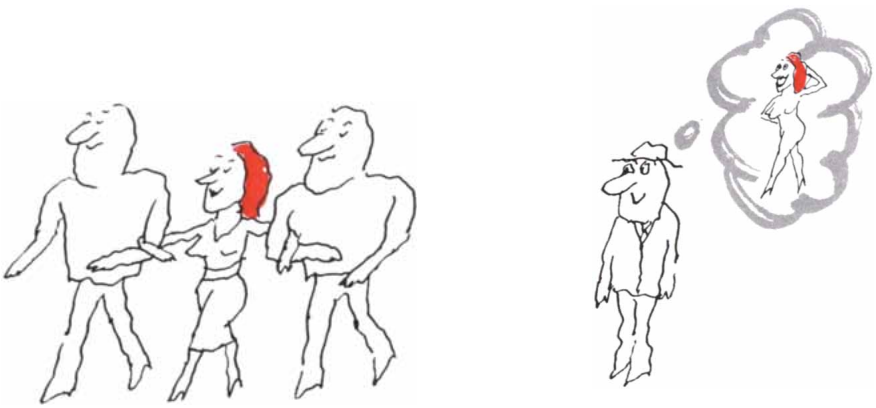
The final set of experiments I shall discuss deals with the consequences of resisting temptation. What happens when a person wants something and discovers that he cannot have it? Does he now want it even more or does he persuade himself that it is really not worth having? Sometimes our common general understanding of human behavior can provide at least crude answers to such questions. In this case,

however, our common understanding is ambiguous, because it supplies two contradictory answers. Everyone knows the meaning of the term "sour grapes"; it is the attitude taken by a person who persuades himself that he really does not want what he cannot have. But we are also familiar with the opposite reaction. The child who is not allowed to eat candy and hence loves candy passionately; the woman who adores expensive clothes even though she cannot afford to own them; the man who has a hopeless obsession for a woman who spurns his attentions. Everyone "understands" the behavior of the person who longs for what he cannot have.

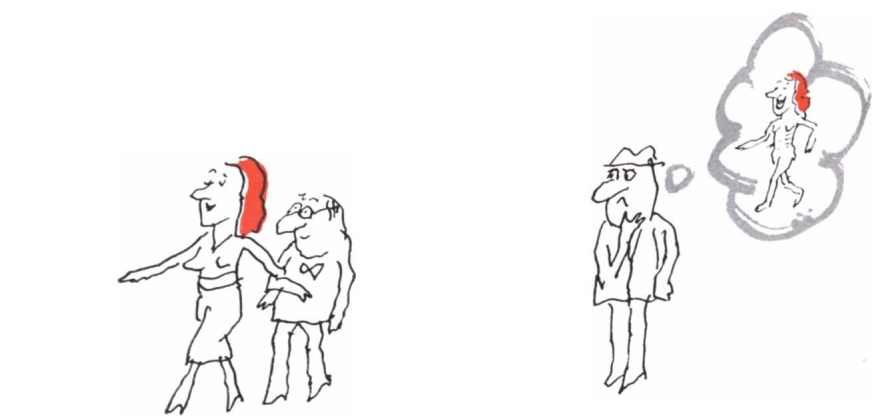
Obviously one cannot say one of these reactions is wrong and the other is right; they both occur. One might at least, however, try to answer the question: Under what circumstances does one reaction take place and not the other? If we examine the question from the point of view of the theory of dissonance, a partial answer begins to emerge.

Imagine the psychological situation that exists for an individual who is tempted to engage in a certain action but for one reason or another refrains. An analysis of the situation here reveals its similarity to the other dissonance-producing situations. An individual's knowledge concerning the attractive aspects of the activity toward which he was tempted is dissonant with the knowledge that he has refrained from engaging in the activity. Once more, of course, the individual has some knowledge that is consonant with his behavior in the situation. All the pressures, reasons and justifications for refraining are consonant with his actual behavior. Nevertheless, the dissonance does exist, and there will be psychological activity oriented toward reducing this dissonance.

As we have already seen in connection with other illustrations, one major way to reduce dissonance is to change one's opinions and evaluations in order to bring them closer in line with one's actual behavior. Therefore when there is

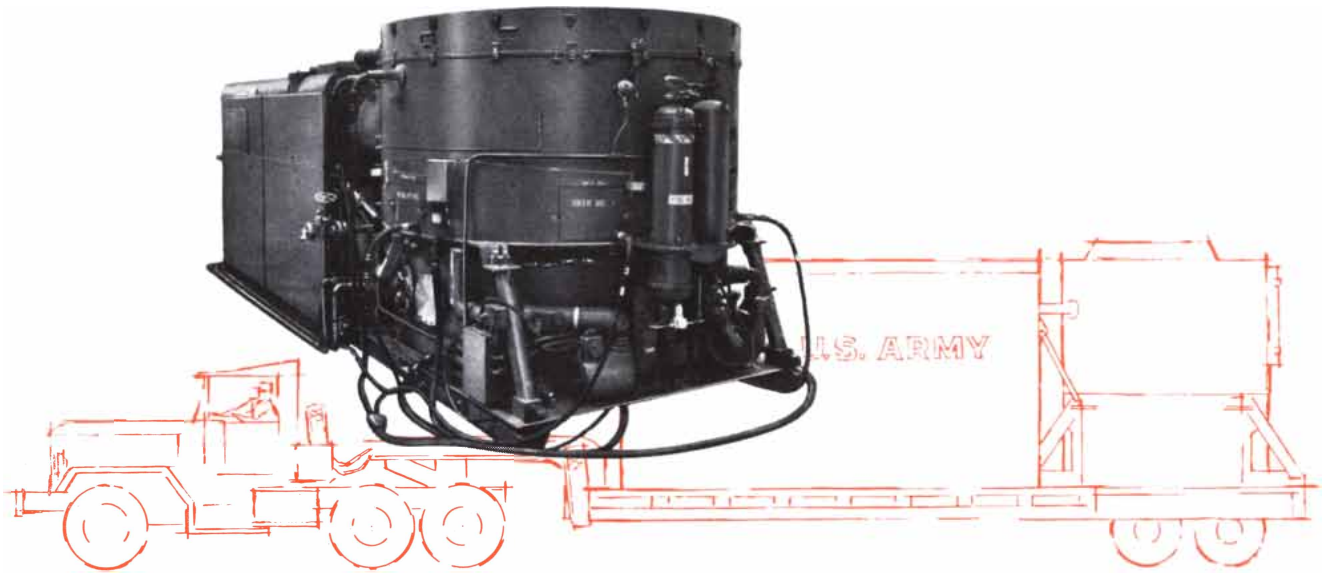


Temptation accompanied by a severe threat



Temptation accompanied by a mild threat

From conception to demonstration at AGN . . .



ML-1: WORLD'S FIRST FULLY MOBILE NUCLEAR POWER PLANT

Aerojet-General Nucleonics is engaged in one of the most challenging projects ever assigned to an organization specializing in reactor activities. The project: conceive, build and demonstrate a nuclear power plant powerful enough to supply 400 kw of electricity continuously for a year without refueling . . . compact enough to be transported by truck-trailer, flatcar, or cargo plane . . . simple enough to be operated by a small crew of trained Army enlisted men . . . tough enough to withstand shock, vibration, pressure, and environmental extremes . . . and safe enough to be picked up and transported to a new site within hours after shutdown. One of the final steps, generation of electricity by the demonstration ML-1, was accomplished in September.

The ML-1 is the smallest (40 tons) and hottest (1200°F. outlet temperature) nuclear power plant ever to produce electricity, and is the only plant in which the reactor is coupled directly to closed-cycle, high-speed turbo machinery. It is gas-cooled, and fueled with $BeO\text{-}UO_2$.

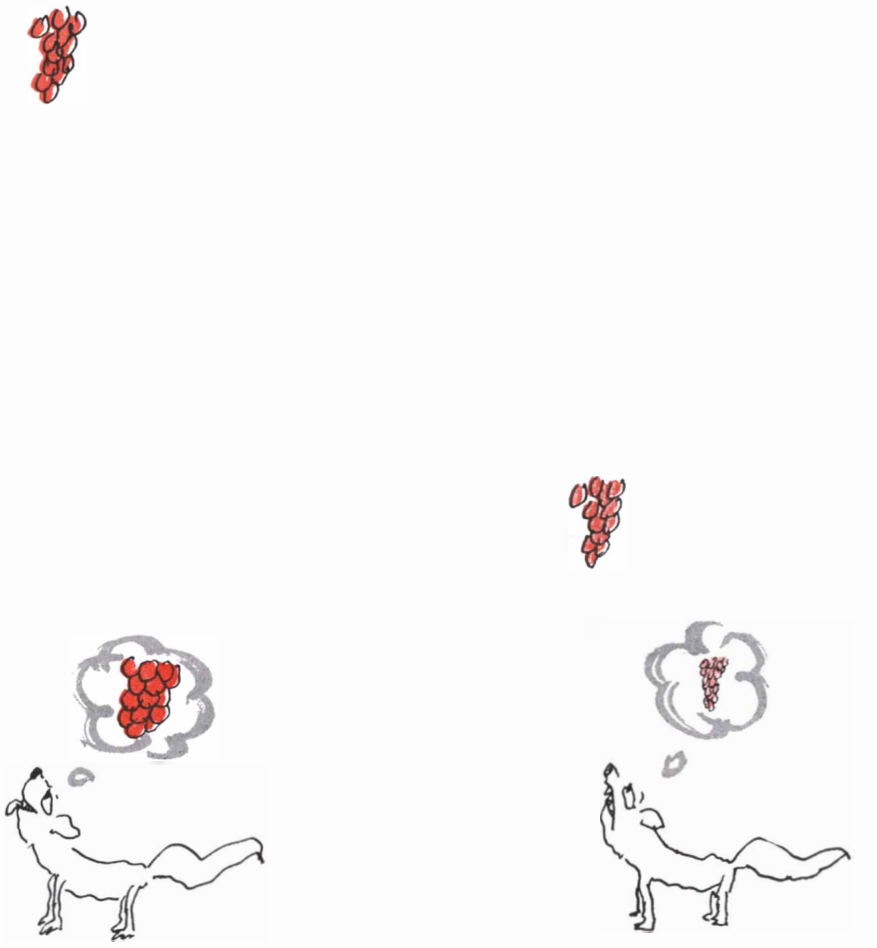
Full responsibility for the ML-1 project was assigned by the Atomic Energy Commission to AGN under the Army Gas-Cooled Reactor Systems Program. During management of the program, AGN has gained broad experience in all phases of lightweight, gas-cooled nuclear power plant design and production. AGN management skills, high-temperature reactor technology, test experience, and project personnel also are being applied to studies of advanced ground power plants, space power systems, and nuclear ram-jets.

ML-1 is a joint project of the U. S. Atomic Energy Commission and the U. S. Army Corps of Engineers.

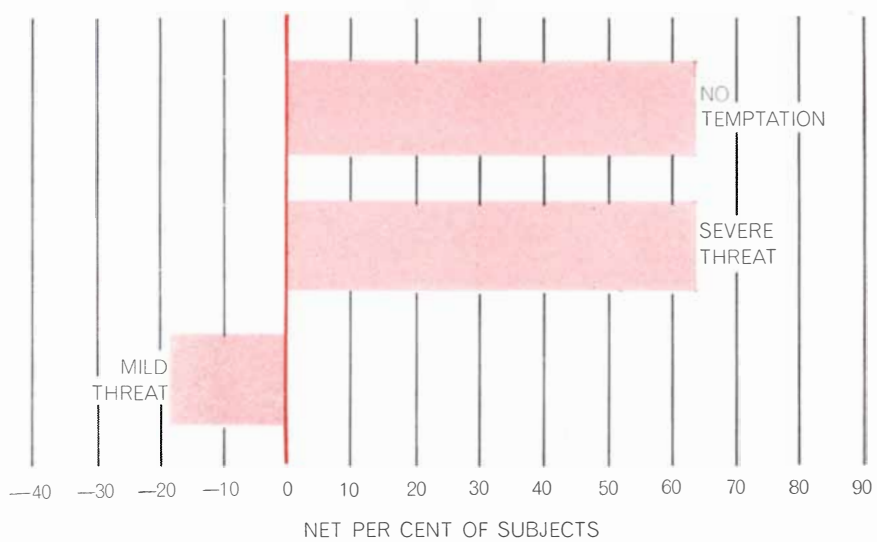
Aerojet-General Nucleonics is located on a 500 acre site in the San Ramon Valley near Livermore, California

AEROJET GENERAL TIRE GENERAL T.M.

AEROJET-GENERAL NUCLEONICS / San Ramon, California



Consequences of resisting temptation when deterrence varies



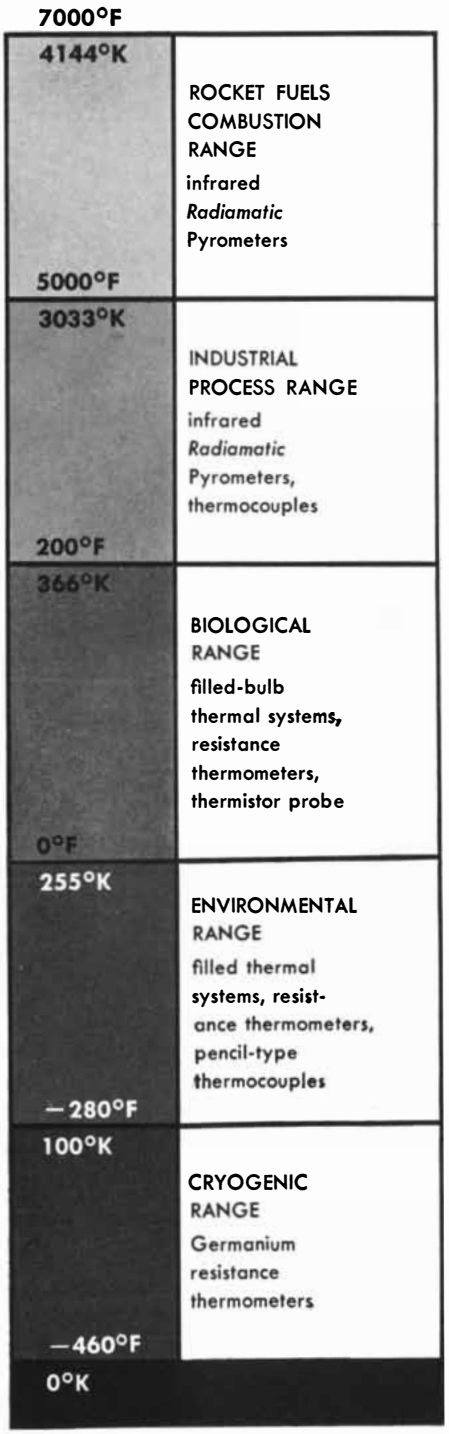
CONSEQUENCES OF TEMPTATION were explored by prohibiting children from playing with a desirable toy. Later the children were asked to re-evaluate the attractiveness of the forbidden toy. In one case the prohibition was enforced by removing the toy from the child's presence. In the second case the prohibition took the form of a threat of severe punishment; in the third case, a threat of mild punishment. The chart shows the net per cent of children who thought the forbidden toy more attractive after the experiment than before. ("Net per cent" means the per cent who found the toy more attractive minus the per cent who found it less so.) Evidently only those threatened mildly experienced much dissonance, and they reduced it by downgrading toy's desirability. Others thought the toy more desirable.

dissonance produced by resisting temptation, it can be reduced by derogating or devaluing the activity toward which one was tempted. This derivation from the theory clearly implies the sour-grapes attitude, but both theory and experiment tell us that such dissonance-reducing effects will occur only when there was insufficient original justification for the behavior. Where the original justification for refraining from the action was great, little dissonance would have occurred and there would have been correspondingly little change of opinion in order to reduce dissonance. Therefore one might expect that if a person had resisted temptation in a situation of strong prohibition or strong threatened punishment, little dissonance would have been created and one would not observe the sour-grapes effect. One would expect this effect only if the person resisted temptation under conditions of weak deterrent.

This line of reasoning leaves open the question of when the reverse effect occurs—that is, the situation in which desire for the "unattainable" object is increased. Experimentally it is possible to look at both effects. This was done by Elliot Aronson and Carlsmith, at Stanford University, in an experiment that sheds considerable light on the problem. The experiment was performed with children who were about four years old. Each child was individually brought into a large playroom in which there were five toys on a table. After the child had had an opportunity to play briefly with each toy, he was asked to rank the five in order of attractiveness. The toy that the child liked second best was then left on the table and the other four toys were spread around on the floor. The experimenter told the child that he had to leave for a few minutes to do an errand but would be back soon. The experimenter then left the room for 10 minutes. Various techniques were employed to "prohibit" the child from playing with the particular toy that he liked second best while the experimenter was out of the room.

For different children this prohibition was instituted in three different ways. In one condition there was no temptation at all; the experimenter told the child he could play with any of the toys in the room and then took the second-best toy with him when he left. In the other two conditions temptation was present: the second-best toy was left on the table in the experimenter's absence. The children were told they could play with any of the toys in the room except

FIRST, CATCH YOUR TEMPERATURE



There's an old recipe for rabbit stew that begins: "First, catch your rabbit." The same could be said of extremely low, high and very precise temperature inputs for data reduction and data handling systems. Here, too, acquiring the proper raw materials for processing is of fundamental importance. And in this latter instance, wouldn't it save a lot of work, worry and wherewithal if the same people who helped you bag your game in the first place also helped you cook it to a turn? Here's what we mean . . .

ALL THE WAY FROM 1°K. Honeywell has developed standard sensors in hundreds of types, sizes and calibration ranges for measuring from the very bottom of the thermal scale to 7000°F, which is well beyond the combustion range of most rocket propellants. Even as you read this, Honeywell researchers are working to extend the measurement of temperature with standard sensors nearer and nearer to absolute zero at one end of the scale, and into the plasma range at the other.

AND IF YOU CAN'T FIND IT IN STOCK, we'll probably be able to make a super-sensor for you. If your project involves taking temperature under the most demanding conditions, extremely close measurement over a very short span, or meeting highly exotic research requirements, we'll custom-tailor a sensing element to order, and give you our word it will work. Some of these super-sensors are taking profile temperatures of aircraft engine exhausts; some, capable of withstanding the shock of ninety times gravity, are reporting rocket engine temperatures; others are measuring atomic reactor temperatures up to 4000°F with a sensing element 30″ long and 0.035″ in diameter.

ONLY THE BEGINNING. You might think that Honeywell would be content with the creation of standard and special temperature sensors for every conceivable area of scientific investigation. Far from it. For Honeywell supplies **everything** in the data processing chain. This includes every kind of sensing device or transducer for accurately measuring variable inputs, and this material is then passed on to Honeywell graphic recorders, oscillographs, data loggers, magnetic tape equipment, computers, and other data handling systems. This makes it highly practical to think in terms of an all-Honeywell system, complete from sensing to readout. Among other things, this offers the unarguable advantage of **compatibility:** every element along the way communicates in the same language, with the requisite speed and accuracy.

SOUND REASONS. There are many sound reasons for having an all-Honeywell data system. One of the most cogent: Honeywell guarantees that the whole assemblage will work satisfactorily, by taking full responsibility for the performance of each and every component making up a system. Still another: Honeywell's experienced manpower resources, which assure on-time installation and readily available follow-up maintenance service from any of 125 Honeywell service centers throughout the U.S. and Canada.

So whether your data handling system involves an environmental test chamber, or leisurely logging the temperature of sea water four times a day, you'll get usable results, faster and easier, if you'll put the whole assignment in the hands of your local Honeywell field engineer. He can tell you many ways that Honeywell can save you time, money and headaches throughout the entire area of data gathering and handling. Or write Industrial Products Group, Minneapolis-Honeywell, 4412 Wayne Avenue, Philadelphia 44, Pennsylvania.

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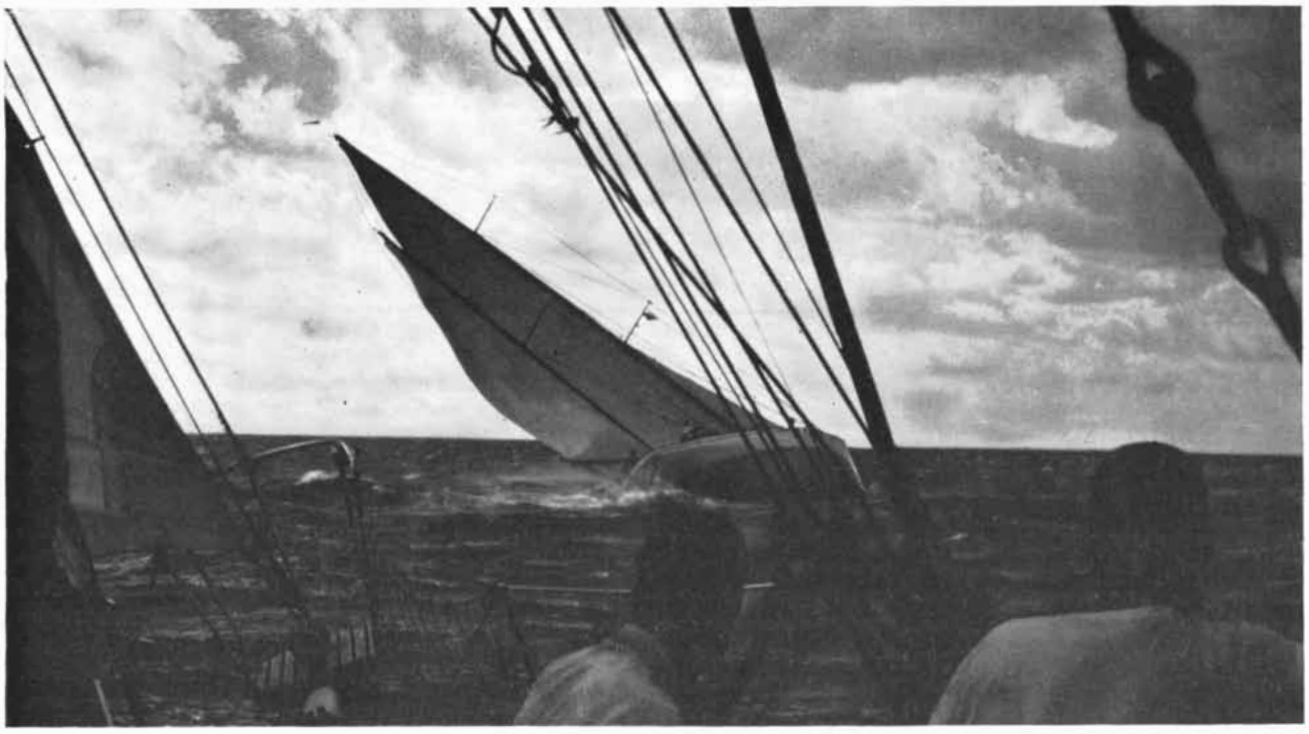
the one on the table. The children in one group were threatened with mild punishment if they violated the prohibition, whereas those in the other group were threatened with more severe punishment. (The actual nature of the punishment was left unspecified.)

During his absence from the room the experimenter observed each child through a one-way mirror. None of the children in the temptation conditions played with the prohibited toy. After 10 minutes were up the experimenter returned to the playroom and each child was again allowed to play briefly with each of the five toys. The attractiveness of each toy for the child was again measured. By comparing the before and after measurements of the attractiveness of the toy the child originally liked second best, one can assess the effects of the prohibition. The results are shown in the chart on page 100.

When there was no temptation—that is, when the prohibited toy was not physically present—there was of course no dissonance, and the preponderant result is an increase in the attractiveness of the prohibited toy. When the temptation is present but the prohibition is enforced by means of a severe threat of punishment, there is likewise little dissonance created by refraining, and again the preponderant result is an increase in the attractiveness of the prohibited toy. In other words, it seems clear that a prohibition that is enforced in such a way as not to introduce dissonance results in a greater desire for the prohibited activity.

The results are quite different, however, when the prohibition is enforced by only a mild threat of punishment. Here we see the result to be expected from the theory of dissonance. Because the justification for refraining from playing with the toy is relatively weak, there is appreciable dissonance between the child's knowledge that the toy is attractive and his actual behavior. The tendency to reduce this dissonance is strong enough to more than overcome the effect apparent in the other two conditions. Here, as a result of dissonance reduction, we see an appreciable sour-grapes phenomenon.

The theory of cognitive dissonance obviously has many implications for everyday life. In addition to throwing light on one's own behavior, it would seem to carry useful lessons for everyone concerned with understanding human behavior in a world where everything is not black and white.



RESEARCH DEFEATS AN OLD ENEMY

Corrosion is a hungry enemy, always ready to feed on anything made of metal. Every year it causes more than 8 billion dollars in damage.

Celanese polymer research is doing something about corrosion by developing new, rust-resistant materials . . . not metals, but tough, rugged plastics that can take the place of metals in many applications. One of the latest is a unique engineering plastic called Celcon. This material won't rust or corrode—even when exposed to the attack of sea water. One of its first uses was in marine bilge pumps, an application that has always demanded expensive brass.

Celcon is already fast replacing metal in hundreds of "corrosion" spots. The automotive industry, for example, is planning to use Celcon's unusual properties to make chrome trim clips, as well as one-piece instrument panels and carburetor parts. Other industries are designing plumbing fixtures, hardware and appliances that will benefit from Celcon's chemical resistance, great strength and surface beauty.

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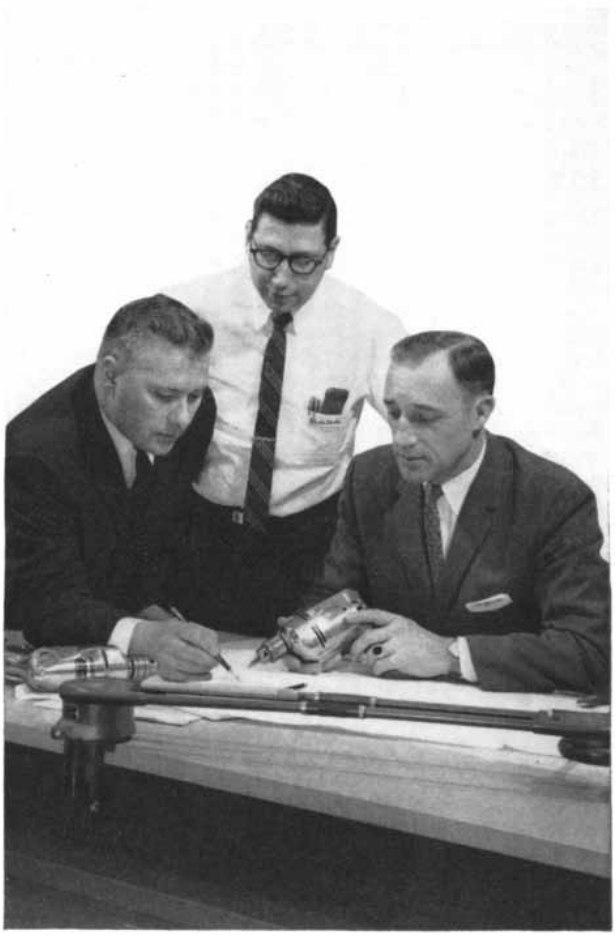
CHEMISTRY FOR YOU

NEW CONCEPT IN A PORTABLE POWER DRILL

Black & Decker has come up with two new professional drills: one a 1/4" model, the other a 3/8" model that provide 20% more usable power. What helped make the new design possible? Torrington Drawn Cup Roller Bearings and Needle Bearings—the first time such bearings have ever been used in a Black & Decker portable power tool.



Principals who collaborated in the development of B&D's high-performing new portable power drill. Left to right, Richard Reichold, Torrington District Engineer; B&D's Samuel H. Kohler, Development Engineering Manager; and B&D's George W. McCarty, V.P., Research & Development.

Black & Decker's research and development engineers are constantly on the alert for new technologies that contribute to the growth of the Company's broad line of power tools. The objectives are one or more of the following: increased efficiency, power and capacity... reduced weight, size and cost.

In the B&D consumer products line of moderately priced tools for the home market and light service trades, the Sales Department saw a need for a higher-performing portable electric drill for the professional.

George W. McCarty, Vice President of B&D's research and development, and Samuel H. Kohler, Development Engineering Manager, recognized the possibility of such a product. But they also saw problems—the need, for example, to get a more efficient armature bearing capable of higher performance. The cost of using ball bearings could be much higher than desired; assembly was time-consuming; mass production economies would be difficult to achieve.

Torrington Drawn Cup Roller Bearing a possibility...

Previous to this, Torrington engineers had developed their new Drawn Cup Roller Bearing and gathered extensive test information on its performance as an armature bearing. From these tests, Torrington engineers felt their new Drawn Cup Roller Bearing was ideal for applications like portable electric tools. It is highly efficient in high-speed operation. (Armatures generally run at 20,000 to 25,000 rpm.) It offers high capacity in a small cross section, has ample provision for lubrication storage and circulation and installs easily by a simple press

fit. Most important of all, the bearings could be counted on to lower armature bearing costs by as much as 50%. Torrington presented the Drawn Cup story to the B&D engineering department for their consideration.

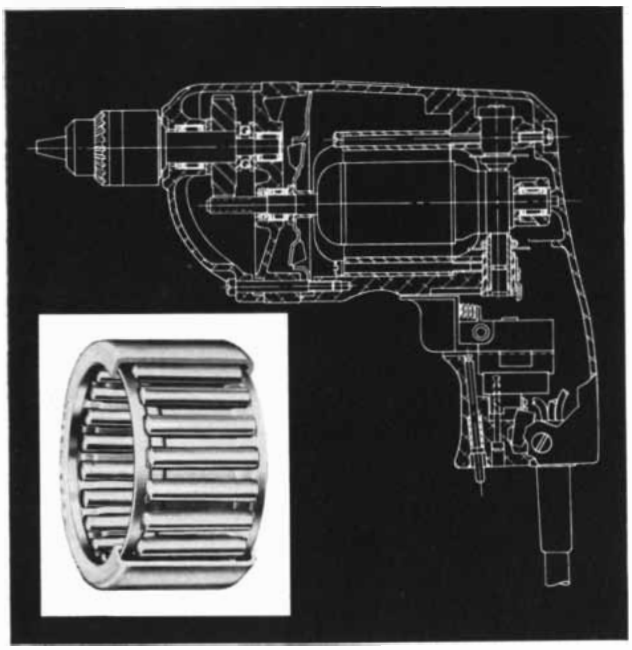
Joint program developed to evaluate new bearing

Acting on information that a Drawn Cup Roller Bearing was available, B&D's engineering department gave Torrington an electric power drill to be fitted with roller bearings on the armature shaft. Torrington installed the bearings and returned the unit to B&D for endurance tests. After life testing and refinements, Kohler and McCarty saw the value of the roller bearings and instituted new tests on a new design—a special 1/4" drill. All of these subsequent tests were completely satisfactory. The use of low-friction roller bearings and needle bearings enabled B&D to utilize many existing components and provide 20% more power. It also resulted in tremendous savings in total bearing costs.

Today, B&D has two new professional drills going for them: one a 1/4" model, the other a 3/8" model. Both are completely equipped with Torrington Drawn Cup Roller Bearings and Needle Bearings—the first time such bearings have ever been used on a B&D portable power tool.

All in all, it's a striking example of collaboration between the industrial design engineer and Torrington engineers at their productive best. Torrington is at your service, too. We make every basic type of antifriction bearing. We'll be glad to help you apply the right bearing to whatever product you have in mind. There's no obligation when you call in a Torrington engineer. At Torrington, service is part of the product.

Black & Decker Portable Power Drill—it's the company's first portable power tool ever to be completely equipped with Torrington Drawn Cup Roller Bearings and Needle Bearings. B&D experts consider it "an entirely new concept in drill power and value that provides 20% more usable power, more get-up-and-go to whiz through the toughest job."



Cross section drawing showing location of Drawn Cup Roller Bearings in Black & Decker's new portable power drill.

Torrington Drawn Cup Roller Bearing has a one-piece, heat-treated steel retainer which guides the rollers. It is compact, lightweight, installs by a press fit in a straight housing bore. Other features include: a long pregreased service life, outstanding efficiency at high speeds and low unit cost.

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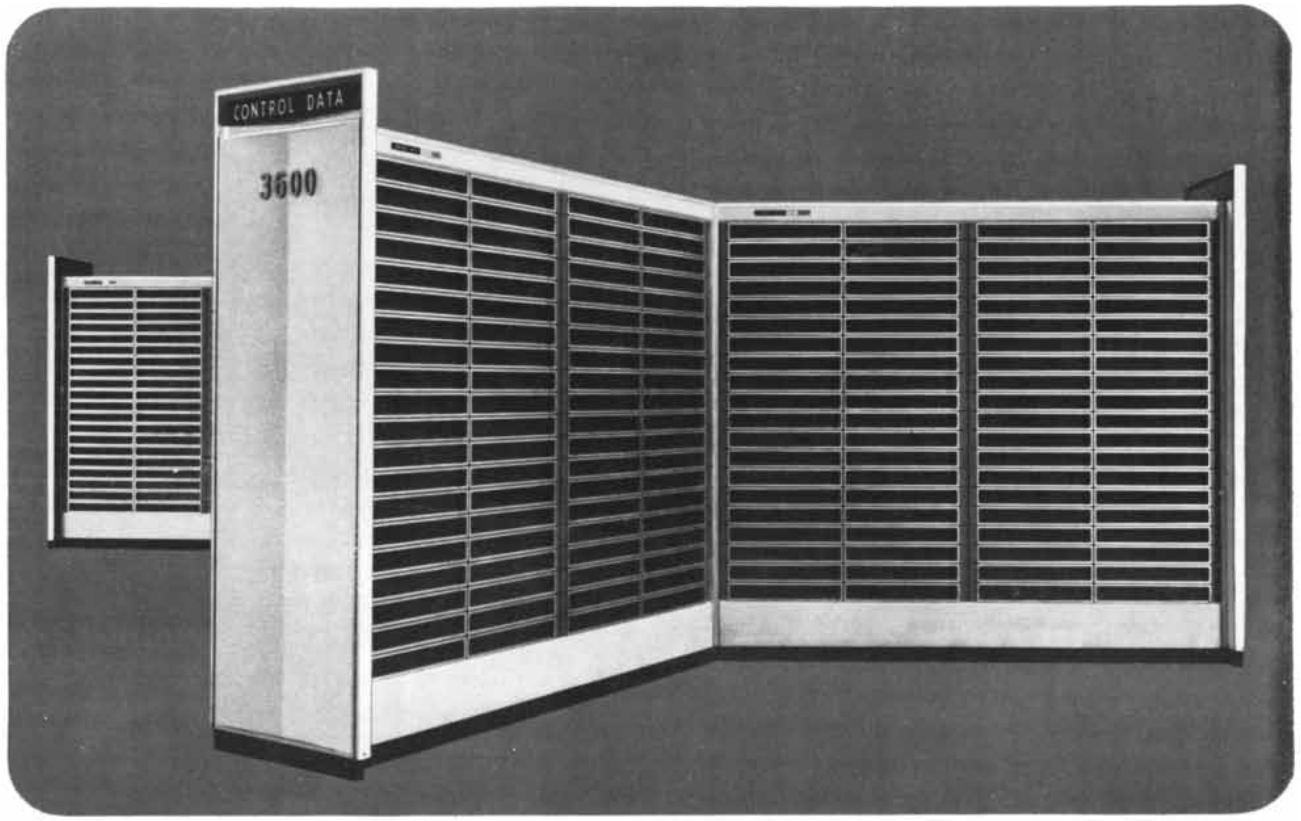

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ELECTRICITY IN PLANTS

Electrical disturbances similar to the nerve impulse are associated with a number of plant life processes. It seems likely that these currents and fields somehow influence plant growth and development

by Bruce I. H. Scott

The processes of life have been found to generate electric fields in every organism that has been examined with suitable and sufficiently sensitive measuring techniques. In some organisms bioelectricity serves well-recognized functions. The electrical disturbance of the nerve impulse, for example, carries information down the length of the nerve fiber. The central nervous system as a whole can be compared with a telegraphic exchange with electrical pathways linking the nerve cells in networks of almost unimaginable complexity. When measuring techniques similar to those used by the nerve physiologist are applied to plants, it is found that they too generate electric fields and currents. Whether electricity plays any part in the growth or other metabolic activity of the plant, or is merely a by-product of these processes, is not yet known. Recent experiments have pointed, however, to possible ways in which the bioelectric fields and currents generated by a plant may serve in the coordination and control of its development. It has been found, for example, that large individual plant cells respond to electrical, chemical or even mechanical stimulation in just the same way as a nerve cell does: with an electrical impulse that sweeps along the surface of the cell.

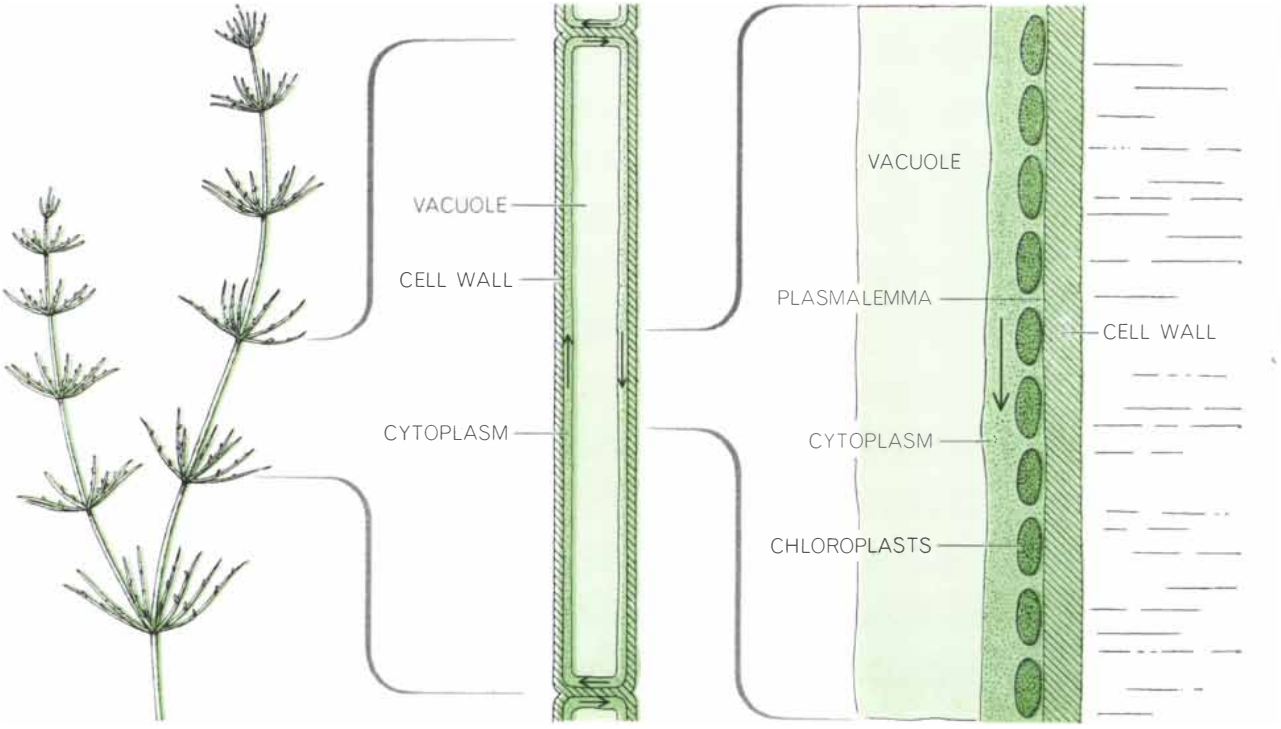
The delicately balanced distribution of inorganic salts in and around a living cell, whether plant or animal, accounts for its electrical properties. Living tissues are largely liquid; they consist of watery solutions of salts separated into compartments by membranes. In solution the salt molecules dissociate into electrically charged ions, some of which can pass more freely through the membranes than others. Where there are concentration differences across a membrane, positive and negative charges become separated and an electric field is set up. These differences in concentration are maintained by pumps, driven by the metabolism of the cell, that push ions through the membrane in one direction or the other [see "Pumps in the Living Cell," by Arthur K. Solomon; SCIENTIFIC AMERICAN, August]. In order to explain the potential difference in a given cell, therefore, one must take a complete inventory of the ions on each side of the membrane, determine how easily each ion can pass through the membrane and establish whether the ion is moving by diffusion or under an electric force across the membrane or is being pumped.

Such observations are at present out of the question on most individual plant cells. They are seldom more than a ten-thousandth of a cubic millimeter in volume. Fortunately, a few species offer cells that are much larger; these are the fresh-water algae *Nitella* and *Chara* and the marine alga *Halicystis*. Individual cells of *Chara* can be as much as 15 centimeters long and 1.5 millimeters in diameter. With respect to size, at least, these cells are freaks, and it may turn out that conclusions based on work with them are far from correct for the rest of the vegetable kingdom. Nevertheless, they have provided a starting point, much as the giant axon of the squid, a correspondingly outsized nerve fiber, facilitated early work on the electrochemistry of the nerve impulse [see "The Nerve Impulse and the Squid," by Richard D. Keynes; SCIENTIFIC AMERICAN, December, 1958].

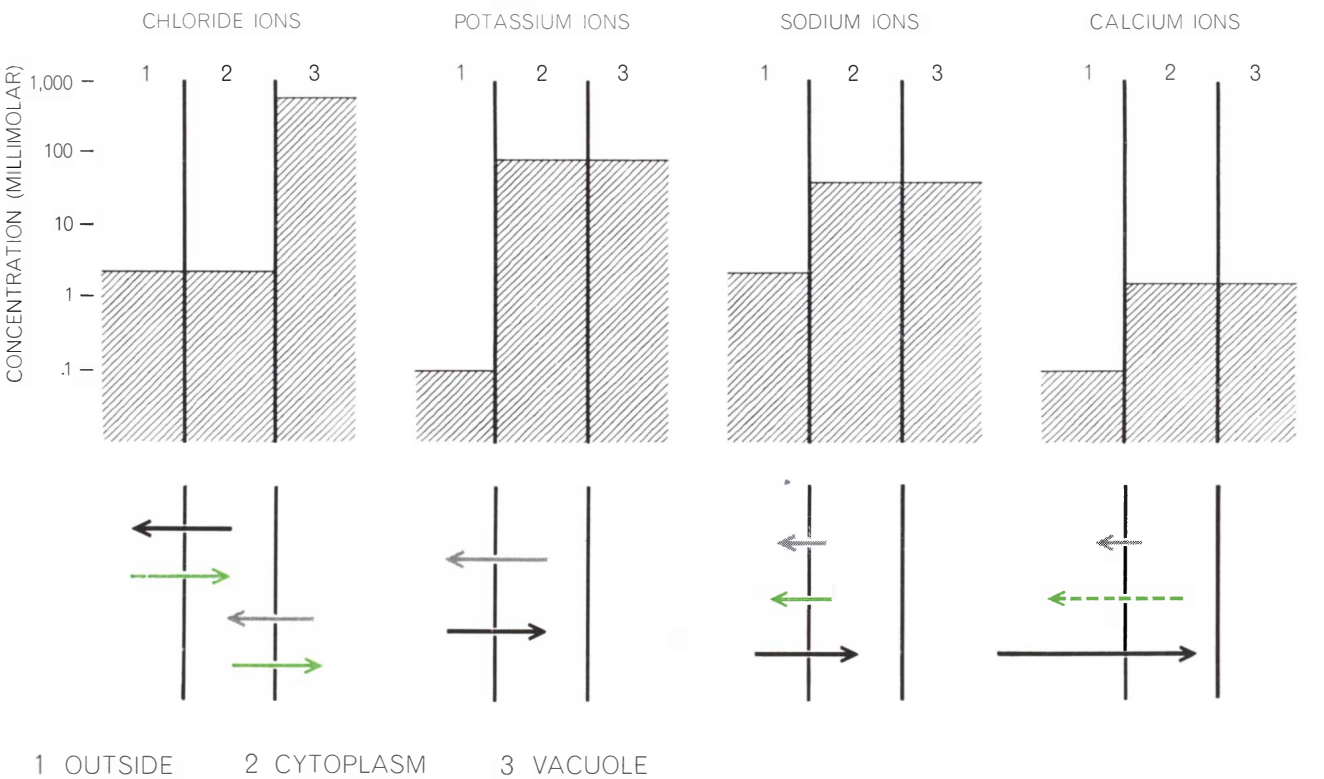
The *Chara* cell has a large central chamber, or vacuole, that contains salts (mainly potassium chloride and sodium chloride) in concentrations much higher than those that occur in the pond or river in which the plant grows. As a result a large osmotic pressure—which tends to equalize the concentration of salt by forcing water into the cell—puffs up the cell inside its tough cellulose wall. Lining the cell wall and separating it from the vacuole is a thin layer of living cytoplasm that streams continuously around the cell interior.

In seeking clues to the working of this cell, investigators have adopted various stratagems. They have extruded the vacuolar sap from the cell and compared its chemical content with that of the pond water. Thanks to ingenious techniques developed by Nobuo Kamiya of Osaka University, even the cytoplasm that envelops the vacuole can be extracted and analyzed, although the results are uncertain because there is so little cytoplasm and one cannot be sure that its ionic content remains unaltered during extraction. By the use of radioactive isotopes information has been gained about the movement of ions between the pond water and the cytoplasm and between the cytoplasm and the vacuolar sap. Finally, investigators have inserted glass micropipettes, filled with conducting salt solutions, into the cell and used them for measuring membrane potential differences and resistances. Essentially the same methods and tools were employed by the nerve physiologists in their work on the giant axon.

The present picture of the electrochemistry of the *Chara* cell is most notably the product of investigations by J. Dainty at the University of Edinburgh and by A. B. Hope and N. A. Walker of the Commonwealth Scientific and Industrial Research Organisation in Australia. It appears that the high salt concentration in the fluids of the cell is principally maintained by a chloride pump



CHARA CELL used in experiments on plant electricity is from *Chara australis*, a large fresh-water alga. The plant, illustrated at left, has a long stem composed of a succession of single giant cells, one of which is indicated by the bracket and is enlarged in the drawing at center. A small segment of the cell wall is in turn enlarged in the drawing at the right. The cytoplasm is the living tissue of the cell and chloroplasts are the organs of photosynthesis. Plasmalemma is the controlling membrane. Vacuole is filled with sap.



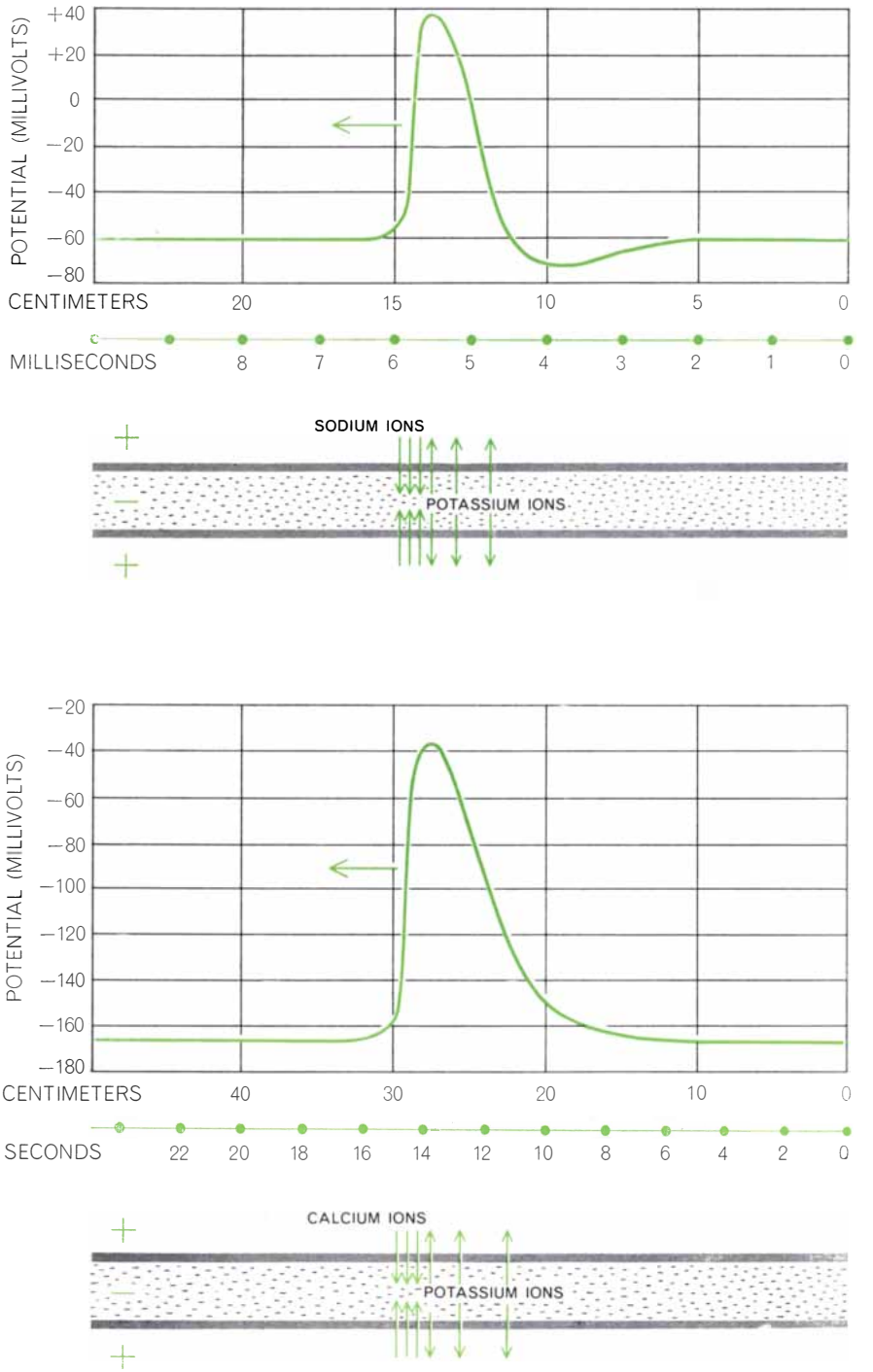
CONCENTRATIONS of four ions inside *Chara* cells and in the pond water are maintained by three processes. The bars show the concentrations of each ion outside the cell (*1*), in the cytoplasm (*2*) and in the vacuole (*3*). Cytoplasmic concentrations are not well established. The gray arrows represent movement of ions due to concentration differences. The potential difference across the plasmalemma causes positive ions to move in and negative ions to move out (*black arrows*). Except in the case of potassium, an active pump (*colored arrows*) is required to balance ion movements. The arrow for pumping is broken in the case of calcium, since these ions may never reach equilibrium across the membrane. The high chloride concentration makes inside of the cell negative.

that pushes the negative chloride ion into the vacuole from the external medium. This makes the inside of the cell negative. As a result the positive ions of potassium, sodium and calcium are pulled in passively. All of these ions tend to leak back into the external medium. The cell's books are balanced in the case of each ion only when the net gain due to the electric force and the active pump, if there is one, offsets the loss through leakage. A weak outward pumping of sodium and calcium thus seems to supplement the inward chloride pump in maintaining the interior negative charge. Because potassium can most easily pass in and out of the cell, it is this ion that has most control over the steady-state, or resting, potential. On the other hand, the resting membrane appears to be relatively impermeable to calcium. The main barrier to leakage of the ions from the cell is apparently the plasmalemma, on the outer surface of the cytoplasm inside the cellulose wall.

This understanding of how the cell behaves when it is undisturbed sets the stage for consideration of the remarkable way in which it reacts to stimulation. One can stimulate the cell by passing a pulse of electric current through it, by treating it chemically in various ways or simply by poking it gently with a fine probe. The effect is to make the inside of the cell momentarily less negative. If the stimulus exceeds a certain threshold, the membrane potential in the stimulated region does not recover immediately; instead it continues to rise rapidly toward zero and then returns more slowly to its resting value. Examination of the ion flow at this moment shows that the membrane in the stimulated region has become permeable to calcium; it is the inward rush of this positive ion that depolarizes the membrane. The local flow of electric current raises the potential above the threshold in a neighboring region of membrane, triggering the same electrochemical changes there. The disturbance thereby travels over the surface of the cell as a wave.

This is almost exactly what happens when a nerve cell is stimulated, and the wave that sweeps over the plant cell fully merits description as an action potential wave, in the same class of phenomena as the nerve impulse. The shapes of the waves are similar, and both waves are initiated by a stimulus that must reach, in each case, a threshold value [*see illustration at right*]. Of course there are differences also. The plant cell is relatively sluggish. A complete action "spike" for *Chara* takes about 20 seconds, compared with a few milliseconds for a nerve, and it moves only a few centimeters per second along the cell (even more slowly when the cell is bathed in a weakly conducting solution) instead of many meters per second. In the nerve cell it is a sudden inward movement of sodium, rather than calcium, that depolarizes the membrane. An outward movement of potassium ions subsequently restores the membrane potential to its resting value in the nerve and probably does so in the plant cell as well.

The most remarkable aspect of this comparison is not that there are differ-

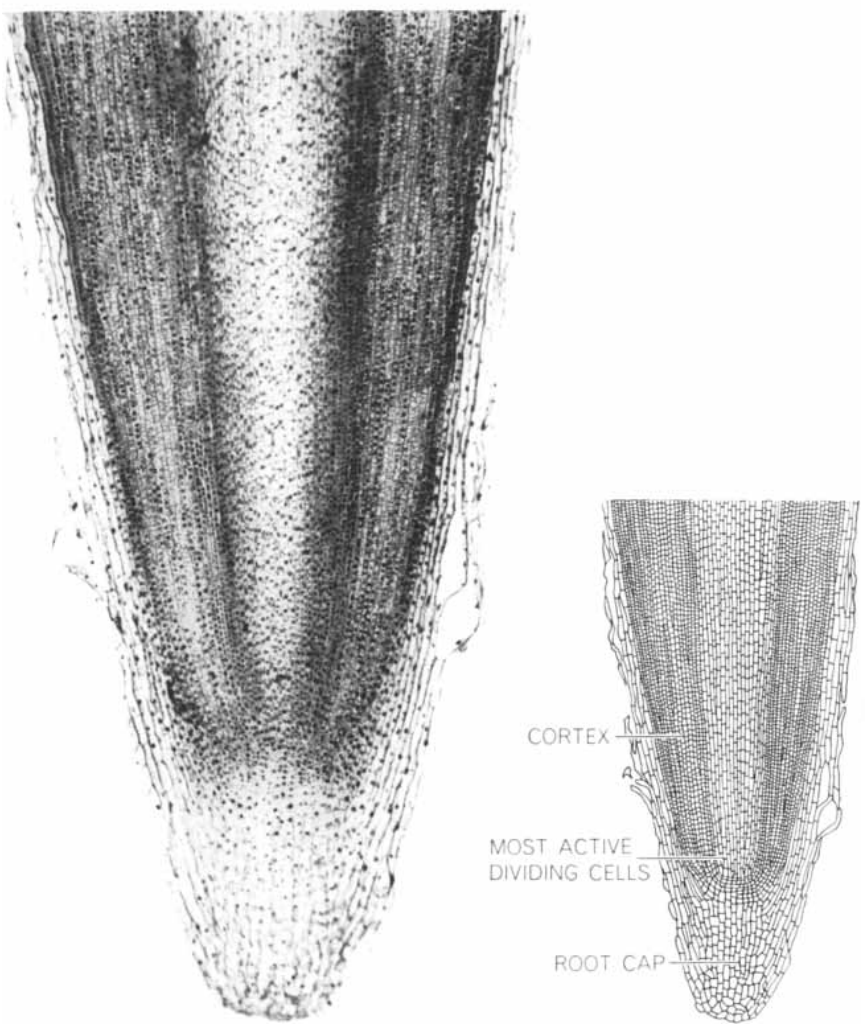


EFFECTS OF STIMULATION on squid axon (*top*) and the *Chara* cell (*bottom*) are compared. In both cases stimulation makes the inside of the cell less negative. At a threshold the membrane potential spikes into an action potential wave (*colored curves*) that moves along the cell. The spike is triggered by a change in membrane permeability: sodium ions flow into the nerve cell, calcium ions into the *Chara* cell. Potassium then flows out to restore the resting potential. Note the marked difference in wave velocity in the two cells.

ences but that two cells so far removed from each other on the biological scale should have active membrane properties with so many features in common. One wonders if the action potential wave may not be a characteristic of all cells that has merely been adapted in the nerve cell to the function of communication. If the relative slowness of the process in *Chara* is a feature of plant cells, this could be related to the general quiescence of plants compared with animals. Anyone who has seen a speeded-up movie of a growing plant, however, must have been impressed by the animal-like character of its movement and responses.

In the case of the *Chara* cell no biological function for the action potential wave has yet been established. It is rarely seen to stimulate neighboring cells, but this may be because these cells are in contact only at their ends. In another plant, with cells in more intimate contact, a stimulus from the environment might be transmitted from cell to cell. It is interesting to note that the passage of the wave is closely linked to the streaming of the cytoplasm in the cell. Streaming in a stimulated cell does not cease everywhere at the instant of stimulation but stops progressively along the cell as the action wave moves along it.

Although it is not possible to follow in detail the electrical activity in the tiny individual cells of higher plants, the plant as a whole and its various organs produce fields and currents that can be measured and plotted. The root of a bean shoot growing in a weakly conducting medium, for example, is found to act as an electric generator sending tiny currents into the medium and back through the root [*see top illustration on opposite page*]. This is probably because the growing plant is actively absorbing ions through its roots. The flow of ions into the root and their movement to other locations in the plant produce a macroscopic electric field that can be mapped by exploration with a voltage-measuring probe connected to a sensitive electrometer. The instrumentation must be highly sensitive, because only about a hundredth of a microampere flows across a square millimeter of root surface. The electric output of 100 billion roots would be needed to light a 100-watt lamp.

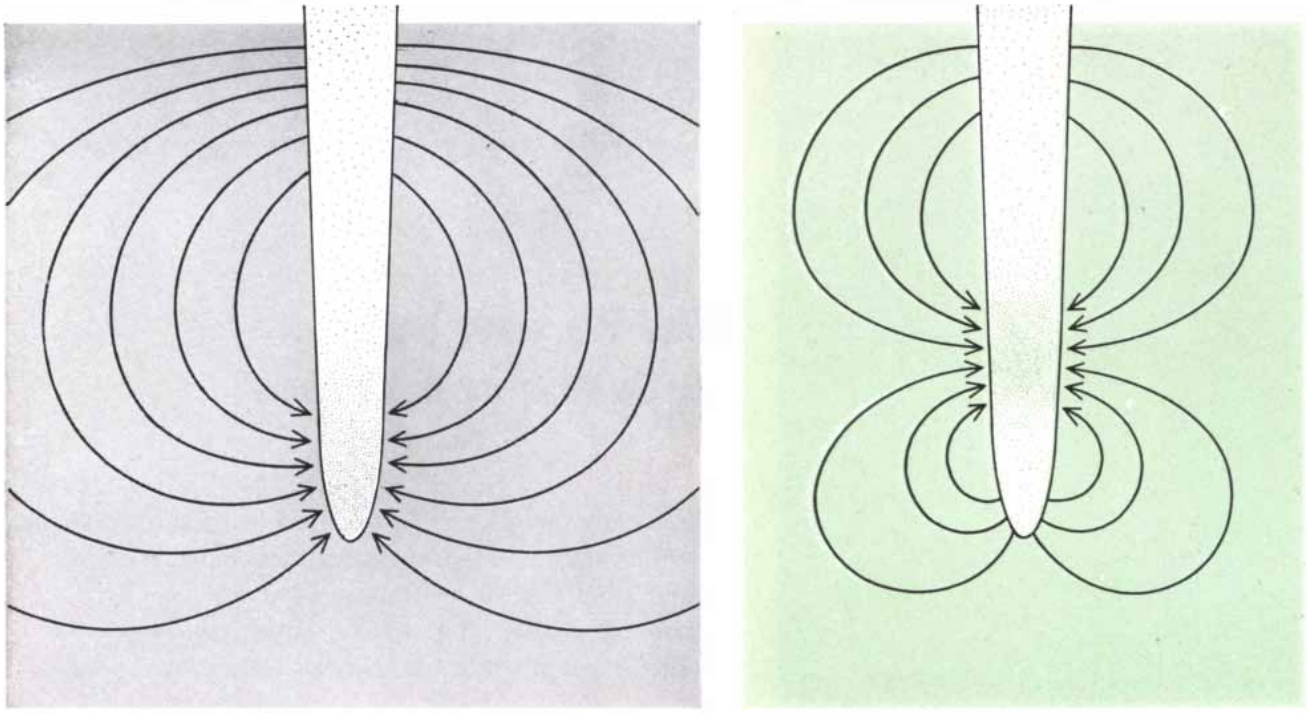


BEAN-ROOT TIP is enlarged about 50 times in the photomicrograph at left. It is composed of a great number of individual cells in various stages of growth, division and development. The root cap protects the tip; cell division is concentrated above the cap; cellular elongation occurs primarily higher in the root, above the three-millimeter section depicted.

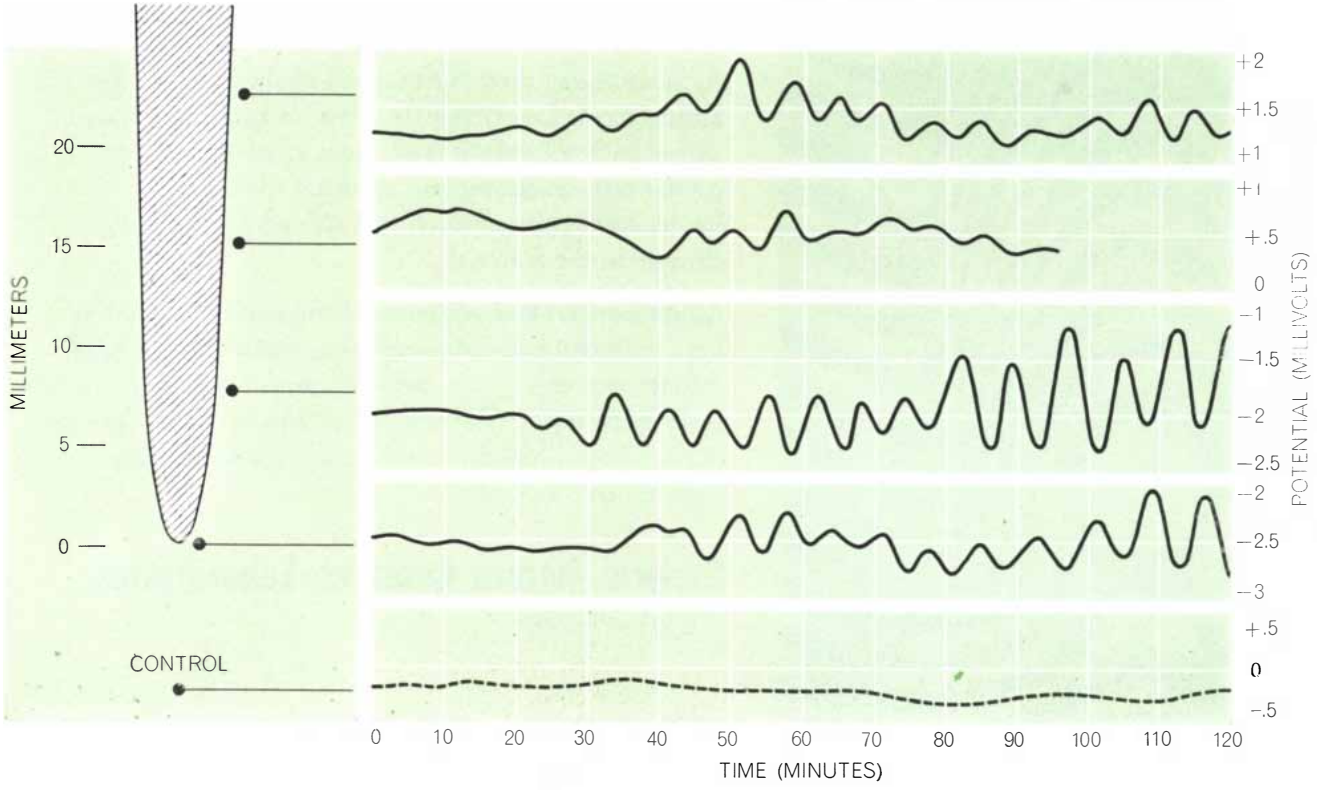
Observation of the flow of current tells some interesting things about what is going on in the plant. In a medium containing potassium, for instance, a root sends out a current from its upper part and back into itself near the tip. Because the cells at the tip are actively dividing and the creation of new cytoplasm sets up a high demand for potassium, one may deduce that the inflow of positively charged potassium ions is associated with the inflow of current at the tip. On the other hand, if the growth medium is rich in sodium, the root sends a current outward from both the tip and the base of the root and inward most strongly where the cells have almost reached their maximum length. This suggests that these cells are now filling their vacuoles with the sodium, contributing to the build-up of osmotic pressure that gives the root its turgor. Analysis of the ion content of successive small cross sections of root tissue from the tip upward confirms these deductions. Further confirmation is supplied by experiments with radioactive sodium and potassium that show that their paths of entry into the root follow the paths indicated by our bioelectric observations.

That the multicellular root tissue responds like the single cell of *Chara* to stimulation can be demonstrated by simply giving the root a gentle poke. The potential at any point near the root changes suddenly and usually makes one or two oscillations before settling down to a steady state. A few roots behave in a more mysterious way. Without any stimulation the potential near the root starts to oscillate in a rhythmic fashion, the oscillations continuing for perhaps several hours before the root reverts to its normal steady electric behavior. The periods of oscillation for the roots we have studied are about five minutes. Evidently in these cases there is an alternating-current generator in the root as well as a direct-current source.

My colleagues and I at the University



ELECTRIC CURRENTS are found around bean roots growing in salt solutions and are related to the concentration of specific ions in the roots. The root at left is growing in a solution of potassium chloride, the one at right in a sodium chloride solution. Concentrations of potassium (*gray*) and sodium (*color*) are indicated by density of shading. Apparently each of the two positive ions is concentrated where it is most needed: potassium in the region of actively dividing cells and sodium in a region of maturing cells.



SPONTANEOUS OSCILLATIONS in electric currents of the kind mapped in the illustration at the top of the page are sometimes recorded near a bean root growing in water. The potentials recorded by probes at various points near the root suddenly start to oscillate, with periods of about five minutes, as shown in the four solid-line graphs. The oscillations are strongest near the root tip.

One of a series briefly describing GM's research in depth

When two solids touch . . . plastic strain or dislocations?

The engineer would talk of a plastically strained material. The solid state scientist, of dislocations occurring on the atomic level. Here at the General Motors Research Laboratories, we're interested in learning more about the mechanical nature of solids from both points of view.

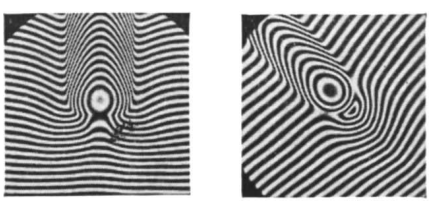
One of our current investigations into the solid state, for example, is aimed at fitting together an atomic picture of what happens when a solid is deformed by a contact force. Simple case: a sapphire ball rolling across a soft single crystal of copper.

For various directions of roll, striking differences in deformation, hardness, and rolling force have been measured and related to the crystal's atomic slip planes. Our work has progressed from this macroscopic correlation to a three-dimensional study of dislocation arrangement. Encouragingly, experimental results have agreed with theoretical predictions as to how specific crystal dislocations interact to cause work hardening—a phenomenon that sharply limits further damage to the material.

A fundamental understanding of mechanical properties may some day help man improve a number of practical contact processes . . . processes where two solids touch. Rolling. Stamping. Pressing. Wear and friction of moving parts. General Motors is seeking this understanding with research in depth.

General Motors Research Laboratories

Warren, Michigan



Ball track across copper crystal is narrower, harder and has higher friction in a cube diagonal direction (right interferogram) than in a cube edge direction.

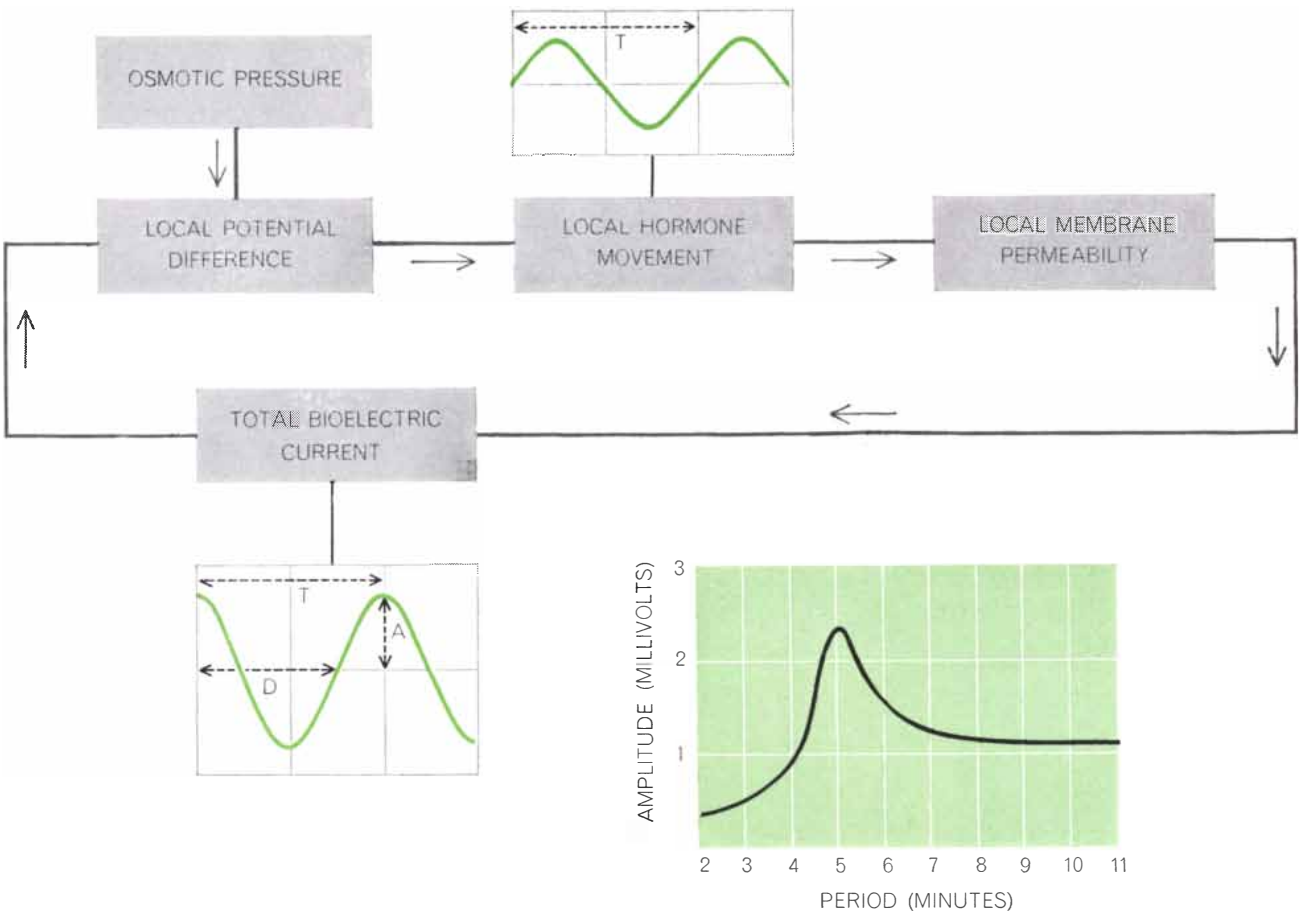
of Tasmania became interested in the reasons for this unstable behavior. We wondered if the oscillations might not be a clue to some function served by the bioelectricity of plants. One possible function was suggested to us by the feedback linkage that stabilized the performance of the sensitive pen recorder we were using to observe the oscillations.

In a feedback control system a small portion of the energy of the output signal is fed back to the input opposite in phase to the input signal. The feedback thus opposes the oscillation of the signal and, when the linkage is properly adjusted, damps the response of the system. In the case of our recorder, the feedback made the pen move quickly to a new position without overshooting and stay there without oscillating, or "hunting." By increasing the amount of the feedback we could cause the pen to make a few rapid oscillations before it settled down, and with a further increase we could make it oscillate wildly back and forth across the scale. The reason for this is that there is always some delay in the feedback path and too much feedback too late can cause overshooting and oscillation instead of control.

It occurred to us that we had a modern recording device and an old-fashioned bean root behaving in the same way. The behavior could be regarded as being perfectly natural in each case, because the feedback loop that is the genius of the automatic-control revolution in contemporary technology is really an adaptation of a universal principle that makes living systems self-regulating.

If the electrical oscillations of the bean root were indeed a symptom that some feedback loop had become overcorrected, what was the nature of the linkage? We considered various sequences of processes that might form a loop with the characteristics required to fit the observed oscillations. The most promising is a scheme that involves the plant hormone called indoleacetic acid. This hormone, it is believed, controls the elongation of the maturing plant cells in the zone just behind the growing point of a root or shoot. In very small concentrations it appears to soften the cell wall; this would allow osmotic pressure in the vacuole to lengthen the cell. At higher concentrations it seems to inhibit elongation.

According to our scheme electric forces set up in the root by the action of indoleacetic acid may provide the feedback linkage that in turn controls the distribution of the hormone. As a weak acid it forms negative ions in solution. The



FEEDBACK LOOP is proposed to explain oscillations in the bean root's field. Rhythmic variation of the indoleacetic acid (IAA) content of the medium induces oscillations of the same period (*T*) in the bioelectric current near the root. But these oscillations lag behind the input oscillations. As the input period is varied, the time delay (*D*) of these oscillations in the bioelectric current, the amount by which they are out of phase with the input oscillations, is found to vary in a manner consistent with a feedback loop. Moreover, resonance, or maximum amplitude (*A*), occurs for periods of about five minutes, indicating that the natural oscillation observed in bean-root currents is caused by feedback. Varying the osmotic pressure instead of the IAA content gives similar results.

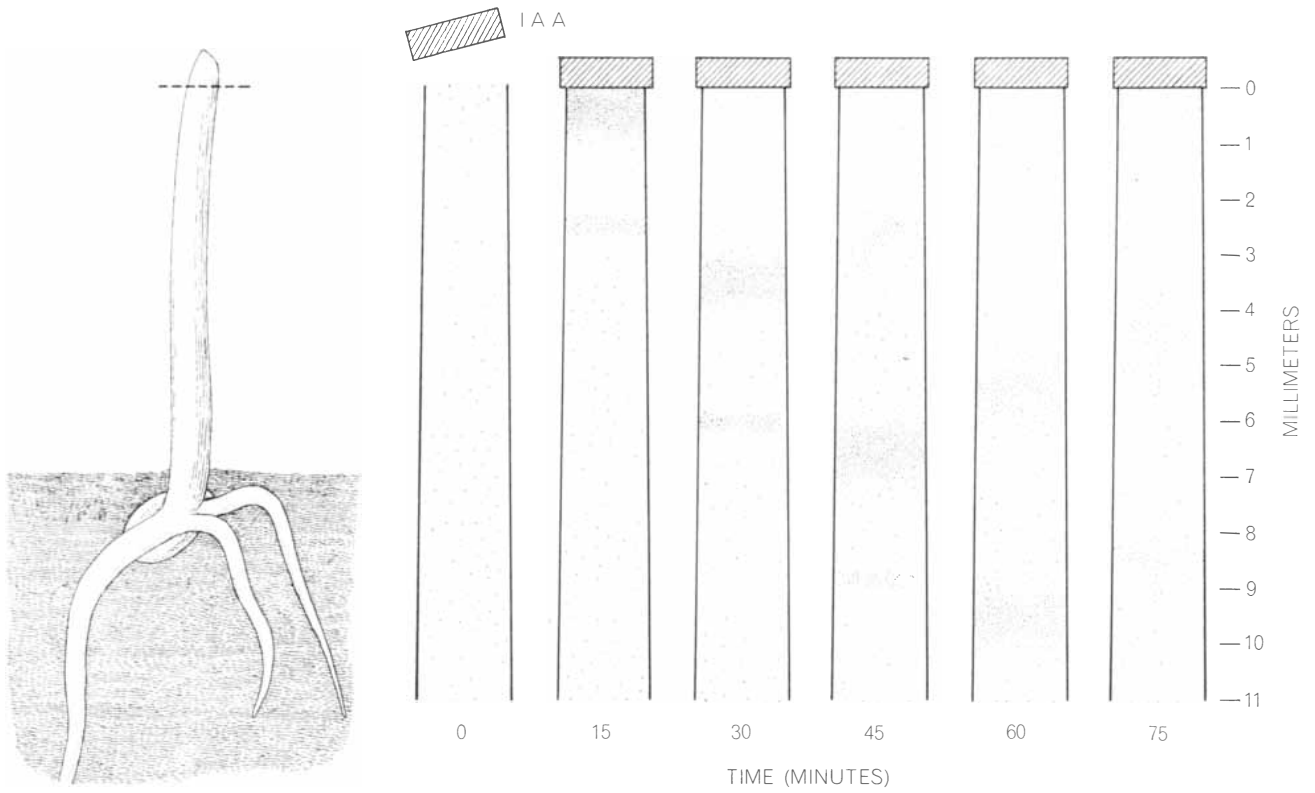
amount of indoleacetic acid reaching sites in the cell where it is active is therefore likely to depend on local electric forces, particularly voltage changes across cellular membranes. Since it appears to modify the permeability of the membrane to various inorganic ions, the movement of indoleacetic acid in the plant tissue may affect the pattern of current flow around the root. These current changes would in turn influence local potential differences in the root tissue through which the negative ions of indoleacetic acid pass. In this way the bioelectric current observed in the vicinity of the root may serve to close the feedback loop between events in the individual cell and processes in the root as a whole.

It is one thing to suggest such a cycle of feedback interactions and quite another to test it in a living plant in which the individual reactions cannot be isolated. In one test we have used we subjected a root that was not itself producing oscillations to deliberately timed oscillation in the concentration of indoleacetic acid in the fluid medium bathing the root. The root responded by producing electric oscillations all of the same period. We found that we could elicit maximum oscillation from the root at a period of about five minutes. This resonance identified the natural period of the loop, because it marked the time required for the imposed disturbance to travel around the loop and return, just one cycle later, to reinforce the next oscillation. The hormone oscillation and the resulting electric oscillation are out of step with each other. This is another expected characteristic of a feedback loop, in which there are always time lags. It gives further clues to the way the components may be linked up in the loop.

We have subjected the root to a similar "frequency response" test by varying the salt content and thereby the osmotic pressure of the culture medium. This variable does not directly form part of the proposed feedback loop, although variation in osmotic pressure intimately affects the system. It quickly alters the membrane potential in the root's outer cells, probably by rapid water movement and change in the salt concentration in these cells. Resonance again occurs at periods of about five minutes. This, we expect, is close to the period of any spontaneous oscillatory behavior of the root.

We are confident that there is a feedback system in the root in which the interactions appear to be as described. It may even be that the over-all growth of the root is co-ordinated by the indicated interaction of hormone and electric field. We have not, however, been able to observe any departure from normal growth in roots that have been subjected to sustained overcorrection and oscillation of the postulated feedback system.

The demonstration in a lower organism of a feedback system with characteristic periods of oscillation is of interest in still another connection. This is the time sense, or "biological clock," of such organisms. It is now well known that all living systems from higher animals down to single-celled organisms behave in ways that vary rhythmically



IAA manufactured by the tip of the coleoptile that sheathes a young oat shoot moves down the coleoptile to its growing region. When a block of agar containing IAA is placed on a decapitated coleoptile, the IAA's progress down the shoot is accompanied by an electric wave. The density of the gray shading indicates the strength of the downward potential gradient that is recorded. A small upward gradient (*color*) precedes the initial downward pulse. The downward gradient may influence IAA movement.

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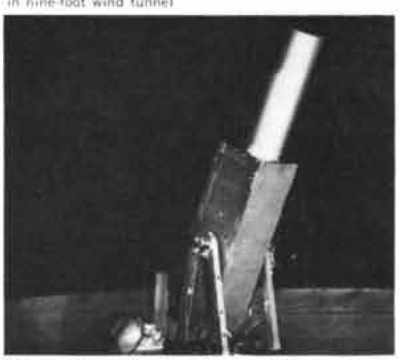

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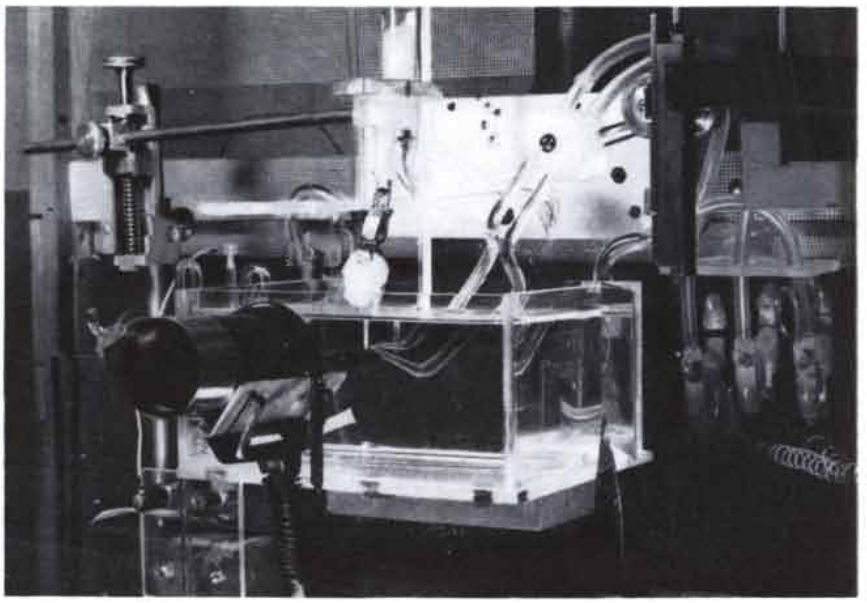
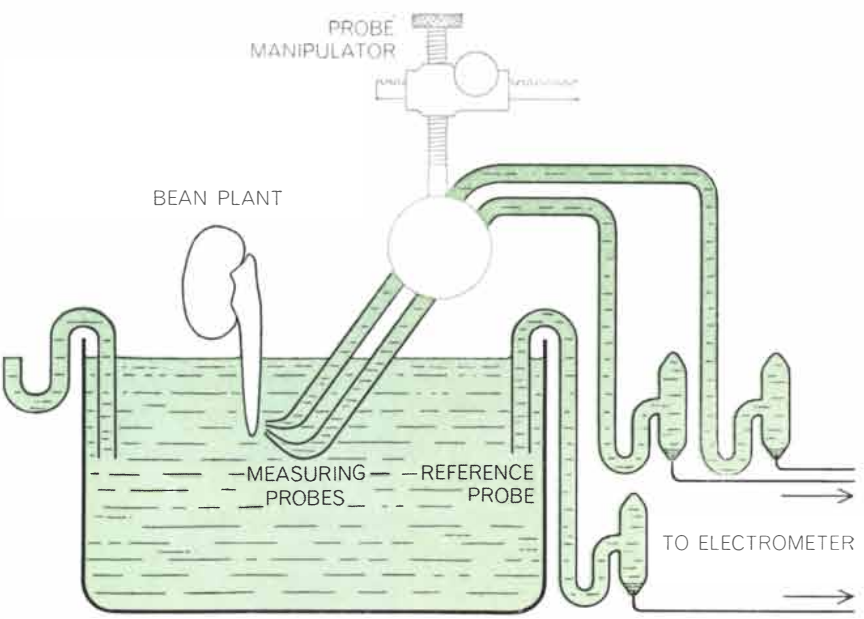
even when there is no apparent periodic change in their environment. A built-in electrochemical oscillator governed by a feedback loop nicely fits the specifications for a biological clock.

No less than the roots, the aboveground portions of the plant generate electric fields that may have significance in growth processes. As long ago as 1932, Frits W. Went, now director of the Missouri Botanical Garden, suggested that indoleacetic acid moves down in the coleoptile of the grasslike plants under the influence of electric forces. The coleoptile is a hollow sheath that grows upward in the seedlings of these plants and serves as protection for the developing shoot; it is a favorite subject for study of the effects of light, gravity and various hormones on the plant bending. Like the root tip, the tip of the coleoptile manufactures indoleacetic acid,



APPARATUS for studying the electric field generated by a bean root is shown in this photograph. The bean plant is held by a clamp at center. The glass tubes are probes to measure bioelectric potentials. The lens at left foreground projects a magnified image of the root.



POTENTIALS are measured as shown in this diagram of the apparatus in the photograph at the top. Two glass probes explore the vicinity of the root and another probe is used as a reference. Probes are connected to an electrometer through mercury-calomel cells.

which moves down the coleoptile to the growing region, where it controls the rate at which the cells elongate. Winslow R. Briggs and his co-workers at Stanford University showed in 1957 that light shining on one side of the tip of a corn coleoptile makes some of the indoleacetic acid that would have traveled down the lighted side move down the darkened side instead. The extra amount of hormone on the darkened side makes the cells there elongate more than those on the lighted side, and the coleoptile bends toward the light.

Recently, in partial confirmation of Went's prediction, A. R. Schrank at the University of Texas has found lateral differences in potential around a coleoptile corresponding to the distribution of indoleacetic acid when the coleoptile is illuminated from one side. C. H. Hertz at the University of Lund in Sweden has found a similar distribution of potential in coleoptiles placed horizontally and in process of bending upward against the force of gravity.

We have addressed our experimental effort in this connection to the question of how the indoleacetic acid moves down the coleoptile as fast as it does. It moves at the relatively high speed of 15 millimeters per hour through tissue that does not appear to contain any long, pipelike cells that might carry it downward in a flowing solution. Our observations show that a change in indoleacetic acid concentration in the coleoptile is accompanied by a change in electric field along the coleoptile surface. As the hormone moves down the plant, the electric change moves with it as an electric wave.

We can initiate these waves either by lighting the coleoptile from one side or by cutting off the tip and placing some of the hormone on the cut end. The association of the hormone and the electric field suggests a possible explanation for the rapid movement of the hormone. Through a feedback interaction, such as that postulated for the root, the advancing front of indoleacetic acid sets up an electric field that in turn may push the hormone farther down the coleoptile.

Observation and speculation so far have not answered the question of whether or not the electric fields set up by a growing plant influence its development. There are encouraging indications that they do play such a role. The discovery of more conclusive evidence awaits further refinement in techniques for the detection and perhaps the manipulation of these fields.

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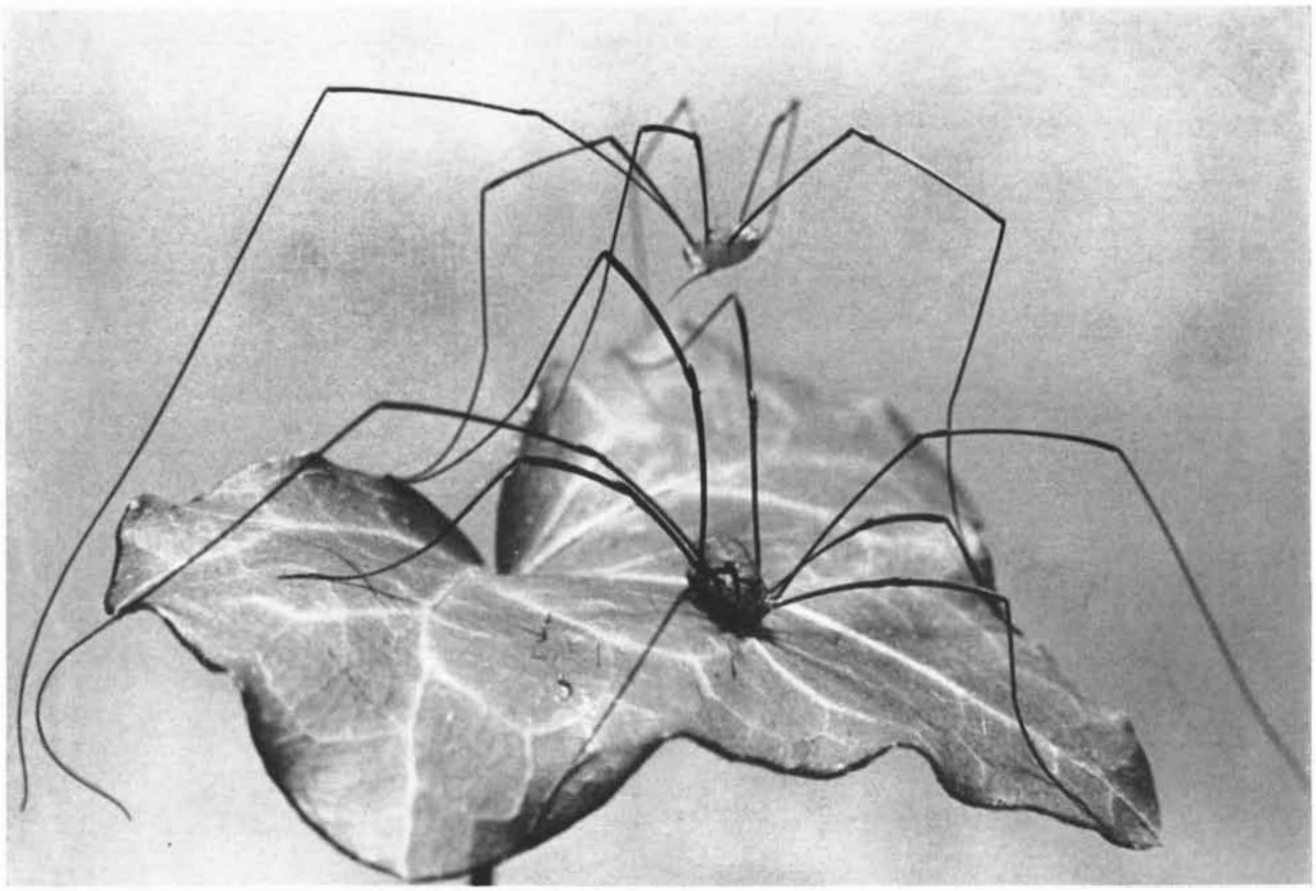
DADDY LONGLEGS

Although these familiar denizens of the countryside have eight legs, they are not spiders. Their elongated limbs are more than a means of locomotion; they also appear to act as sense organs

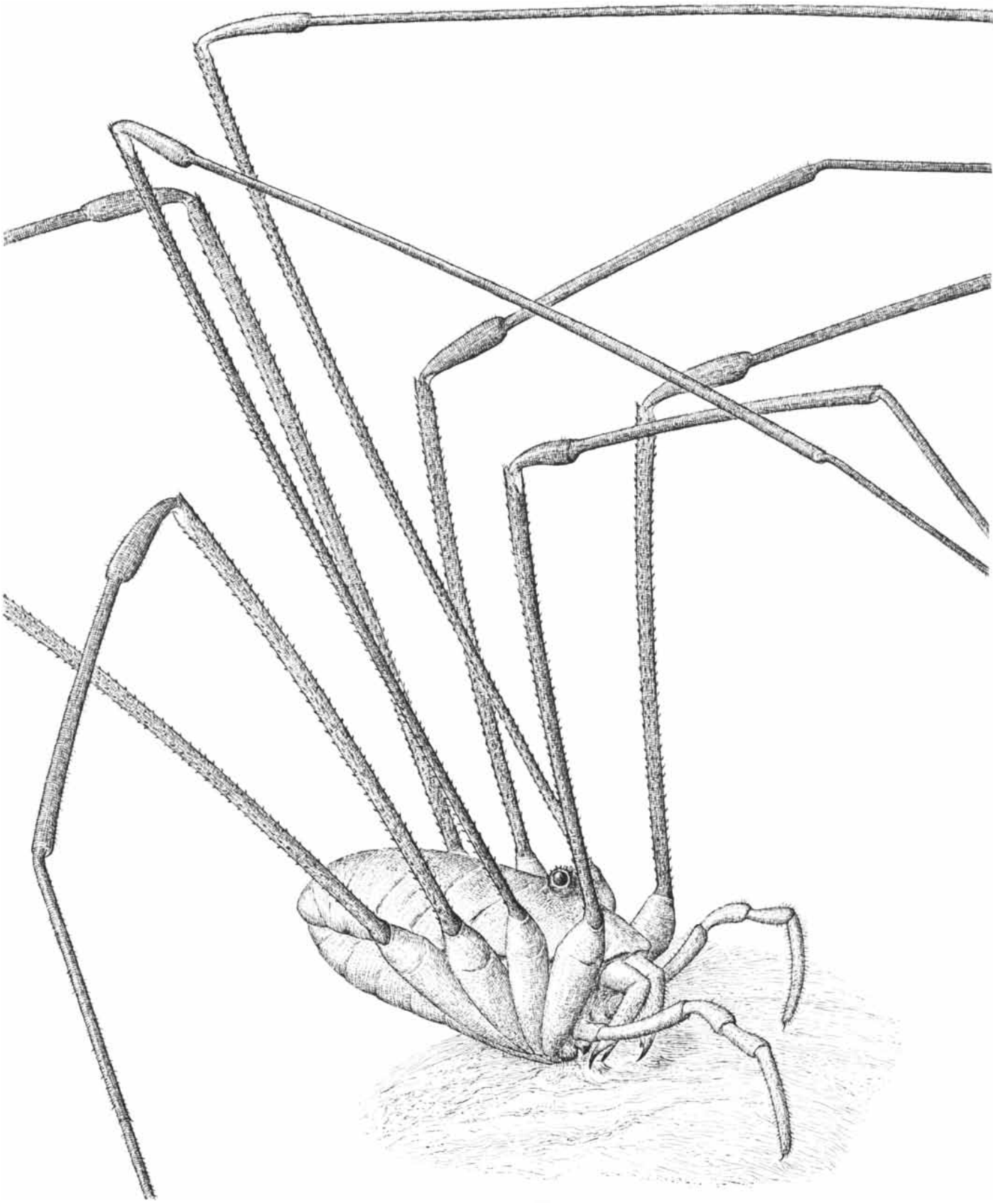
by Theodore H. Savory

The harvestmen, as the British call them, or *les faucheux* (the reapers), as the French call them, put in their appearance during the late summer and early fall, when they are to be seen wandering in the woods, in the long grass, in hedgerows and ditches or hiding under window sills and in dark, damp places among the fallen leaves and vegetable rubbish on the ground. The Germans call them, among other things, *die Afterspinnen,* or "near spiders." Near spiders but not spiders; near, because they have eight legs and belong to the same arachnid class; but not, because they belong to the distinctly different order of Phalangida, their round or oval bodies have no waist, their pincer-like jaws produce no poison, they do not spin and they have two eyes (not eight, as in spiders) set in turrets on their backs.

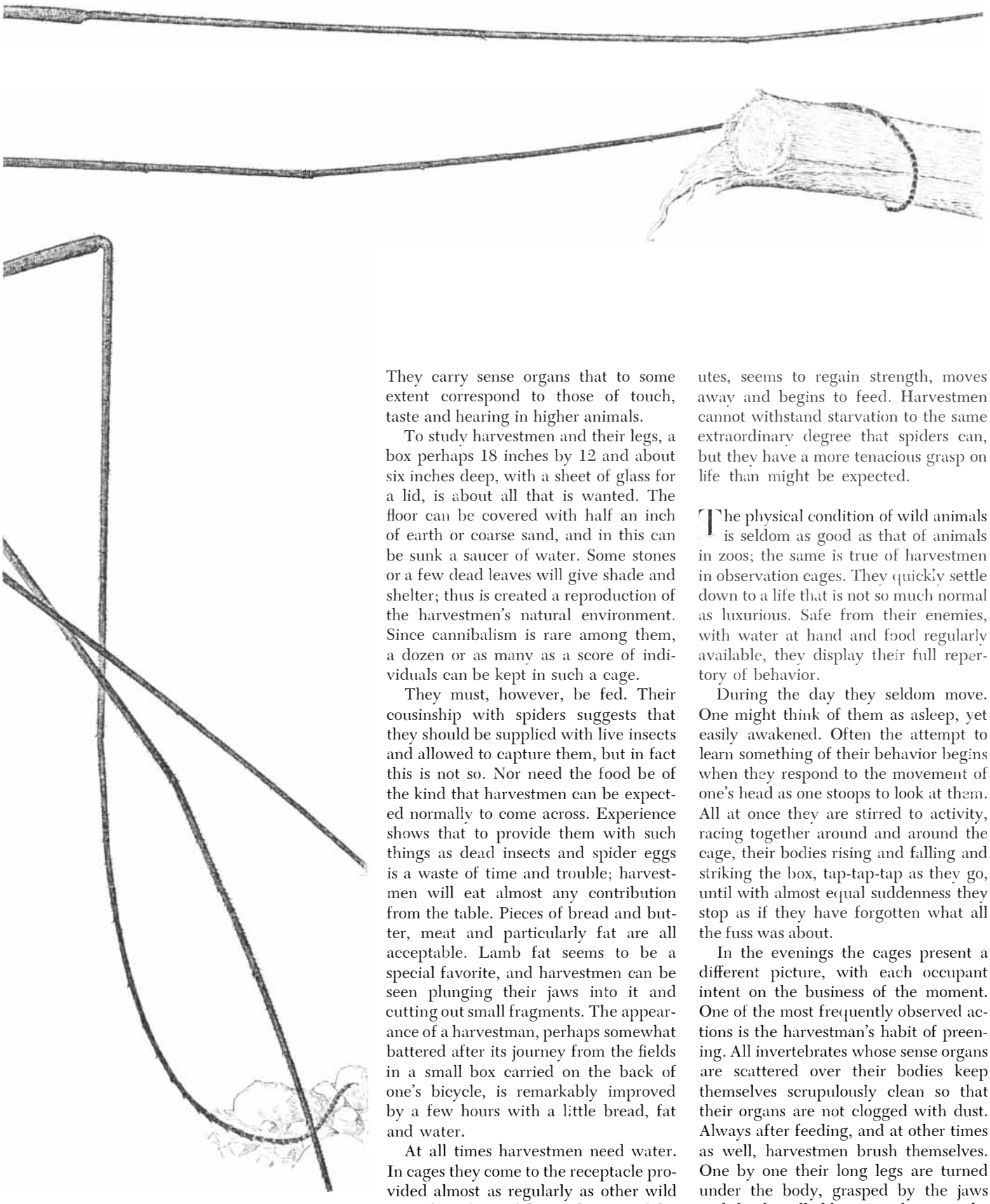
Americans call them by the most immediately descriptive name of all: daddy longlegs. The name has special relevance to the present inquiry. As I wrote in 1938, "the study of harvestmen is the study of legs." My remark has since been quoted so often by other zoologists that it can be supposed to express a truth. Indeed, as will be seen, legs make up a large part of the story. For one thing, a harvestman's legs are much more than mere organs of locomotion.



TWO DADDY LONGLEGS walk along an ivy leaf in this photograph. These animals, which are also known as harvestmen, constitute the order Phalangida. Like spiders, they are members of the arachnid class. The harvestman at the rear in this photograph has only six legs. Although the normal complement is eight, harvestmen drop their limbs easily and cannot regenerate them. Of all the legs, the most important are the long second pair. These precede other legs as the animal walks and so perform the function of antennae.



STRUCTURAL DETAILS of the harvestman's body are seen in a drawing of the animal in feeding position, magnified 30 times. The two eyes are set on each side of a turret atop the cephalothorax, the forward part of the body. The six pairs of appendages (jaws, short limbs called pedipalpi and four pairs of legs) are attached to the six segments of the cephalothorax. The pedipalpi and the



legs also have six segments each. Behind the cephalothorax is the segmented abdomen, which contains the internal organs.

They carry sense organs that to some extent correspond to those of touch, taste and hearing in higher animals.

To study harvestmen and their legs, a box perhaps 18 inches by 12 and about six inches deep, with a sheet of glass for a lid, is about all that is wanted. The floor can be covered with half an inch of earth or coarse sand, and in this can be sunk a saucer of water. Some stones or a few dead leaves will give shade and shelter; thus is created a reproduction of the harvestmen's natural environment. Since cannibalism is rare among them, a dozen or as many as a score of individuals can be kept in such a cage.

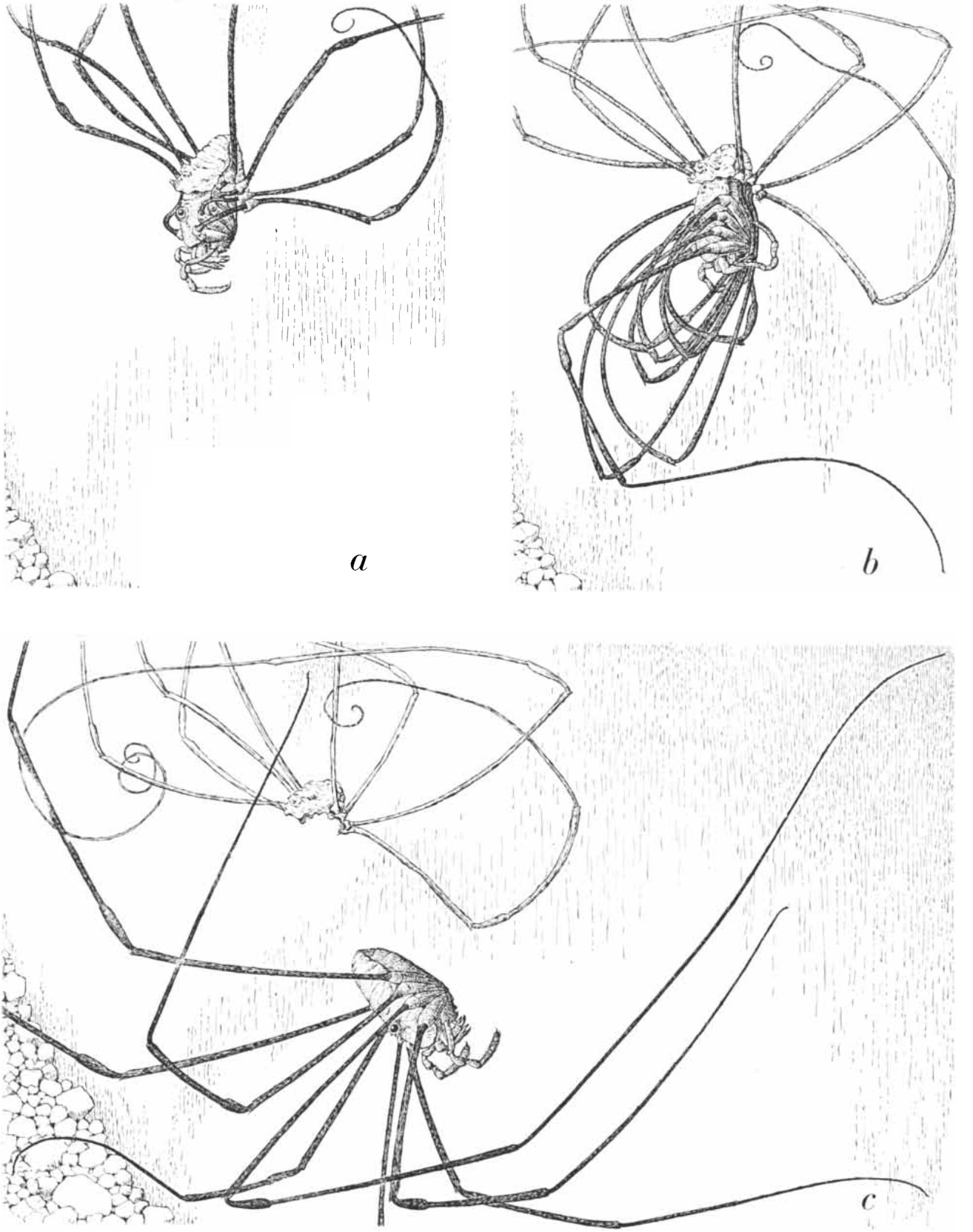
They must, however, be fed. Their cousinship with spiders suggests that they should be supplied with live insects and allowed to capture them, but in fact this is not so. Nor need the food be of the kind that harvestmen can be expected normally to come across. Experience shows that to provide them with such things as dead insects and spider eggs is a waste of time and trouble; harvestmen will eat almost any contribution from the table. Pieces of bread and butter, meat and particularly fat are all acceptable. Lamb fat seems to be a special favorite, and harvestmen can be seen plunging their jaws into it and cutting out small fragments. The appearance of a harvestman, perhaps somewhat battered after its journey from the fields in a small box carried on the back of one's bicycle, is remarkably improved by a few hours with a little bread, fat and water.

At all times harvestmen need water. In cages they come to the receptacle provided almost as regularly as other wild animals gather at lakes and rivers. If deprived of water for several days, a harvestman becomes stiff and torpid. Given access to water, it drinks for several minutes, seems to regain strength, moves away and begins to feed. Harvestmen cannot withstand starvation to the same extraordinary degree that spiders can, but they have a more tenacious grasp on life than might be expected.

The physical condition of wild animals is seldom as good as that of animals in zoos; the same is true of harvestmen in observation cages. They quickly settle down to a life that is not so much normal as luxurious. Safe from their enemies, with water at hand and food regularly available, they display their full repertory of behavior.

During the day they seldom move. One might think of them as asleep, yet easily awakened. Often the attempt to learn something of their behavior begins when they respond to the movement of one's head as one stoops to look at them. All at once they are stirred to activity, racing together around and around the cage, their bodies rising and falling and striking the box, tap-tap-tap as they go, until with almost equal suddenness they stop as if they have forgotten what all the fuss was about.

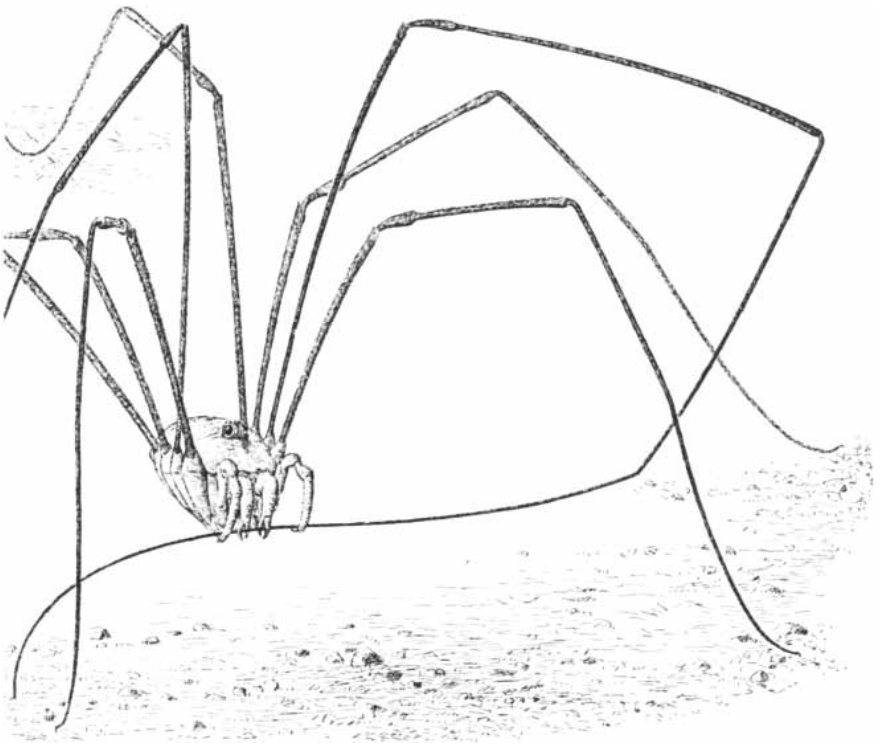
In the evenings the cages present a different picture, with each occupant intent on the business of the moment. One of the most frequently observed actions is the harvestman's habit of preening. All invertebrates whose sense organs are scattered over their bodies keep themselves scrupulously clean so that their organs are not clogged with dust. Always after feeding, and at other times as well, harvestmen brush themselves. One by one their long legs are turned under the body, grasped by the jaws and slowly pulled between them. By the time the last segment has been reached the leg is curved almost into a circle; when the claws are released, the leg



MOLTING HARVESTMAN usually hangs by its claws. In this position it struggles vigorously until it has split the skin on the top of its body from the skin on the bottom. This frees jaws, body and top segments of legs from the old skin, which remains on the back of the body (*a*). Next it frees the remaining segments of its legs. The pedipalpi hold the legs together in a bundle and force them toward the jaws. The jaws then drag each leg in turn out of its old skin, cleaning them at the same time (*b*). This process may take a full 20 minutes. When it is completed and the harvestman has molted, the cast skin is left hanging by the empty claws (*c*).

shoots out like a spring. To clean its jaws the harvestman dips them in water.

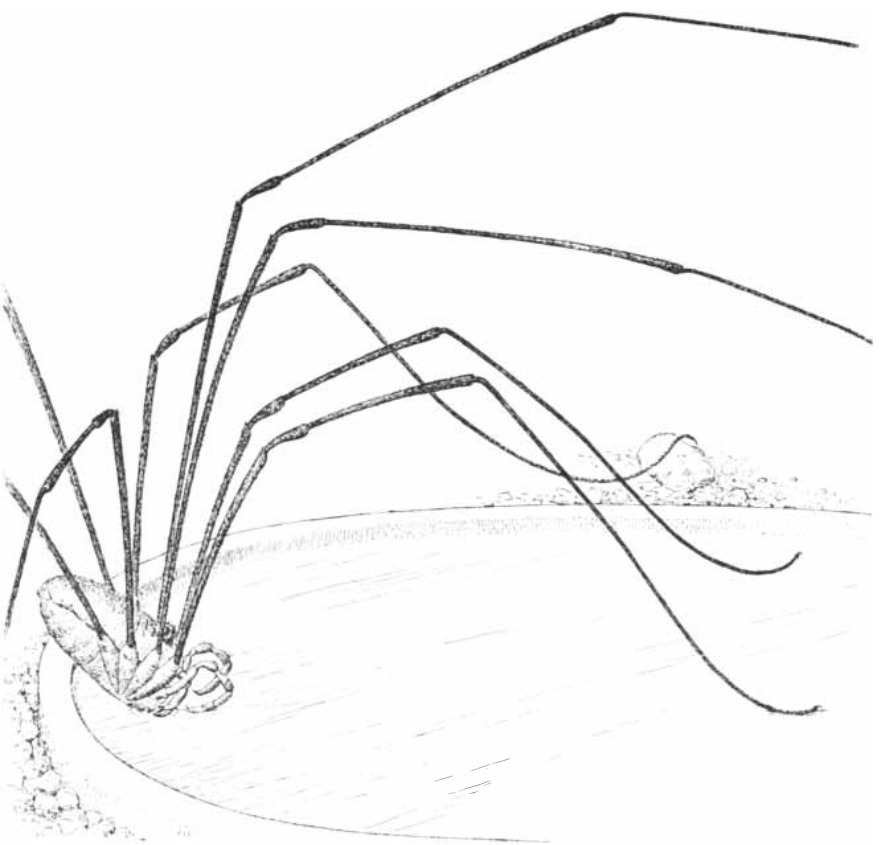
One of the most surprising differences between harvestmen and other arachnids, particularly spiders, is the ease and frequency with which they mate. It is well known that a male spider enters into a long and elaborate courtship before it undertakes the roundabout process of fertilization peculiar to its particular species [see "Unorthodox Methods of Sperm Transfer," by Lord Rothschild; SCIENTIFIC AMERICAN, November, 1956]. Scorpions similarly indulge in a dance together, and the small false scorpions exhibit a complex ritual in which the male leads the female to a spermatophore deposited on the ground. There has been much discussion, and little general agreement, as to the meaning and function of these remarkable activities. To these speculations harvestmen add nothing, for they seem to have no form of courtship, either tactile or visual. Even in captivity they mate immediately on meeting.



HARVESTMAN PREENS by grasping the top of each leg between its jaws and pulling the leg along its entire length. When the claws are reached, the leg almost forms a circle; as the jaws release it, it snaps back like a spring. Harvestmen preen to clean their sense organs.

The behavior that so distinguishes the harvestmen among the Arachnida can be related to an anatomical distinction that sets them apart. Unlike spiders, male harvestmen possess a definite sex organ, a hard chitinous duct that can be easily dissected from the body and mounted for microscopic study and that differs appreciably from one species to another. It is extruded from the male abdomen, passes between the female's chelicerae, or jaws, and delivers the sperm inside the genital operculum, the plate on the underside of the body that covers the genital organs. The actual union occupies barely a minute. After separation the partners, continuing their wanderings in the cage, are likely to mate again, either with each other or with other occupants. Harvestmen are, indeed, the Casanovas of the arachnid world. Some species of harvestmen seem to be particularly insatiable and, when well fed, will spend the evening in no other occupation.

Female harvestmen have an extensible tubular ovipositor that they push into the ground when laying their eggs. On observing that a female harvestman had laid her eggs in the saucer of drinking water in one of my cages, it occurred to me that egg laying may depend on the availability of moist ground, soft enough for the entry of the ovipositor. I placed a shallow tray of moist sand in the cage and was rewarded a month later to find three batches of eggs within. No eggs had been laid anywhere else. The eggs



HARVESTMAN DRINKS by immersing its jaws in water while resting pedipalpi and one or more legs on water's surface. The animal also assumes this posture to clean its jaws of the debris accumulated in preening. Harvestmen can survive without water only a few days.

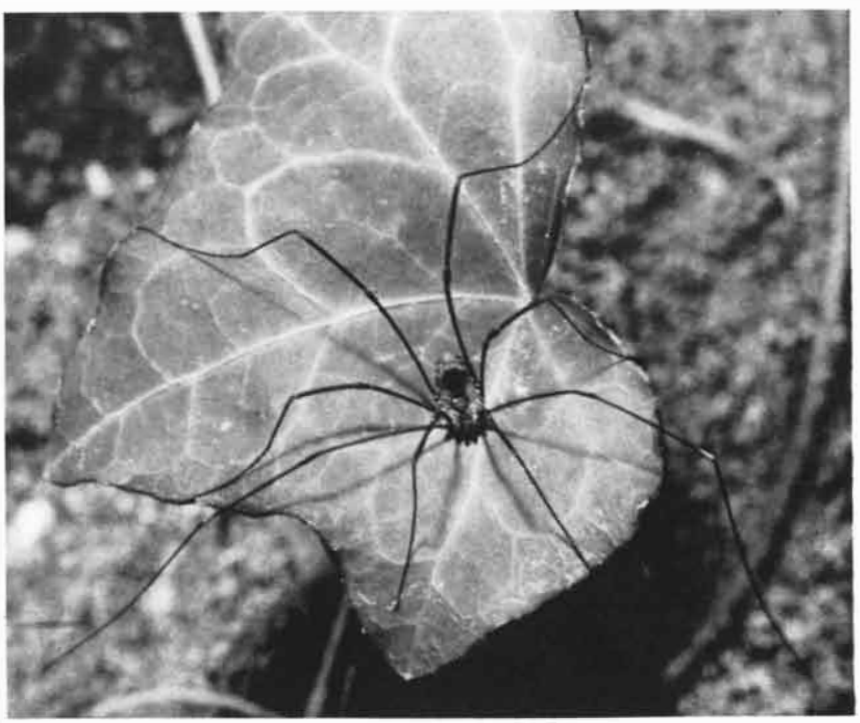
are small, pale spheres, less than half a millimeter across and unprotected. Although species differ somewhat in their seasonal habits, many harvestmen in temperate climates lay their eggs near winter; others hatch more quickly and the young hibernate until the spring.

I shall not easily forget the thrill with which I first saw a baby harvestman staggering across the sand of the cage shortly after hatching. Very young harvestmen seem at first to be feeble little creatures and to have difficulty co-ordinating their long legs. For full appreciation of all their miniature detail, one must look at them under the microscope. A young harvestman is not much more than an hour old, however, before its growth compels the first casting of its skin.

Discontinuous growth by molting is characteristic of the great phylum of Arthropoda, which includes the crustaceans and the insects as well as the arachnids, all of them encased in tough external skeletons. The harvestmen molt, or undergo ecdysis, seven or eight times at intervals of about 10 days before reaching maturity. They generally do their molting at night. In the morning the empty skeleton is found, usually hanging by its hind legs and with all eight legs of the former tenant discernible in the tangle of withered tissue.

To visualize the topologically improbable process by which the harvestman withdraws its long, thin, segmented legs from the skeleton it has outgrown one must inspect the animal's anatomy more closely. The body still shows, in the first place, traces of the segmentation of the annelid worm that is the common ancestor of the arthropods. Six segments can be recognized in the cephalothorax (the joined head and thorax that constitutes the forward portion of the body) and nine in the abdomen. A remarkable feature, to which the shortness of the harvestman's body is partly due, is the forward displacement of the sternites, or ventral plates, of the abdomen. This has the apparent effect of bringing the tergites, or dorsal plates, down over the tip of the abdomen and around onto its underside. As a result the two plates above and below one another on the abdomen do not belong to the same segment. At the same time the genital operculum is pushed forward, obscuring much of the detail of the underside of the cephalothorax.

The six segments of the cephalothorax each bear a pair of segmented appendages: the chelicerae, or jaws, the pedipalpi and the four pairs of legs. The jaws are like the claws of a lobster on a much smaller scale; they act as forceps with the terminal segment closing against a prolongation of the segment immediately behind it. In the adult these fixed and



BLACK HOURGLASS PATTERN on its back distinguishes the harvestman *Mitopus morio* from all other species. Of all harvestmen, this species has the widest distribution. It is found throughout Europe and North America and is the only known harvestman in Greenland.

movable fingers are sharply pointed but smooth; in the newly hatched young they are conspicuously and even strongly toothed. As many as 11 sharp teeth have been counted on the fixed finger and five on the movable one, which suggests a more formidable armament in compensation for the small size and feeble strength of the infant. The pedipalpi are limbs of six segments, like short legs. They are often covered with bristles, variously arranged; no doubt they function as sense organs, largely of a tactile nature. On the coxae, or base segments, of the first two pairs of legs the harvestman is equipped with projections called gnathobases, which hold the food against the mouth. The external mouth therefore appears as a longitudinal opening that runs backward from the jaws the full length of the cephalothorax to the forward edge of the genital operculum.

When the harvestman begins to molt, hanging by its claws, it starts operations with vigorous struggles. These split the skin; the jaws and the first long segments of the legs spring at once through the gap and the body follows. The freeing of the legs, the most protracted part of the business, now begins. The pedipalpi hold the bundle of legs together and force them forward toward the jaws. One at a time, the jaws drag the legs out and free of the outgrown skeleton. As in preening, the legs are bent around in a circle until the claws come loose. In the infant this last step is facilitated because the claws have fewer segments. By the time each leg springs straight it has been thoroughly cleaned and kneaded by the jaws.

Although the time interval between two molts averages about 10 days, it seems to be influenced by temperature and diet. Apparently the animal does not have to hang upside down during the process; I have had specimens that have molted on the ground. Sometimes a harvestman eats its cast skin, but in captivity this is unusual. Perhaps the behavior is induced by hunger or by a shortage of protein in the food recently eaten.

Collectors who try to pick up a harvestman by a leg often see the animal escape on seven legs, leaving the eighth in the forceps. The leg always separates at the junction between the coxa and trochanter, the first and second segments. It continues reflex activity, jerkily bending and straightening, for some time. Occasionally one has the strange experience of finding a leg lying alone on the grass vigorously kicking at noth-

ing. Most animals that grow by molting can shed their limbs with ease. This capacity, which is known as autotomy, is generally accompanied by the capacity to regenerate the lost limb. Spiders, in fact, can regenerate more than one lost limb at a time. If the loss occurs too close to the time of the next molt, the new limb (or limbs) will be somewhat undersized. This is not a severe handicap; spiders with an asymmetric appearance are not uncommon. Under laboratory care, spiders have even been known to regenerate all eight legs at once.

Strangely enough, the harvestman does not have the ability to regrow the limbs it may shed in this manner. No matter what dire alternative fate it would elude by autotomy, it must remain short of a leg. Only the coxal segment is left between its now larger fellows. Toward the end of the season, in fact, harvestmen with the full complement of eight legs are in the minority. Octavius Pickard-Cambridge once found a specimen running actively about on only two! As harvestmen get older they are likely to lose their legs while drinking. They stand on the water to drink, and if they are unable to pull their legs free from the surface tension, they may lose one or more. Unable to free their legs or shed them in time, they may drown. I have seen this happen to captive harvestmen on more than one occasion; if it happens in the wild, it must be one of the few examples of a natural death that does not consist in being eaten.

Harvestmen have another and less Pyrrhic defense against an approaching enemy. On each flank, just behind the first legs, there lies a pair of dark-colored glands that have sometimes been mistaken for eyes. These secrete an odorous fluid that repels a sensitive predator. Among some species of harvestmen the stimulus of danger provokes the emission of visible drops of fluid. Unlike spiders, which are normally odorless, harvestmen always have a slight atmosphere of their own. Some authors have compared the scent of different species to various familiar odors, for which fetid serves as a common denominator. Most surprising is the effect of this secretion on the animals themselves. If all the harvestmen collected in an afternoon are put into a jam jar or similar closed container, they will be found, on return to the laboratory, to be apparently unconscious, as if anesthetized by each other. They recover their usual activity, however, soon after they are shaken out into the cages.

On observing harvestmen in action for a little while, one's attention is attracted to their second pair of legs. They are usually the longest, and one of the first things noticed is that this pair is generally stretched forward, feeling and testing the ground ahead as the harvestmen run. In this regard these legs recall the antennae of insects and crustaceans. Whenever a harvestman moves slowly or uncertainly, it touches the ground in front with its second legs before proceeding. A resting harvestman often moves or lifts a leg of the second pair as if it were an alerted sentinel, suspicious of the approach of danger. I have seen a harvestman react to the slamming of my laboratory door by raising a second leg with a sudden jerk. I have also seen a thirsty harvestman take a step with one of its fourth legs into water, turn and touch the water with a second leg before moving forward to drink. A chemical, a tactile and a kind of auditory sense all seem to be incorporated in this pair of legs.

Although the loss of one of the second legs is not an incapacitating handicap, their importance becomes more obvious when an individual has lost them both. Its movements then are slower; it seems to hesitate as it moves, after the manner of a blindfolded man in a crowd. In the wild it would probably not survive for long.

One observation of mine seems to suggest that essential functions are associated with this pair of legs. By chance I had at the same time a male that had lost its right second leg and a female of the same species that had lost its left second leg. As soon as they met they attempted to mate. But because their second legs were missing from the same side as they faced each other, they failed to unite. Frustration continued, in spite of constant attempts.

About 2,000 species of harvestmen have been found and described in all parts of the world except the polar regions. From this multitude three species common to the North Temperate Zone stand out as worthy of individual mention.

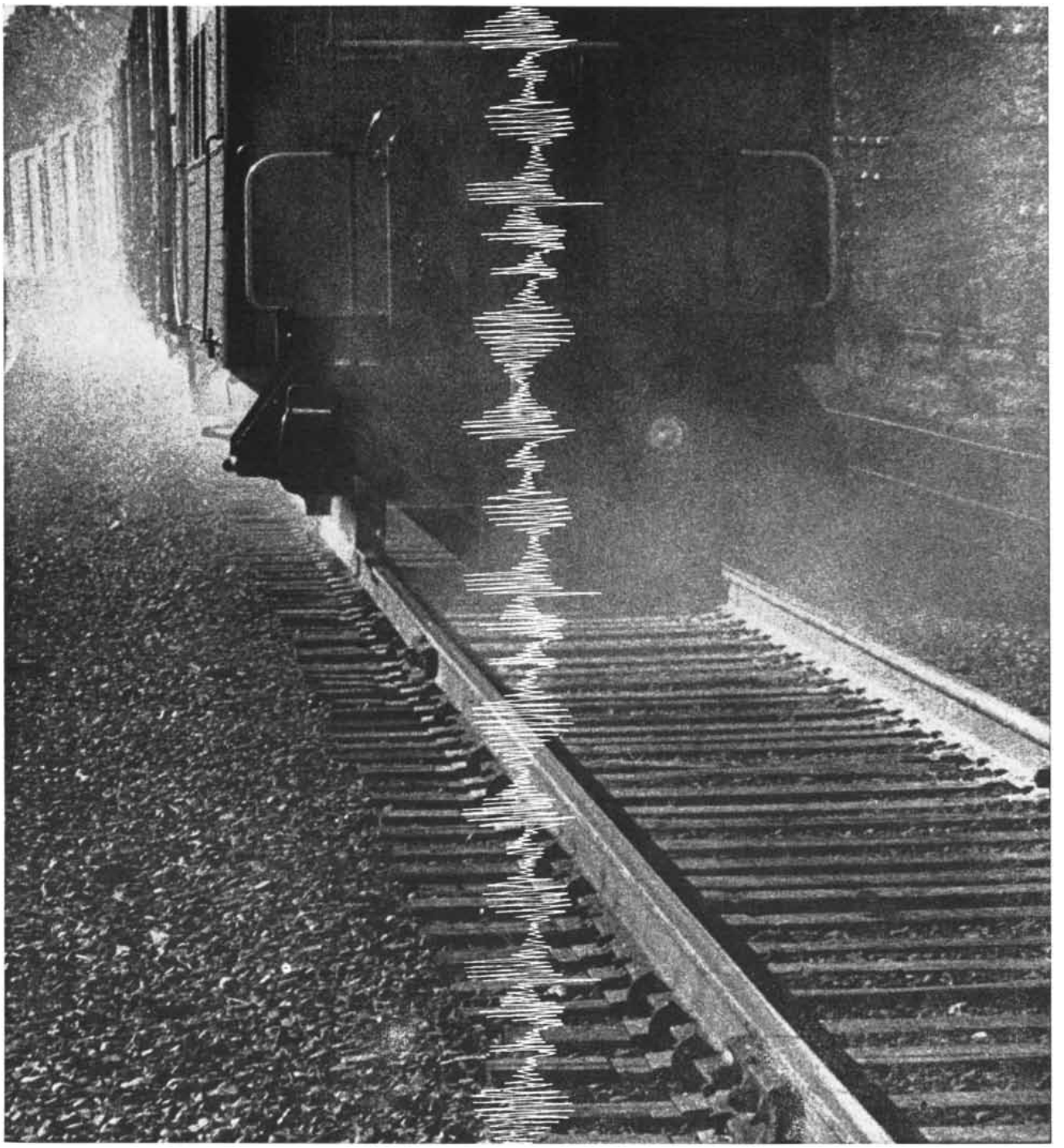
The species *Phalangium opilio* is common both in Europe and North America. Known to Aristotle, mentioned by Robert Hooke, named by Linnaeus and recognizably illustrated by many of the medieval naturalists, it holds a unique position in the order. It is larger than most species of harvestman, with a body almost a centimeter long; it is also one of the few species in which the sexes are distinguishable at a glance. The custom-

ary statement that males have smaller bodies and longer legs than females has no significance if an observer has only one specimen before him and cannot say whether its legs are "long" or "short." In *P. opilio,* however, the male has upward horns to its chelicerae that distinguish it at once. What the value or function of this distinction is, and why it is not found among most other species, no one can yet say.

A harvestman with a personality, if this is not stretching language too far, is *Mitopus morio.* Its back bears the design of a black hourglass, a feature that makes it recognizable both to its captors today and in the drawings of naturalists of earlier times. Its really interesting characteristic is its breadth of distribution. Not only is it found over most of Europe and in many parts of North America, it also extends northward into Iceland, and it is the only known harvestman in Greenland. A large and active species, as befits one that can endure the temperatures of near-arctic lands, it scarcely deserves a name that means "thread-foot fool."

The third species is of a different kind. Its name is *Megabunus diadema* and it leads a much more obscure life. In Britain careful collectors can find it on hilltops and on the sides of mountains at altitudes higher than those inhabited by most of its fellows. It is a beautiful little creature, bearing a delicate pattern of silver, green and black, recognizable at once by the long spines on its ocular turrets that form the crown, or diadem, that gives it its name. But its claim to fame is more bizarre. Collectors have rarely found males of *Megabunus;* one statistically minded enthusiast recorded only one male in a total of 407 specimens. Laboratory investigation then showed that the females of this species are able to produce their young parthenogenetically and so avoid the normal consequences of a scarcity of males. Parthenogenesis has been demonstrated in a few other species; *M. diadema* seems to be the only one in which it is virtually the normal practice.

Not long ago the spiders were the most neglected of the most interesting animals. Today the dual title of most neglected and most interesting belongs to the harvestmen. With their rounded bodies ornamented with little spikes; two eyes perched crazily atop, back to back, like the faces of a clock tower; ungainly legs, insecurely attached; occasional puffs of mephitic vapors—they suggest that evolution is not without a sense of humor.



What can ride the rails and still record with laboratory precision? AMPEX CP-100.

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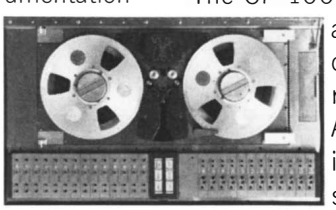


MATHEMATICAL GAMES

A collection of puzzles involving numbers, logic and probabilities

by Martin Gardner

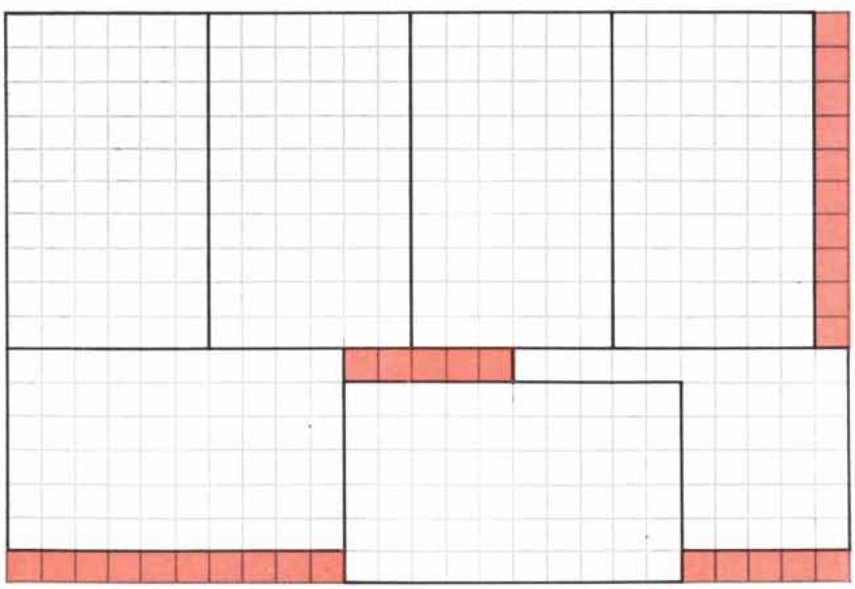
Every eight months or so this column presents a selection of short problems of various types. The nine problems that follow can for the most part be solved by anyone who "thinks mathematically." The only one that calls for knowledge of mathematics beyond the high school level is the third, Leo Moser's problem concerning a family chess tournament, but even here the probability theory involved is elementary. Answers to all problems will be given next month.

1.

A sheet of legal-sized paper, 8½ by 12½ inches, has an area of 106¼ square inches. Seven file cards of the three-by-five-inch size have a combined area of 105 square inches. Obviously it is not possible to cover the large sheet completely with the seven cards, but what is the largest area that *can* be covered? The cards must be placed flat, and they may not be folded or cut in any way. They may overlap the edges of the sheet, however, and it is not necessary for their sides to be parallel with the sides of the sheet. The illustration below shows how the seven cards can be arranged to cover an area of 98¾ square inches. This is not the maximum.

Everyone in the family, young and old, will enjoy working on this puzzle. If the required materials are not handy, a sheet of cardboard can be cut to the 8½-by-12½-inch size, and the seven three-by-five rectangles can be cut from paper. It is a good plan to rule the large sheet into half-inch squares so that the area left exposed can be computed quickly.

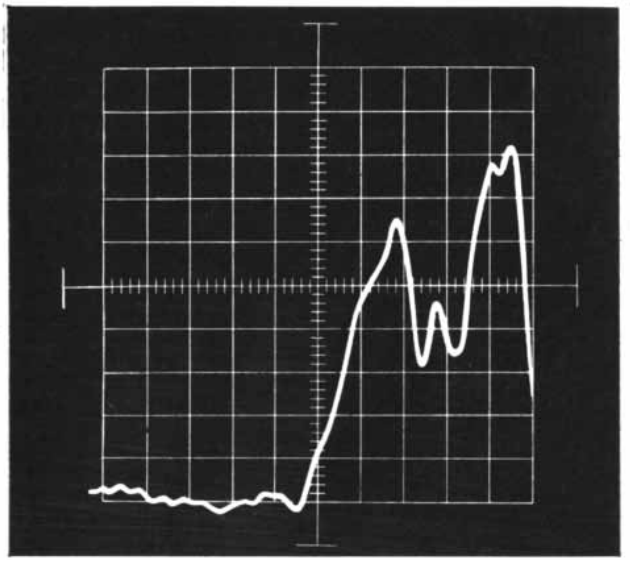
The problem has at least two elements of surprise. It was first posed last December by Jack Halliburton in *Recreational Mathematics Magazine,* and the first surprise was the discovery by readers of an answer that exceeded Halliburton's. The second surprise was the more recent discovery, by Stephen Barr, of a still better solution. Barr's solution will be disclosed here next month for



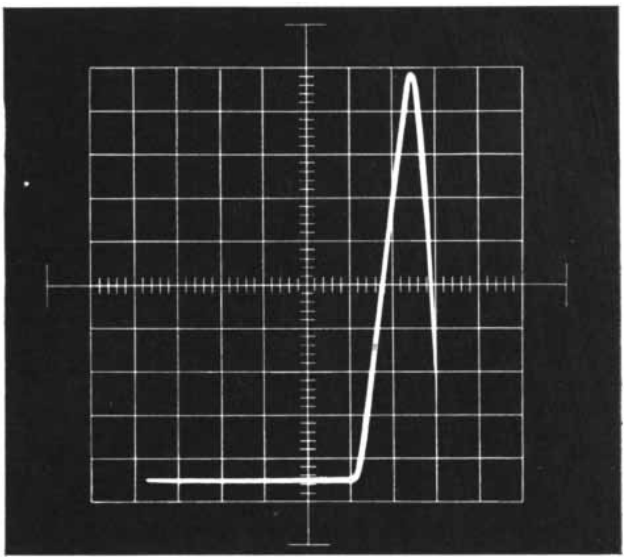
How much of the paper can be covered with seven file cards?

IBM asks basic questions in mechanical analysis

What is the best design?



This is an example of the force-time relationship of impact printing as the striking head of an output printing device comes into contact with its platen.



After modifications were made in the printing mechanism, the force-time relationship reflected a cleaner impact, producing a sharper impression from the printer.

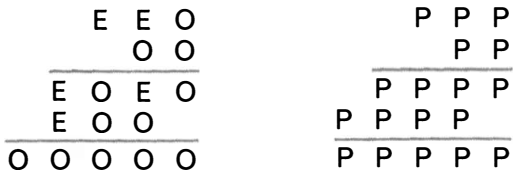
As computers go faster, so must the machines which work with them. The tremendous speed at which these mechanisms function magnifies traditional problems of wear, elasticity, and timing. To meet rigorous new standards of performance, IBM engineers are applying the techniques of mechanical analysis to the development of high-speed mechanisms.

Through a combination of experimental measurements and mathematical analyses, IBM engineers attempt to determine exactly what is taking place at any given instant during the machine cycle. For example, our engineers recently were given the assignment of increasing the operating speed of the output printing element in a data processing system by as much as twenty-five percent without major redesign. To do so, they progressively varied mass, spring forces, and the elasticity of several components, and measured resulting changes in the system's physical characteristics. By translating these experimental results into mathematical terms, they were able to arrive at a solution to the problem which might have been impossible to obtain using only trial-and-error methods.

The exact description of the way in which many variables interact during the machine cycle requires advanced measurement and analysis techniques. For example, the impact curves shown above were produced by a mechanical structure with several degrees of freedom—a system extremely complicated to calculate. IBM engineers chose to alter one structural member slightly to produce an overriding, dominant frequency. They could then analyze the structure's operation mathematically.

Mechanical analysis is helping IBM engineers to create mechanisms with fundamentally new designs. For instance, in a revolutionary new typewriter, the IBM Selectric,™ they were able to design a mechanism to compensate automatically for wear and elasticity in the print-selection system. In an important new development in disk storage, they used a hydraulic actuator to position magnetic read-write heads which float on air bearings. And they have developed a high-speed printer, controlled by a computer's program, which prints by means of engraved type suspended on a chain which moves past the paper at high speed. Mechanisms with advanced designs like these are helping to make it possible to take full advantage of the immense capabilities of the computer.

If you have been searching for an opportunity to make important contributions in mechanical analysis, space, programming systems, or any of the other fields in which IBM scientists and engineers are finding answers to basic questions, please contact us. IBM is an Equal Opportunity Employer. Write to: Manager of Professional Employment, IBM Corp., Dept. 659X, 590 Madison Avenue, N. Y. 22, N. Y.



Two unorthodox cryptarithms

the first time. There is as yet no proof that Barr's solution is the maximum, so perhaps some reader of this department will find a third level of surprise.

2.

Six Hollywood stars form a social group that has very special characteristics. Every two stars in the group either mutually love each other or mutually hate each other. There is no set of three individuals who mutually love one another. Prove that there is at least one set of three individuals who mutually hate each other. The problem leads into a fascinating new field of graph theory, "blue-empty chromatic graphs," the nature of which will be explained when the answer is given next month.

3.

A certain mathematician, his wife and their teen-age son all play a fair game of chess. One day when the son asked his father for $10 for a Saturday night date, his father puffed on his pipe a moment and replied:

"Let's do it this way. Today is Wednesday. You will play a game of chess tonight, another tomorrow and a third on Friday. Your mother and I will alternate as opponents. If you win two games in a row, you get the money."

"Whom do I play first, you or Mom?"

"You may have your choice," said the mathematician, his eyes twinkling.

The son knew that his father played a stronger game than his mother. To maximize his chance of winning two games in succession, should he play father-mother-father or mother-father-mother?

Leo Moser, a mathematician at the University of Alberta, is responsible for this amusing question in elementary probability theory. Of course you must prove your answer, not just guess.

4.

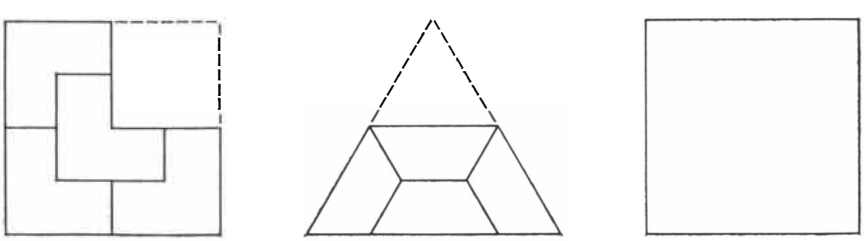
In most cryptarithms a different letter is substituted for each digit in a simple arithmetical problem. The two remarkable cryptarithms shown above are unorthodox in their departure from this practice, but each is easily solved by logical reasoning and each has a unique answer.

In the multiplication problem at the left in the illustration, newly devised by Fitch Cheney of the University of Hartford, each *E* stands for an even digit, each *O* for an odd digit. The fact that every even digit is represented by *E* does not mean, of course, that all the even digits are the same. For example, one *E* may stand for 2, another for 4, and so on. Zero is considered an even digit. The reader is asked to reconstruct the numerical problem.

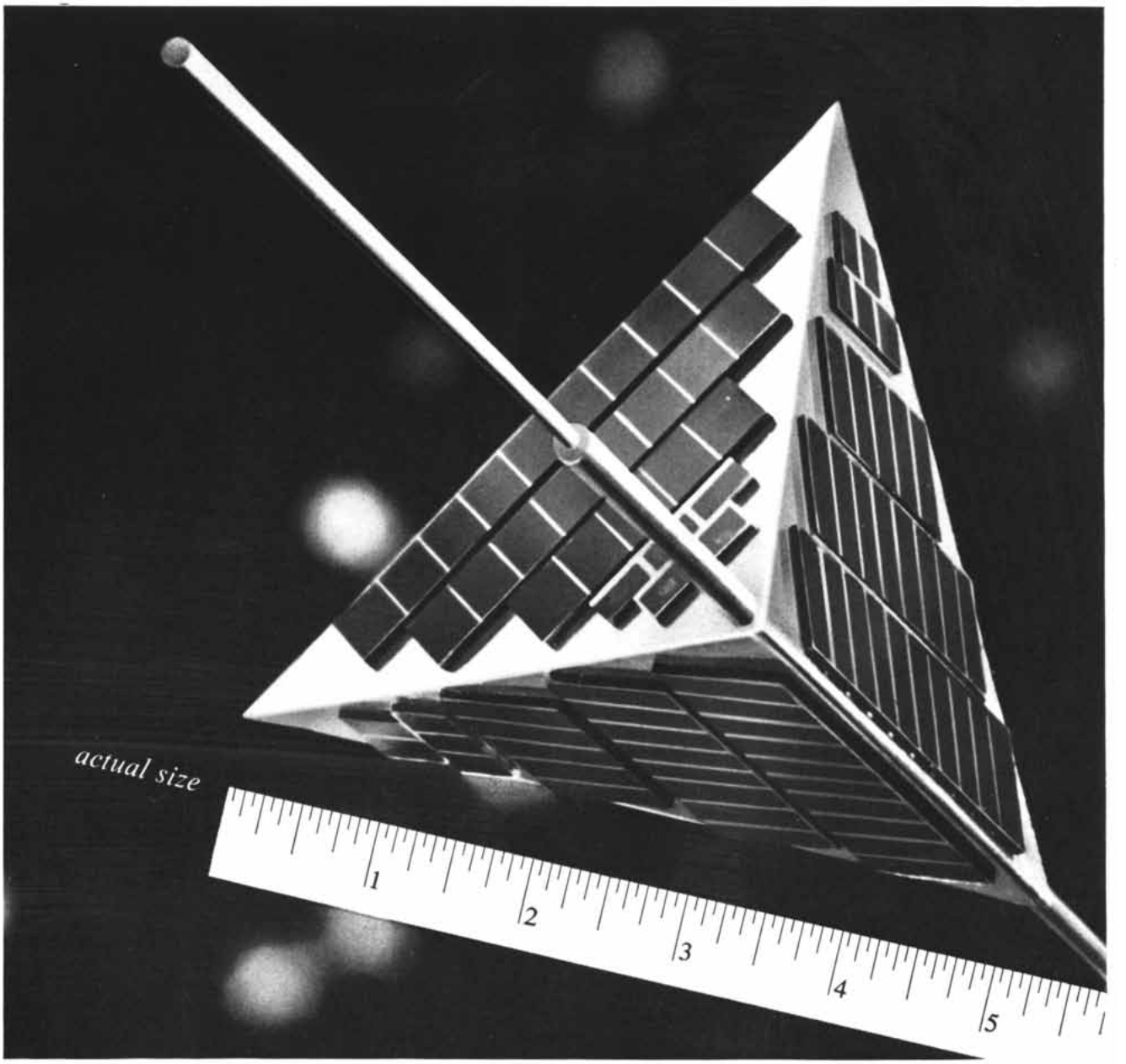
In the multiplication problem at the right, each *P* stands for a prime digit (2, 3, 5 or 7). This charming problem was first proposed some 25 years ago by Joseph Ellis Trevor, a chemist at Cornell University. It has since become a classic of its kind.

5.

If one-fourth of a square is taken from its corner, is it possible to dissect the remaining area into four congruent (same size and shape) parts? Yes, it can be done in the manner shown at the left in the illustration below. Similarly,



Three dissection puzzles



The world's smallest satellite has been developed by Space Technology Laboratories. Its shape will be different from all other satellites before it. STL engineers and scientists have used a tetrahedral configuration to bring about some remarkable characteristics in a space vehicle. There will be no need for batteries nor regulators in flight. The satellite will have no hot side, no cold side. It will require no attitude control devices. No matter how it tumbles in space it will always turn one side toward the sun to absorb energy, and three sides away from the sun to cool instrumentation and telemetry equipment inside. It can perform isolated experiments in conjunction with other projects. Or it can be put into orbit by a small rocket to make studies of its own, up to five or more separate experiments on each mission it makes.

STL is active on hardware projects such as this and as prime contractor for NASA's OGO and an entirely new series of classified spacecraft for Air Force – ARPA. We continue Systems Management for the Air Force's Atlas, Titan and Minuteman programs. These activities create immediate opportunities in: Space Physics, Radar Systems, Applied Mathematics, Space Communications, Antennas and Microwaves, Analog Computers, Computer Design, Digital Computers, Guidance and Navigation, Electromechanical Devices, Engineering Mechanics, Propulsion Systems, Materials Research. For So. California or Cape Canaveral opportunities, please write Dr. R. C. Potter, Dept. J10, One Space Park, Redondo Beach, California, or P. O. Box 4277, Patrick AFB, Florida. STL is an equal opportunity employer.

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an equilateral triangle with one-fourth of its area cut from a corner, as in the center figure in the illustration, can also be divided into four congruent parts. These are typical of a large variety of geometric puzzles. Given a certain geometric figure, the task is to cut it into a specified number of identical shapes that completely fill the larger figure.

Can the square at the right in the illustration be dissected into five congruent parts? Yes, and the answer is unique. The pieces can be any shape, however complex or bizarre, provided that they are identical in shape and size. An asymmetric piece may be "turned over"; that is, it is considered identical with its mirror image. The problem is annoyingly intractable until suddenly the solution strikes like lightning.

6.

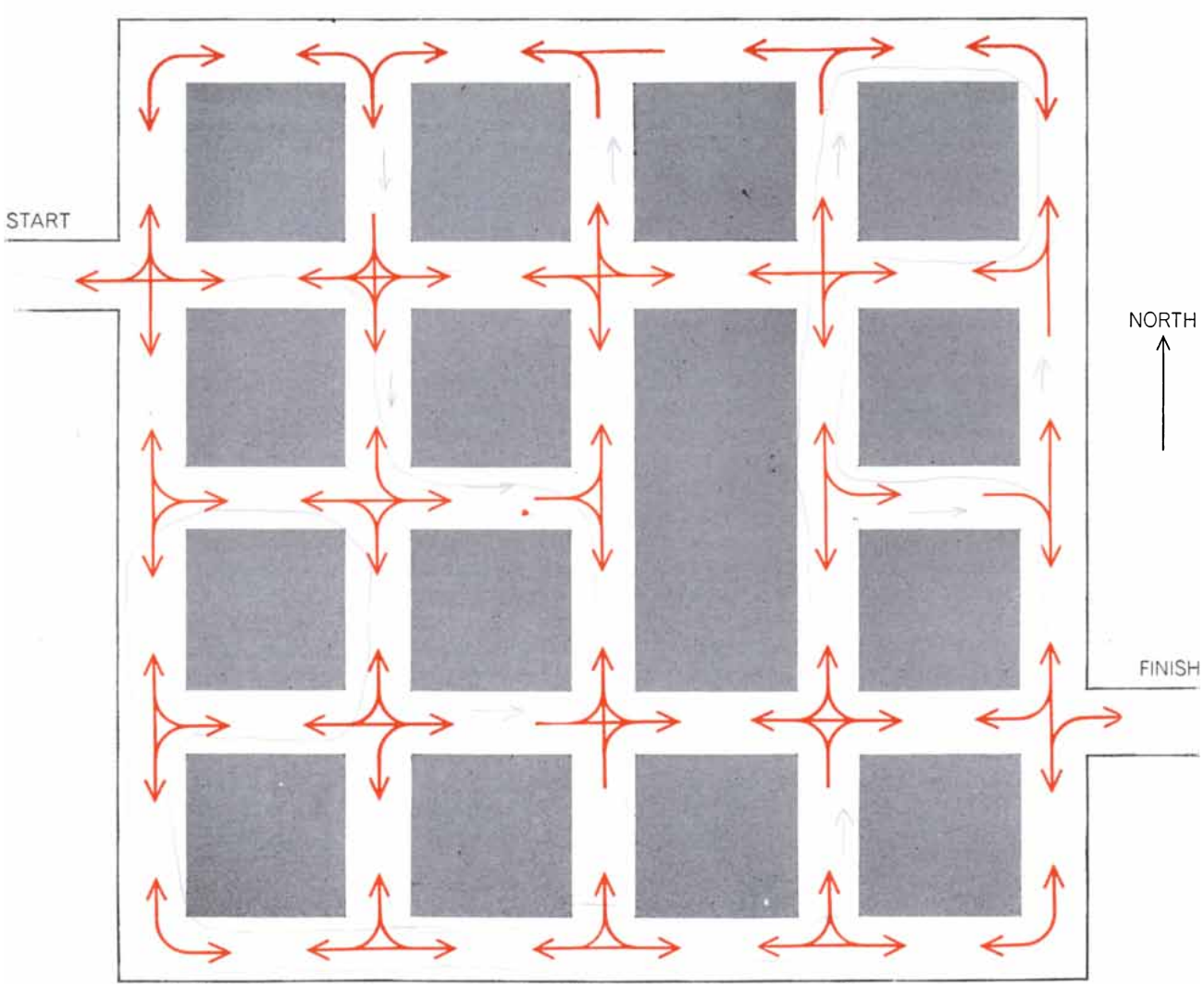
Robert Abbott, author of the recently published book *Four Card Games,* provided the curious street map reproduced below, accompanied by the following story:

"Because the town of Floyd's Knob, Indiana, had only 37 registered automobiles, the mayor thought it would be safe to appoint his cousin, Henry Stables, who was the town cutup, as its traffic commissioner. But he soon regretted his decision. When the town awoke one morning, it found that a profusion of signs had been erected establishing numerous one-way streets and confusing restrictions on turns.

"The citizens were all for tearing down these signs until the police chief, another cousin of the mayor, made a surprising discovery. Motorists passing through town became so exasperated that sooner or later they made a prohibited turn. The police chief found that the town was making even more money from these violations than from its speed trap on an outlying country road.

"Of course everyone was overjoyed, particularly because the next day was Saturday and Moses MacAdam, the county's richest farmer, was due to pass through town on his way to the county seat. They expected to extract a large fine from Moses, believing it to be impossible to drive through town without at least one traffic violation. But Moses had been secretly studying the signs. When Saturday morning came, he astonished the entire town by driving from his farm through town to the county seat without a single violation!

"Can you discover the route Moses took? At each intersection you must follow one of the arrows. That is, you may turn in a given direction only when there is a curved line in that direction, and you may go straight only when there is a straight line to follow. You may leave an intersection only at the head of an arrow. For instance, at the first intersection after leaving the farm, you have only two choices: to go north or to go straight. If you go straight, at the next intersection you must either go straight or turn south. True, there is a curved line to the north, but there is no arrow pointing



The traffic maze in Floyd's Knob

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One problem was the selection of a material to cover the diaphragm. It had to be flexible, to transmit vibration to the throat; tough, to resist puncture. It had to reject corrosive perspiration; remain thermally stable in all climates. Above all, it had to operate for years without drying out or cracking. A material which met all these requirements was thin "Mylar" polyester film.

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north, so you are forbidden to leave that intersection in a northerly direction."

7.

Every now and then a magazine runs a cover picture that contains a picture of the same magazine, on the cover of which one can see a still smaller picture of the magazine, and so on presumably to infinity. Infinite regresses of this sort are a common source of confusion in logic and semantics [see "Paradox," by W. V. Quine; SCIENTIFIC AMERICAN, April, 1962]. Sometimes the endless hierarchy can be avoided, sometimes not. The English mathematician J. E. Littlewood, commenting on this topic in one of his books, recalls three footnotes that appeared at the end of one of his papers. The paper had been published in a French journal. The notes, all in French, read:

"1. I am greatly indebted to Prof. Riesz for translating the present paper.

"2. I am indebted to Prof. Riesz for translating the preceding footnote.

"3. I am indebted to Prof. Riesz for translating the preceding footnote."

Assuming that Littlewood was completely ignorant of the French language, on what reasonable grounds did he avoid an infinite regress of identical footnotes by stopping after the third footnote?

8.

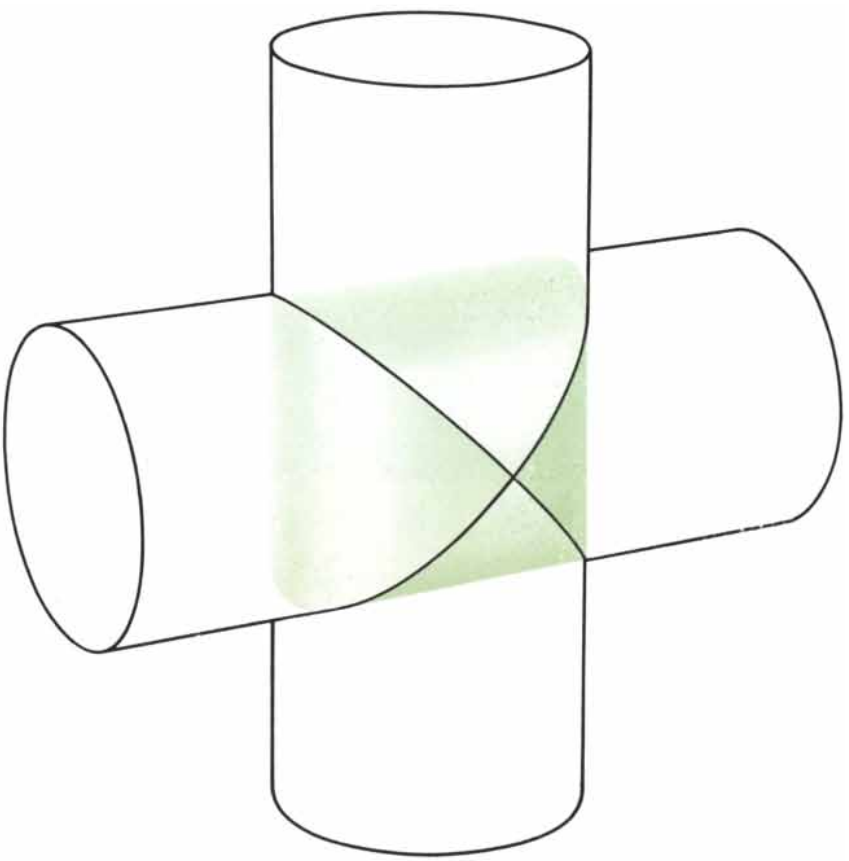
An old numerical problem that keeps reappearing in puzzle books as though it had never been analyzed before is the problem of inserting mathematical signs wherever one likes between the digits 1, 2, 3, 4, 5, 6, 7, 8, 9 to make the expression equal 100. The digits must remain in the same sequence. There are many hundreds of solutions, the easiest to find perhaps being

$$1 + 2 + 3 + 4 + 5 + 6 + 7 + (8 \times 9) = 100 .$$

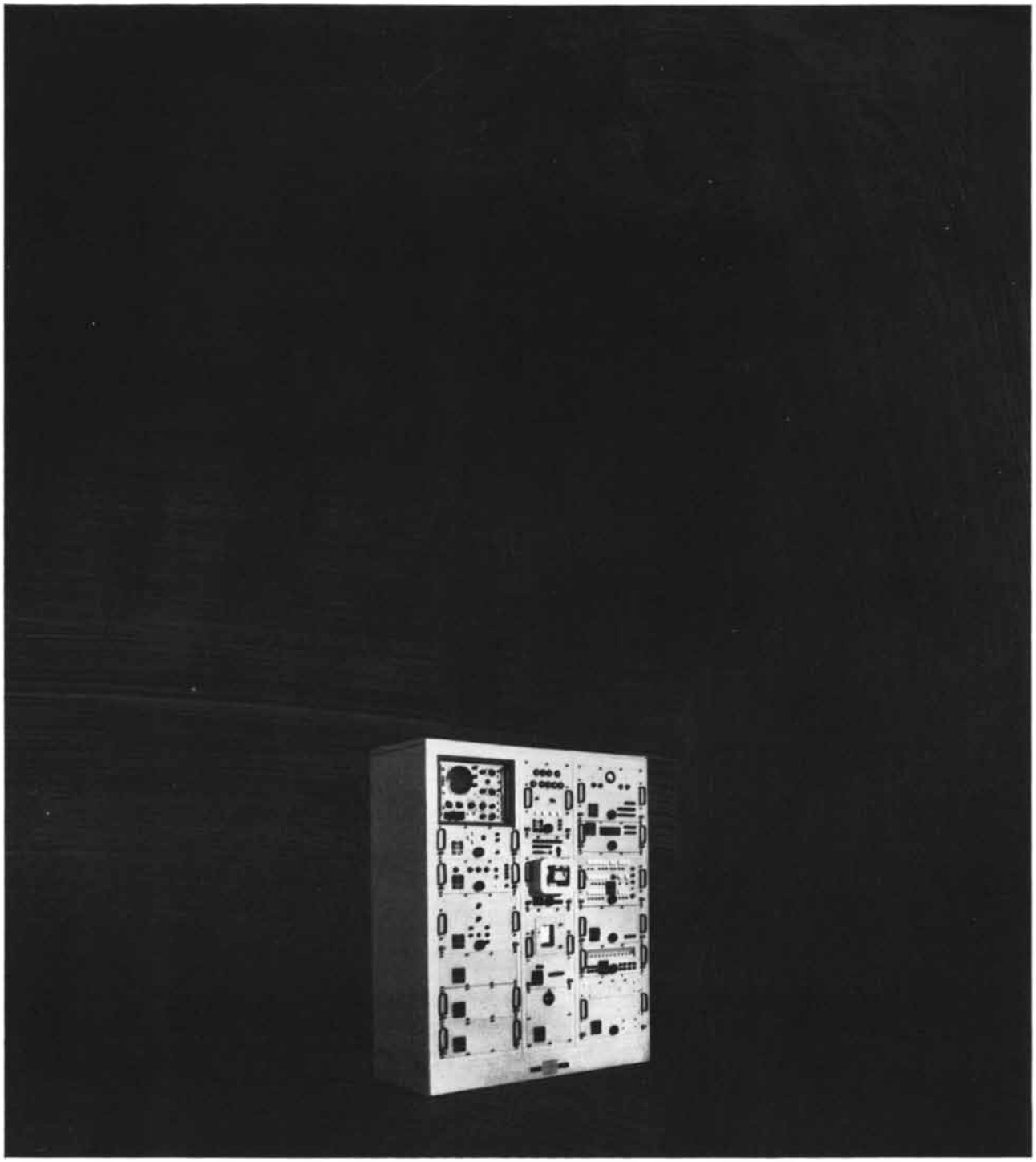
The problem becomes more of a challenge if the mathematical signs are limited to plus and minus. Here again there are many solutions, for example

$$1 + 2 + 34 - 5 + 67 - 8 + 9 = 100 ,$$
$$12 + 3 - 4 + 5 + 67 + 8 + 9 = 100 ,$$
$$123 - 4 - 5 - 6 - 7 + 8 - 9 = 100 ,$$
$$123 + 4 - 5 + 67 - 89 = 100 ,$$
$$123 + 45 - 67 + 8 - 9 = 100 ,$$
$$123 - 45 - 67 + 89 = 100 .$$

"The last solution is singularly simple." writes the English puzzlist Henry



Archimedes' problem of the crossed cylinders



Blabbermouth

NARATE is an automatic radar test system developed for the Navy by Northrop. One of its main functions is to warn the radar operator when anything goes wrong with his equipment. But that's just the first step.

When it discovers a fault in the radar, NARATE can be programmed to find out what the trouble is, and isolate it down to the lowest removable unit. Or it can be directed to bypass the fault in order to continue the test.

NARATE has been tested at the Navy Electronics Laboratory, San Diego, for integration and compatibility with a complex air search radar. It is now installed aboard the USS Columbus for evaluation in fleet operations. Based on the proven Datico automatic test equipment concept, NARATE was developed for the Navy by the Nortronics Division of Northrop.

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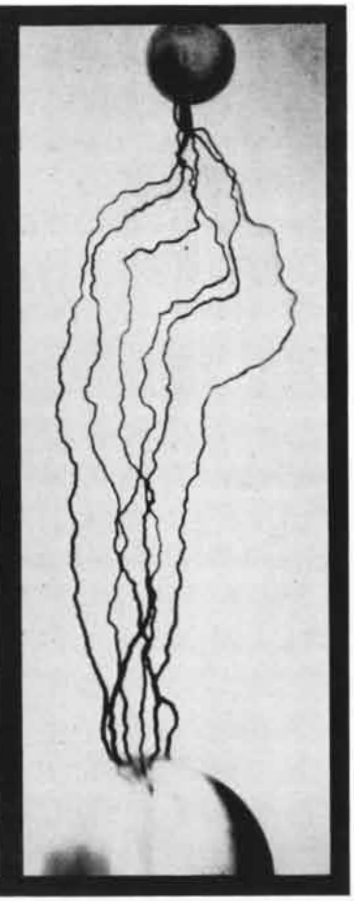


Ernest Dudeney in the answer to Problem No. 94 in his *Amusements in Mathematics*, "and I do not think it will ever be beaten." As far as I know, Dudeney's claim has never been challenged.

In view of the popularity of this problem it is surprising that so little effort seems to have been spent on the problem in reverse form. That is, take the digits in descending order, 9 through 1, and form an expression equal to 100 by inserting the smallest possible number of plus or minus signs. The answer to this problem is still open, but next month I shall give the best solution I know.

9.

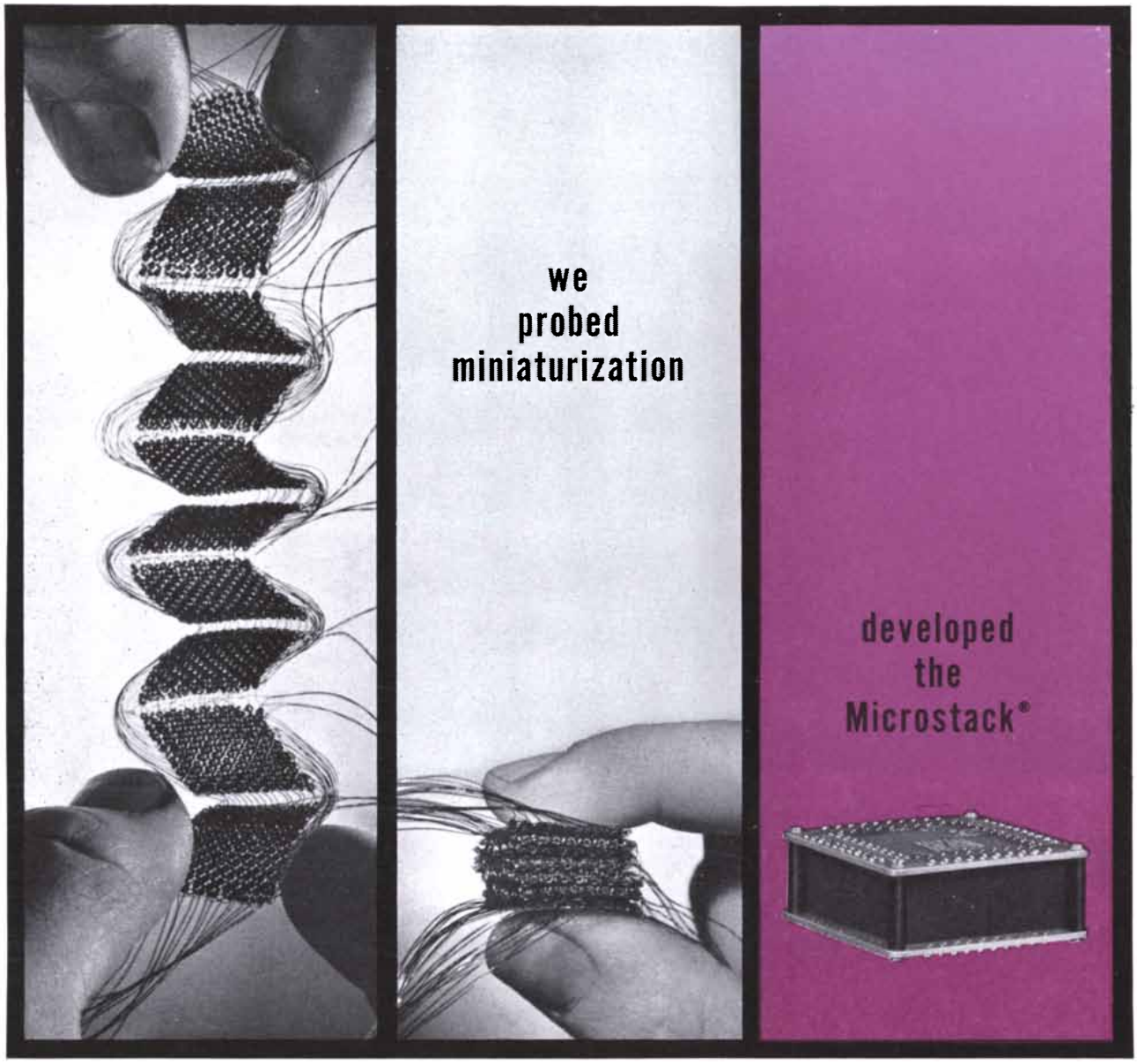
One of Archimedes' greatest achievements was his anticipation of some of the fundamental ideas of calculus. The problem illustrated on page 136 is a classic example of a problem that most mathematicians today would regard as unsolvable without a knowledge of calculus (indeed, it is found in many calculus textbooks) but that yielded readily to Archimedes' ingenious methods. The two circular cylinders intersect at right angles. If each cylinder has a radius of one unit, what is the volume of the shaded solid figure that is common to both cylinders?

No surviving record shows exactly how Archimedes solved this problem. There is, however, a startlingly simple way to obtain the answer; in fact, one need know little more than the formula for the area of a circle (pi times the square of the radius) and the formula for the volume of a sphere (four-thirds pi times the cube of the radius). It may have been the method Archimedes used. In any case, it has become a famous illustration of how calculus often can be completely side-stepped by finding a simple approach to a problem.

The six divisibility problems presented in last month's department are solved as follows:

1. To prove that a number of the form ABABAB must be evenly divisible by 7, we have only to note that such a number is the product of AB and 10101. Because 10101 is a multiple of 7, the number ABABAB must be also.

2. When the digits 1 to 7 are randomly arranged to form a number, the probability that the number is divisible by 11 is 4/35. To be divisible by 11 the digits must be arranged so that the difference between the sum of one set of alternate digits and the sum of the other set of alternate digits is either 0 or a multiple of 11. The sum of all seven



Indiana General engineers probed new ways to increase the packaging density and extend the operating temperature range of memory stacks. By using a continuous wire method of inserting drive lines through memory planes — and then folding the individual arrays — the MICROSTACK was developed. This unique stringing technique eliminates bulky frames and all solder connections between planes. As a result, a MICROSTACK slashes space requirements 90% compared to conventional stacks and offers new standards of reliability. ■ IGC MICROSTACKS are available with up to 32,768 cores in a single matrix enclosure. Individual units may be stacked to provide any desired memory capacity. Temperature-controlled MICROSTACKS operate between −55° C and +85° C. ■ **MEMORY SYSTEMS ARE OUR BUSINESS.** MICROSTACKS are typical of the advanced engineering you receive when you let IGC engineers solve your memory system problems. **Write today for facilities brochure to** Indiana General Corporation, Electronics Division, Keasbey, New Jersey.

INDIANA GENERAL

digits is 28. It is easy to find that 28 can be partitioned in only two ways that meet the 11 test: 14|14 and 25|3. The 25|3 partition is ruled out because no sum of three different digits can be as low as 3. Therefore only the 14|14 partition need be considered. There are 35 different combinations of three digits that can fall into the B positions in the number ABABABA. Of the 35, only four (167, 257, 347, 356) sum to 14. Therefore the probability that the number will be divisible by 11 is 4/35.

3. The smallest number that has a remainder of one less than the divisor, when divided by each integer from 2 to 10 inclusive, is 2519. It is amusing to note that "Professor Hoffmann," in his book *Puzzles Old and New* (1893), calls this a "difficult problem" and devotes more than two pages to solving it by a complicated application of divisibility rules. Hoffmann failed to note that each division falls just one short of being exact, so we need only to find the lowest common multiple of 2, 3, 4, 5, 6, 7, 8, 9, 10, which is 2520, then subtract 1 to get the answer.

4. The problem of the cube with the missing edge of smaller cubes is equivalent to showing that a number of the form $n^3 - n$ (where n is any positive integer greater than 1) must always be evenly divisible by 6. The following is perhaps the simplest proof:

$$n^3 - n = n(n^2 - 1) = n(n-1)(n+1).$$

The expression to the right of the second equal sign reveals that the number $(n^3 - n)$ is the product of three consecutive integers. In any set of three consecutive integers, it is easy to see that one integer must be divisible exactly by 3 and that at least one integer must be even. (These two properties may, to be sure, unite in the *same* integer, e.g., 17, *18*, 19.) Since 2 and 3 are factors of the product of the three consecutive integers, the product must be divisible by 2×3, or 6.

5. The remainder, when 3 to the power of 123456789 is divided by 7, is 6. The short cut here is that successive powers of 3, when divided by 7, have remainders that repeat endlessly the six-digit cycle 3, 2, 6, 4, 5, 1. Divide 123456789 by 6 to obtain a remainder of 3, then note the third digit in the cycle. It is 6, the answer to the problem.

6. The problem asked for a set of four different digits, excluding 0, that could not be arranged to make a four-digit number divisible by 7. Of the 126 different combinations of four digits, only three work: 1238, 1389 and 2469.

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This is the source of new scientific measuring accuracy

PROGRESS

in scientific measurement depends in part on continuing improvement of the oscilloscope, a basic measuring tool that visually displays repetitive or fleeting electrical phenomena.

Dramatic improvements in circuitry have made the oscilloscope a versatile and indispensable tool. Yet, refined and sophisticated as scope circuitry may be, the limitations of conventional cathode ray tubes can create reading errors which only improved CRT design can correct. Hewlett-Packard has combined both electronic and *manufacturing* achievements to produce oscilloscope CRTs that come closer than ever before to eliminating human reading error.

Three basic improvements have been made: a 50% greater picture size on a high-frequency scope, removal of parallax viewing error, and the elimination of reflected glare.

For high speed (50 MC) oscillography, hp has produced an entirely new cathode ray display tube. This new 12,000 volt CRT displays high speed electrical signals on a full 6 cm x 10 cm calibrated screen (50% larger than previously available for high frequencies). Deflection defocusing has been eliminated, and the sensitivity of the CRT has been doubled. Less amplification is needed to swing the electron beam so simpler, more reliable driving circuits can be used. The 50% larger display that stays in focus at full deflection significantly reduces the reading error.

Second, hp developed a manufacturing technique to eliminate a parallax viewing error which, on most oscilloscopes sold today, can be as great as 5% unless every portion of the trace is viewed from precisely in front of that part of the screen. This parallax error was caused by a separation as great as ¼" between the trace, falling on the inside of the CRT face, and the square-centimeter-scribed scaling graticule, placed on the outside surface of the CRT face. hp completely eliminated parallax error by placing the graticule on the inside of the tube, in the same plane as the trace. Readout is now identical from any angle.

Finally, glare and reflections from ambient light have always plagued scope users. Viewing screens blocked out reflected light but limited viewing to one person at a time. Now, an etching process on the surface of the safety glass face plate on hp CRTs eliminates glare, at the same time preserving clear viewing.

Illustrated here is the electron gun against a background of flame from the gas jets of the assembly fixture.

Hewlett-Packard oscilloscope technology includes the continuing improvement of cathode ray tube design and construction for new scientific measuring accuracy.

hp 175A 50 MC Universal Oscilloscope

is the first hp scope to incorporate the new 12 Kv no-parallax CRT as standard equipment, although the no-parallax feature is available as standard or as an optional extra on other hp scopes. The 175A offers a 50 MC main vertical amplifier; plug-in versatility for dual trace viewing to 40 MC, high sensitivity, sweep delay, time marker, X-Y recorder output; simple calibration and maintenance; preset automatic trigger over entire bandwidth; new hp modular packaging for bench and rack mount in a single instrument. $1,325.00 (Basic instrument. Versatile plug-ins optional at extra cost.)

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THE AMATEUR SCIENTIST

How to make a ripple tank to examine wave phenomena

Conducted by C. L. Stong

Waves of one kind or another are found at work everywhere in the universe, ranging from gamma rays of minute wavelength emitted by nuclear particles to the immense undulations in clouds of dust scattered thinly between the stars. Because waves of all kinds have in common the function of carrying energy, it is not surprising that all waves behave much alike. They move in straight lines and at constant velocities through uniform mediums and to some extent change direction and velocity at junctions where the physical properties of the mediums change. The part of a sound wave in air that strikes a hard object such as a brick wall, for example, bounces back to the source as an echo, an effect identical in principle with the image cast by a mirror and with the seismic disturbances that ricochet from layers of rock in the earth's interior. All are examples of wave reflection. Disjunctions in wave mediums account for the power transformers that hang from poles on city streets. Offhand they may seem to bear little resemblance to the bluish coating on camera lenses or to the megaphones used by cheerleaders. But the three devices have a function in common: helping waves to travel across junctions between mediums of differing characteristics without reflecting energy back to the source. All three are transformers.

Such similarities suggest the underlying simplicity and order that characterize nature. By learning how waves of one kind behave the experimenter learns what behavior to expect of others, and problems solved by the study of waves in one medium can be applied, with appropriate modification, to those in other mediums. Some acoustic properties of an auditorium, for instance, can be investigated by observing the action of waves in a shallow pan of water. When the pan is fitted with a glass bottom, illuminated by a point source of light and equipped with a motor-driven agitator to generate waves, it becomes a ripple tank, a fascinating apparatus that is widely used for investigating wave behavior of all kinds.

The pan of a simple ripple tank that can be made in the home consists of a picture frame about two inches thick and two feet square, closed at the bottom by a sheet of glass calked to hold water, as shown in the top illustration on the opposite page. The tank is supported about two feet above the floor by four sheet-metal legs. A source of light to cast shadows of ripples through the glass onto a screen below is provided by a 100-watt clear lamp with a straight filament. Because the lamp is suspended above the tank with the filament axis vertical, the end of the filament approximates a point source and casts sharp shadows. The lamp, partly enclosed by a fireproof cardboard housing, is suspended about two feet above the tank on a framework of dowels. The wave generator hangs on rubber bands from a second framework made of a pair of metal brackets notched at the upper end to receive a wooden crossbar. The distance between the wave generator and the water can be adjusted either by changing the angle of the metal brackets or by lifting the crossbar from the supporting notches and winding the rubber bands up or down as required. The agitator of the wave generator is a rectangular wooden rod. A wooden clothespin at its center grasps a 1½-volt toy motor driven by a No. 6 dry-cell battery. Several glass or plastic beads are attached to the agitator by stiff wires, bent at right angles, that fit snugly into any of a series of holes spaced about two inches apart. Details of the wave generator are shown in the bottom illustration on the opposite page. Attached to the shaft of the motor is an eccentric weight, a 10–24 machine screw about an inch long. The shaft runs through a transverse hole drilled near the head of the screw, which is locked to the motor by a nut run tight against the shaft; another nut is run partly up the screw. The speed of the motor is adjusted by a simple rheostat: a helical spring of thin steel wire (approximately No. 26 gauge) and a small alligator clip. One end of the spring is attached to a battery terminal, and the alligator clip is made fast to one lead of the motor. The desired motor speed is selected by clipping the motor lead to the spring at various points determined experimentally. (A 15-ohm rheostat of the kind used in radio sets can be substituted for the spring-and-clip arrangement.)

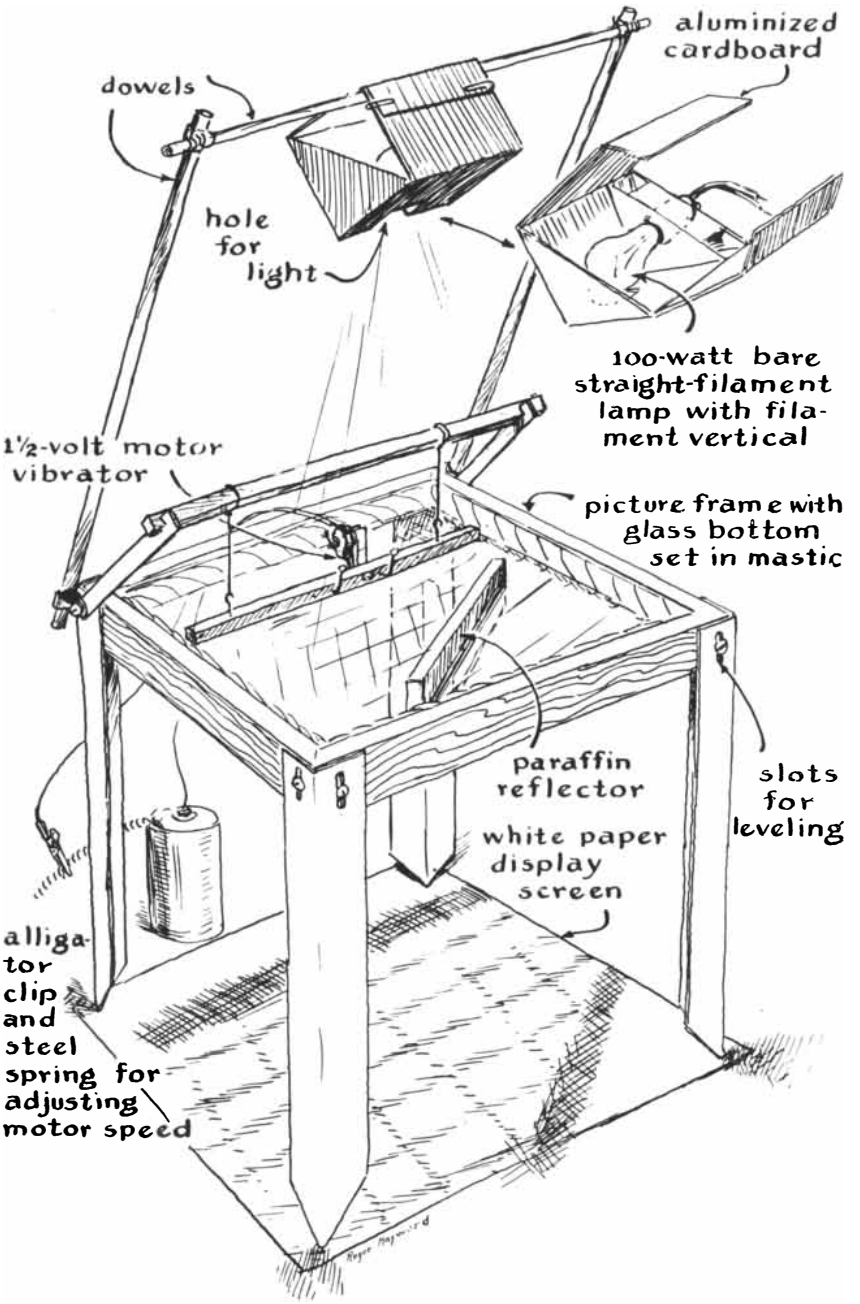
The inner edges of the tank are lined with four lengths of aluminum fly screening three inches wide bent into a right angle along their length and covered with a single layer of cotton gauze bandage, either spiraled around the screening as shown in the upper illustration on page 146 or draped as a strip over the top. The combination of gauze and screening absorbs the energy of ripples launched by the generator and so prevents reflection at the edges of the tank that would otherwise interfere with wave patterns of interest.

The assembled apparatus is placed in operation by leveling the tank and filling it with water to a depth of about 3/4 inch, turning on the lamp, clipping the motor lead to the steel spring and adjusting the height of the wave generator until the tip of one glass bead makes contact with the water. The rotation of the eccentric weight makes the rectangular bar oscillate and the bead bob up and down in the water. The height, or amplitude, of the resulting ripples can be adjusted by altering the position of the free nut on the machine screw. The wavelength, which is the distance between the crests of adjacent waves, can be altered by changing the speed of the motor. The amount of contrast between light and shadow in the wave patterns projected on the screen can be altered by rotating the lamp. The wave generator should be equipped with at least one pair of beads

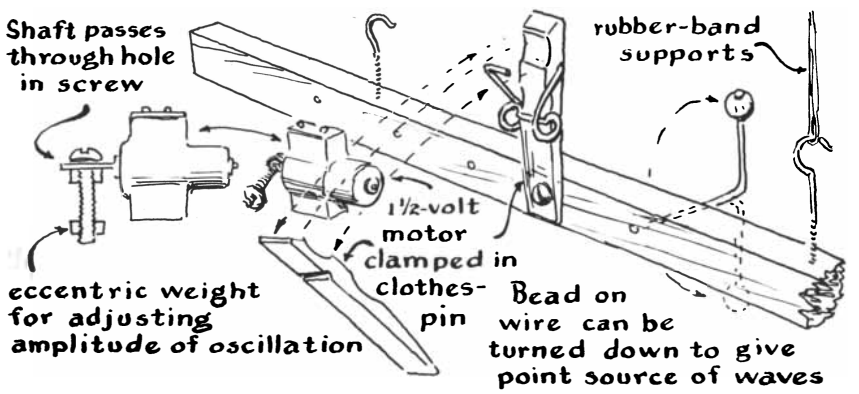
so that ripples can be launched from two point sources. Waves with straight fronts (analogues of plane waves that travel in mediums of three dimensions) are launched by turning the bead supports up and lowering the rectangular bar into the water.

As an introductory experiment, set up the generator to launch plane waves spaced about two inches from crest to crest. If the apparatus functions properly, the train of ripples will flow smoothly across the tank from the generator and disappear into the absorbing screen at the front edge. Adjust the lamp for maximum contrast. Then place a series of paraffin blocks (of the kind sold in grocery stores for sealing jelly), butted end to end, diagonally across the tank at an angle of about 45 degrees. Observe how the paraffin barrier reflects waves to one side, as in the upper illustration on page 148. In particular, note that the angle made between the path of the incident waves and a line perpendicular to the barrier (θ_i) equals the angle made by the path of the reflected rays and the same perpendicular (θ_r). Set the barrier at other angles larger and smaller than 45 degrees with respect to the wave generator and also vary the wavelength and amplitude of the waves. It will be found that the angle of incidence equals the angle of reflection whatever the position of the barrier, a law of reflection that describes waves of all kinds.

Next replace the paraffin barrier with a slab of plate glass about six inches wide and a foot long and supported so that its top surface is about 1/2 inch above the tank floor. Adjust the water level until it is between 1/16 and 1/8 inch above the glass and launch a series of plane waves. Observe how the waves from the generator slow down when they cross the edge of the glass and encounter shallow water, as shown in the lower illustration on page 148. As a result of the change in speed the waves travel in a new direction above the glass, just as a rank of soldiers might do if they marched off a dry pavement obliquely into a muddy field. In this experiment waves have been diverted from their initial direction by refraction, an effect observed in waves of all kinds when they cross obliquely from one medium to another in which they travel at a different velocity. Water waves are unique in that they travel at different speeds when the thickness, or depth, of the medium changes. To a very good approximation the ratio of wave velocity in shallow and deep water is proportional to the ratio of the depths of the water. This ratio is in ef-



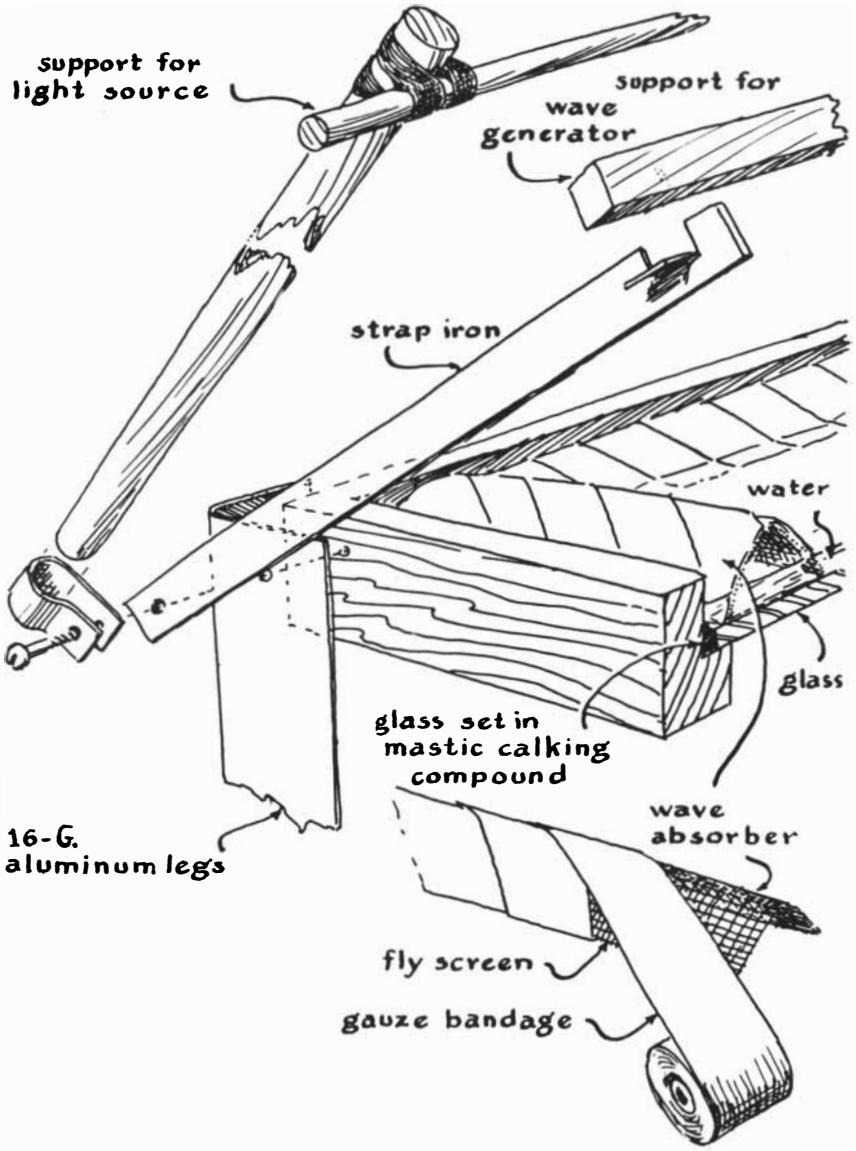
Ripple tank for demonstrating wave behavior



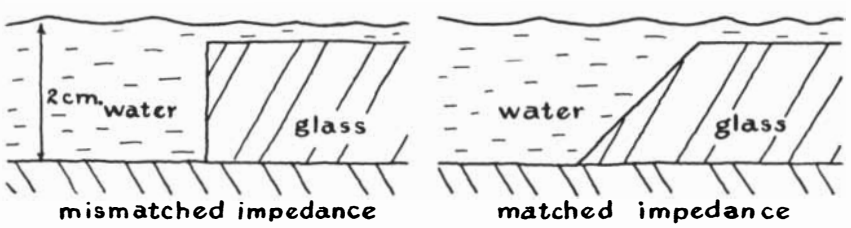
Details of ripple generator

fect the "index of refraction" of the two "mediums." In the case of electromagnetic waves (such as light) or mechanical waves (such as sound) the velocity of wave propagation varies with the density of the mediums. Light waves travel at 186,200 miles per second in a vacuum but somewhat slower in air and much slower in dense materials, such as flint glass. A dense medium shaped in the form of a lens will focus or disperse light rays, radio waves and even mechanical vibrations.

Note in the illustration that the edge of the glass facing the generator reflects waves of low amplitude toward the side.



Details of tank brackets and wave absorbers



Matching the impedance of two water-wave mediums

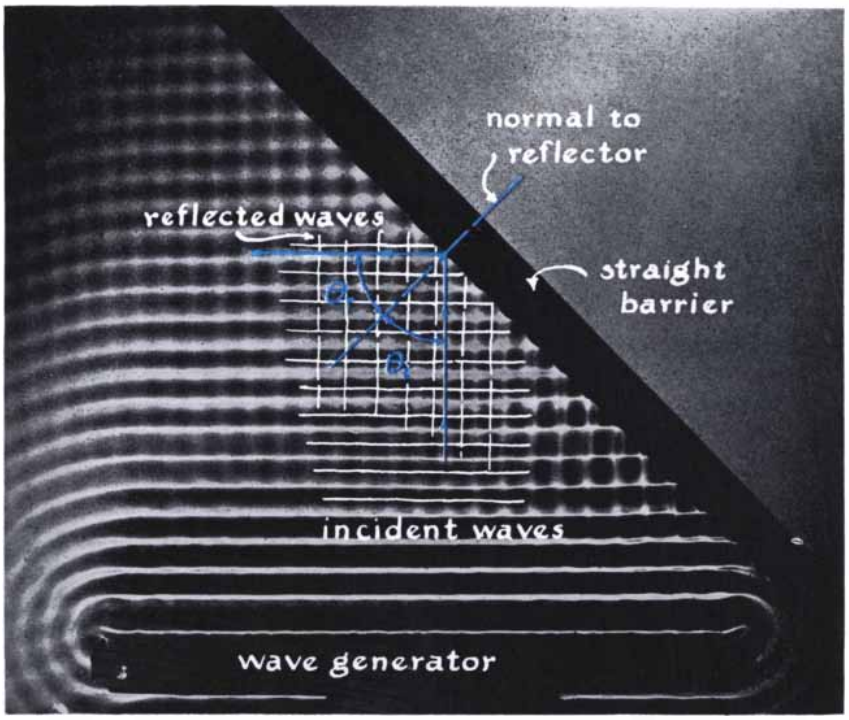
Some energy is reflected by waves of all kinds when they encounter an abrupt difference in the refractive index of mediums. The net reflection at the disjunction between the deep and shallow water can be minimized by beveling the edge of the glass (or any other smooth, solid material substituted for glass) as shown in the lower illustration on the opposite page. Reflection still occurs. But reflections cast by the front part of the wave oppose those set up by following parts of the wave and cancellation takes place. The beveled edge thus acts as a transformer that in effect matches the impedance of the two mediums. Similarly, the optical density of the bluish coating on camera lenses is made intermediate between that of air and glass to minimize the loss of light by partial reflection, much as the tapered megaphone minimizes the reflection back into a cheerleader's throat from the acoustic disjunction between his lips and open air.

Wave energy can also be focused, dispersed and otherwise distributed as desired by barriers of appropriate shape, as exemplified by the parabolic reflectors used in telescopes, searchlights, radars and even orchestra shells. The effect can be demonstrated in two dimensions by the ripple tank. Make a barrier of paraffin blocks or rubber hose in the shape of a parabola and direct plane waves toward it. At every point along the barrier the angle made by the incident waves and the perpendicular to the parabola is such that the reflected wave travels to a common point: the focus of the parabola. Conversely, a circular wave that originates at the focus reflects as a plane wave from the parabolic barrier, as shown in the upper illustration on page 150. In this experiment the wave was generated by a drop of water.

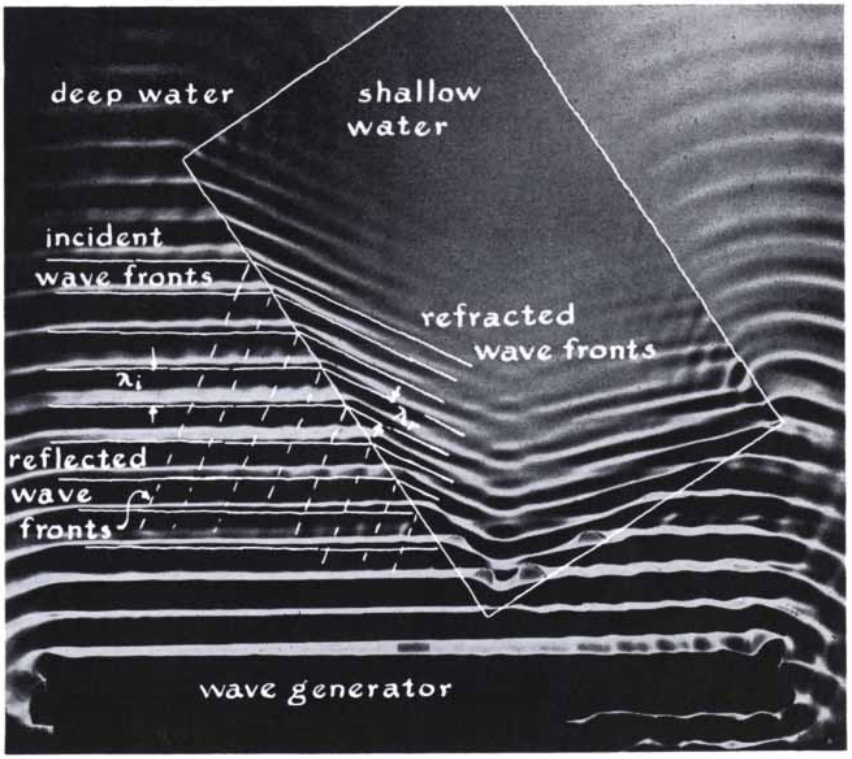
Waves from two or more sources travel through a uniform medium independently of one another, although the wave energy at any point in the medium is at each instant the algebraic sum of all waves impinging on that point. Where the crests of waves from two sources coincide, the amplitudes add, and where the crest of one wave coincides with the trough of another of equal amplitude they cancel. The effect is called wave interference. Two reflecting surfaces can be spaced in such a way that light waves of all colors except one cancel. Such optical interference accounts for the rainbow hues of soap bubbles, which change with variations in the thickness of the soap film.

Interference effects can be demon-

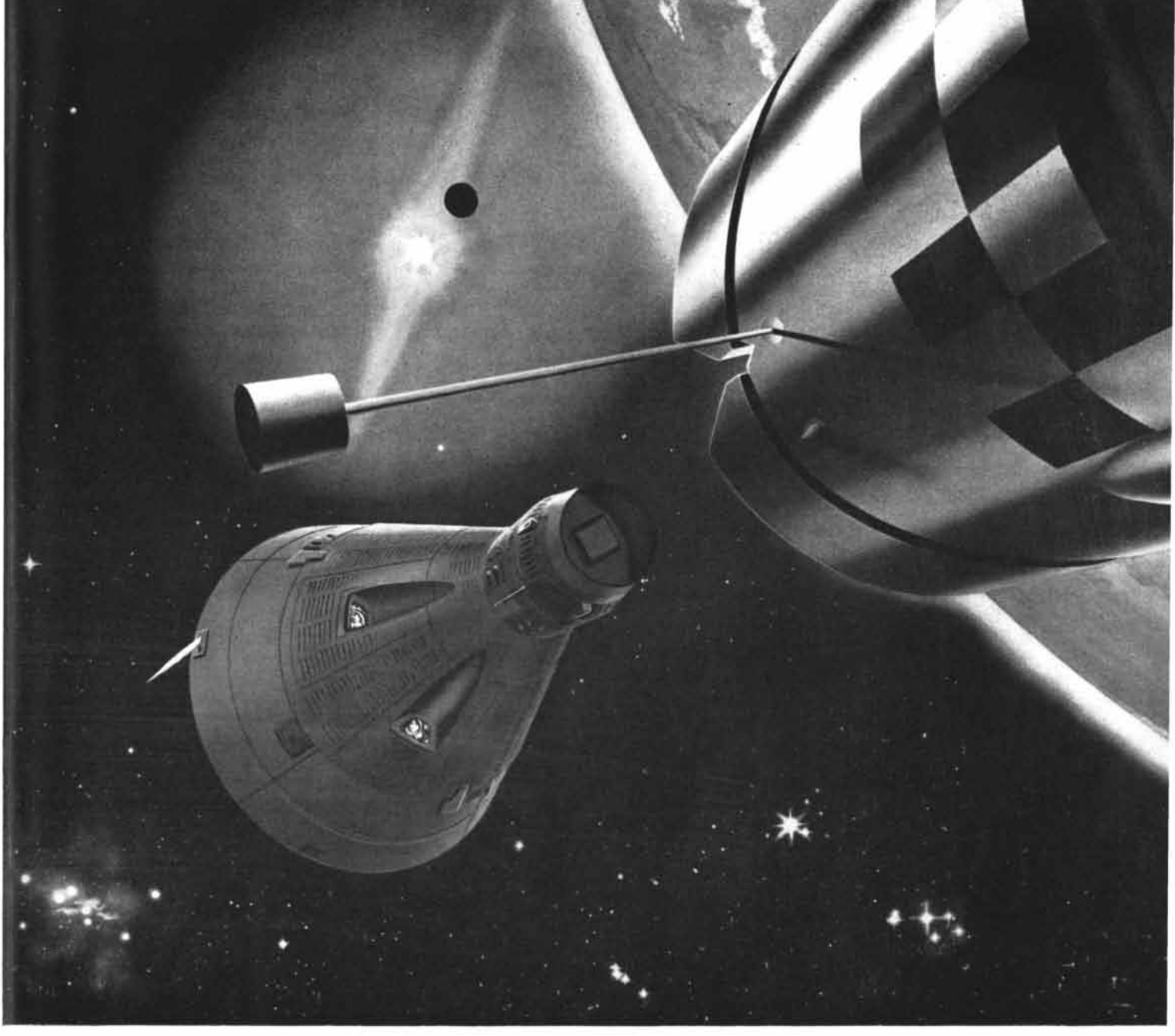
strated in the ripple tank by adjusting a pair of beads so that they make contact with the water about two inches apart. A typical interference pattern made by two beads vibrating in step with each other is shown in the lower illustration on page 150. Observe that maximum amplitude occurs along paths where the wave crests coincide and that nodes appear along paths where crests coincide with troughs. The angles at which maxima and nodes occur can be calculated easily. The trigonometric sine of the angles for maxima, for exam-



Wave reflection



Wave refraction



RENDEZVOUS CONTROL: *By Astronaut*

Primary control responsibilities during Gemini rendezvous and docking operations will be assigned to the Astronauts. Man, with his ability to see, analyze, reason and judge, will be fully utilized for this important phase of America's first spacecraft rendezvous operation.

Gemini is a two man, extended mission, orbital rendezvous and docking spacecraft now being designed and built for the National Aeronautics and Space Administration by McDonnell.

Rendezvous in space can have several applications in speeding America's space exploration efforts. Rendezvous will permit launching of multiple payloads with two or more smaller boosters rather than one large vehicle. With such techniques it will be possible to assemble large space stations, ferry space crews and supplies, refuel and/or assemble chemical upper stages for deep space missions, and refuel re-usable nuclear upper stages for deeper space explorations.

Space Rendezvous, the key to a quickened pace in manned space exploration, is another facet of manned space flight being pioneered by McDonnell.

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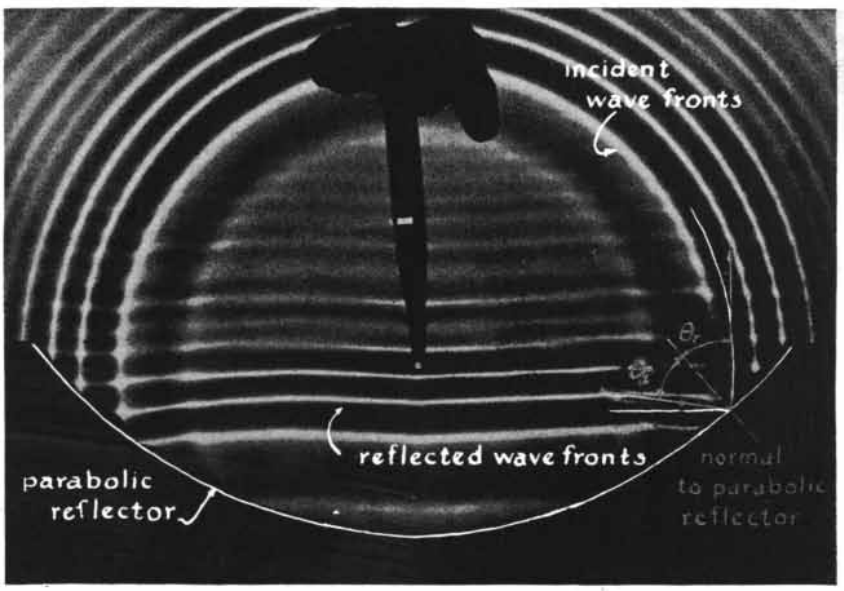
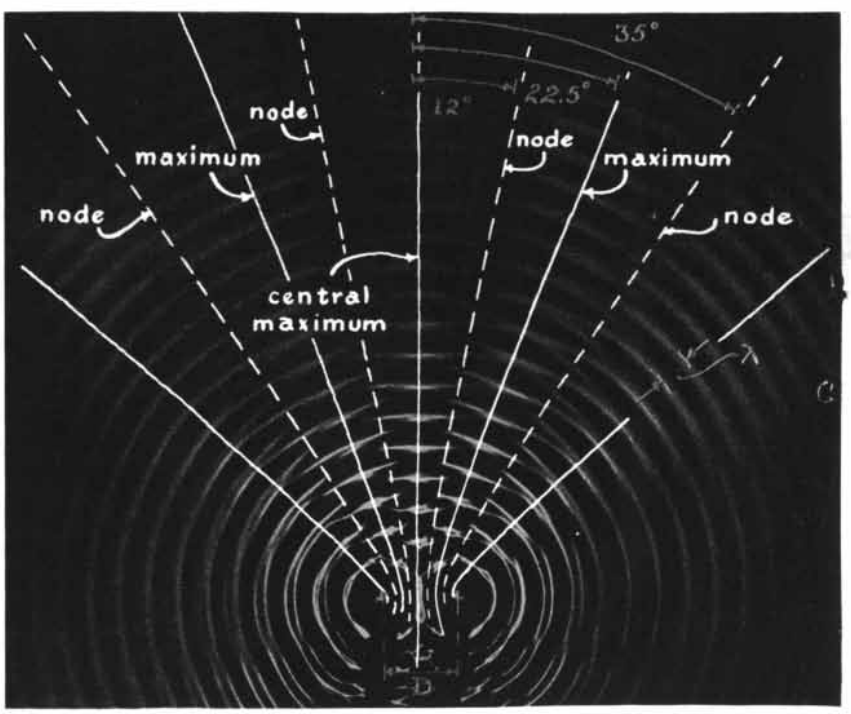
ple, is equal to $n\lambda/d$, where n is the order of the maximum (the central maximum, extending as a perpendicular to the line joining the source, is the "zeroth" order, and the curving maxima extending radially on each side are numbered "first," "second," "third" and so on consecutively), λ is the wavelength in inches and d is the distance between sources in inches. Similarly, minima lie along angular paths given by the equation $\sin\theta = (m - \frac{1}{2})\ \lambda/d$, where m is the order of the minima and the other terms are as previously defined. In the illustration the ratio λ/d was approximately .39. Wave interference finds application in the determination of standards of length by means of such instruments as the interferometer, in receiving antennas that favor television signals from a desired direction and in many other fields.

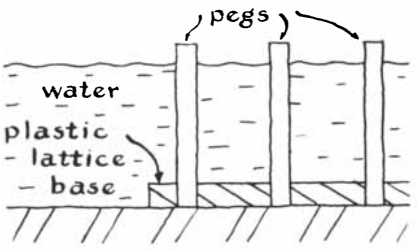
Barriers need not be solid to reflect waves. A two-dimensional lattice of uniformly spaced pegs arranged as in the illustration on the opposite page will re-



Reflection from a parabolic barrier



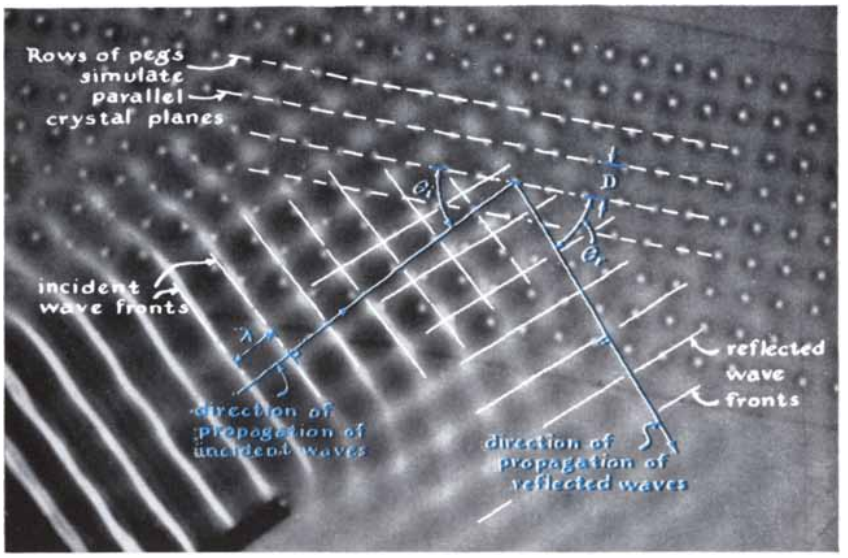
Wave interference



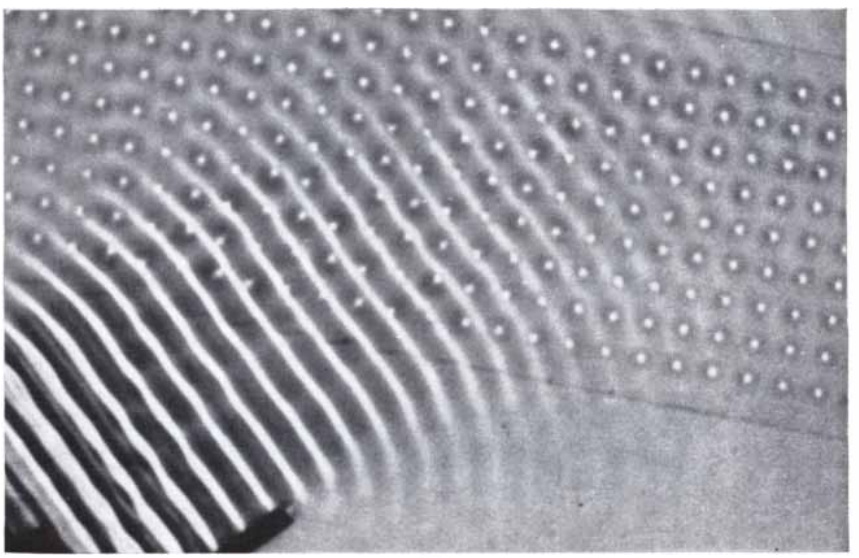
Cross section of peg lattice

flect waves in the ripple tank that bear a required geometrical relation to the lattice. When a train of plane waves impinges obliquely against the lattice, circular waves are scattered by each peg and interfere to produce a coherent train of plane waves. The maximum amplitude of this train makes an angle with respect to the rows making up the lattice such that $\sin \theta \ max = n\lambda/2d$, where $\sin \theta \ max$ designates the direction of maximum wave amplitude, n the order, λ the wavelength and d the spacing between adjacent rows of pegs (the lattice spacing). This equation, known as Bragg's law in honor of its British discoverers, the father-and-son team of Sir William Bragg and Sir Lawrence Bragg, has been widely applied in computing the lattice structure of crystal solids from photographs of wave maxima made by the reflection of X-ray waves from crystals. X-ray waves are reflected from the three-dimensional lattice of atoms constituting crystals in the same way and for the same reason that water waves reflect from the two-dimensional array of brass pegs in the ripple tank. The phenomenon is seen in the series of three illustrations on the next page. In the top illustration, which shows strong reflection, the ratio of λ/d is 1.36 and $n = 1$. After this picture was made the ripple generator was speeded up to launch waves of shorter length. The middle illustration was then made at the λ/d ratio of .96. Substantially no reflection was recorded. The wavelength was then made still shorter for a λ/d ratio of .74, and relatively strong reflection was recorded in the second order, as seen in the bottom illustration.

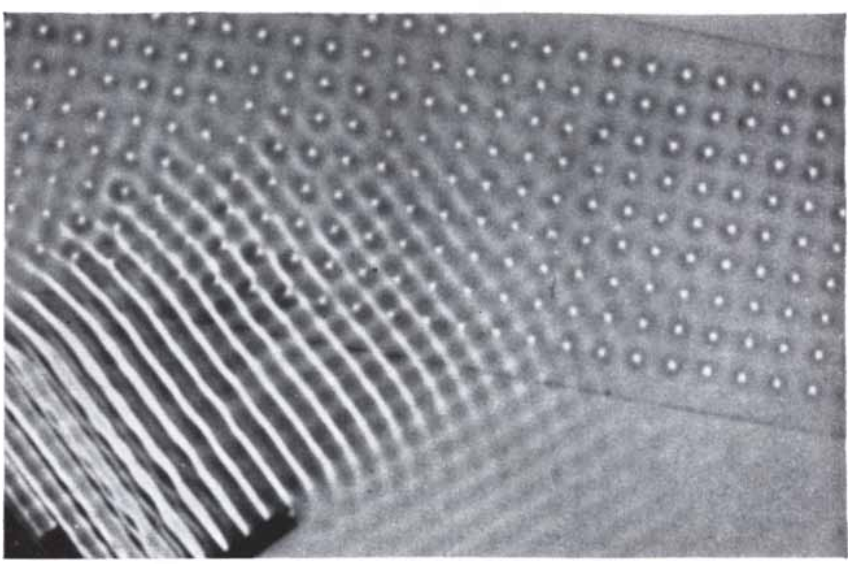
Another of the many aspects of wave behavior that can be investigated with the ripple tank is the Doppler effect, first studied intensively by the Austrian physicist Christian Johann Doppler. He recognized the similarity in wave behavior that explains the apparent increase in pitch of an onrushing train whistle and the slight shift toward the blue end of the spectrum in the color of a star speeding toward the earth.



Bragg reflection in first order



Wavelength adjusted to cancel Bragg reflection



Wavelength adjusted for Bragg reflection in second order

Both effects are observed because it is possible for moving wave sources to overtake and in some cases to outrun their own wave disturbances. To demonstrate the Doppler effect in the ripple tank, substitute for the agitator bar a small tube that directs evenly timed puffs of air from a solenoid-actuated bellows against the surface of the water while simultaneously moving across the tank at a controlled and uniform speed. (A few lengths of track from a toy train can be mounted along the edge of the tank and a puffer can be improvised on a toy car.)

When the puffer moves across the tank at a speed slower than that of the waves, crests in front of the puffer crowd closely together, whereas those behind spread apart, as shown in the upper illustration on page 154. If the puffer is imagined to be the whistle of an approaching train, an observer stationed at point *A* in the photograph would hear more sound waves per second than an observer at *B* and consequently would hear a higher pitch. Similarly, an earthbound observer at *A* would describe the color of an approaching star (represented by the puffer) as containing more blue than would an observer at *B* simultaneously looking at the receding star. The Doppler effect is observed in waves of all kinds, including radio signals. By means of relatively simple apparatus the effect can be applied to determine the direction and velocity of an artificial satellite from its radio signals [see "The Amateur Scientist," SCIENTIFIC AMERICAN, January, 1958].

In the first Doppler-effect illustration the puffer was moving about a third as fast as the ripples. When the speed of the puffer across the tank exceeds that of the ripples, shock waves appear, as shown in the lower illustration on page 154. During this experiment the source was moving across the stationary medium at a speed about 1.6 times the wave speed, or at Mach 1.6. The source is clearly outdistancing its own waves, just as a speedboat outdistances its bow waves. If the medium were air and the puffer a supersonic aircraft, an observer at point *A* would be outside the "Mach cone" and would hear nothing. An observer at point *B*, however, would hear a violent shock wave and one at *C* would hear a continuous rumble.

These experiments merely suggest the many wave phenomena that can be demonstrated by the ripple tank. The apparatus is not capable of duplicating all forms of wave behavior by analogy because water waves arise from the

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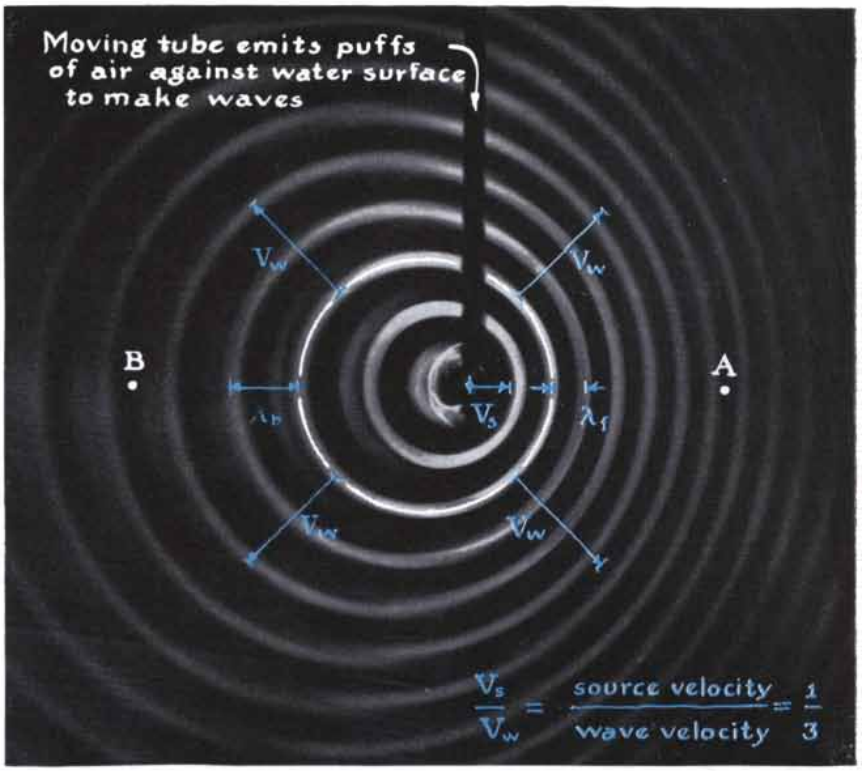
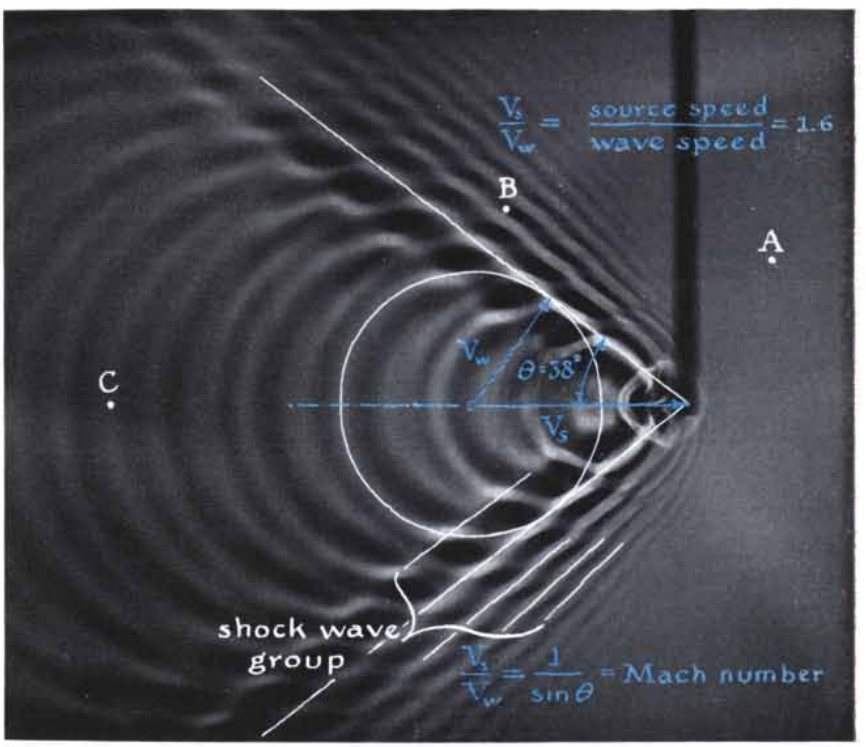
elliptical motion of water molecules; sound waves, on the other hand, are propagated by molecules of gas oscillating in the direction of the advancing wave front, and electromagnetic waves are propagated by transverse changes in the strength of electric and magnetic fields, somewhat as a kink travels on a stretched clothesline when one end is snapped sideways. Nevertheless, anyone who builds and operates a ripple tank will find it appropriate for enough fascinating experiments to occupy many rainy afternoons.



Doppler effect at Mach .3



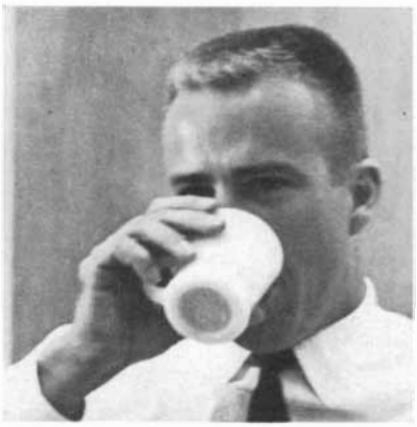
Doppler effect at Mach 1.6

We've got 1980 on the drawing boards.

Solar probes. Landings on Mars. Round trip trajectories. That's my field. Working on trajectories of future spacecraft with advanced propulsion systems. Ion propulsion, for example.

The normal chemical rocket has a high initial thrust. Everything happens all at once, when it leaves the Earth. Then it coasts the rest of the way with a small maneuver to trim things up.

Advanced propulsion-type trajectories are more efficient but have low thrust, which causes the rocket to operate over most of the trajectory. A typical mission, for example, is one where the spacecraft approaches its destination target with the same velocity as the target.



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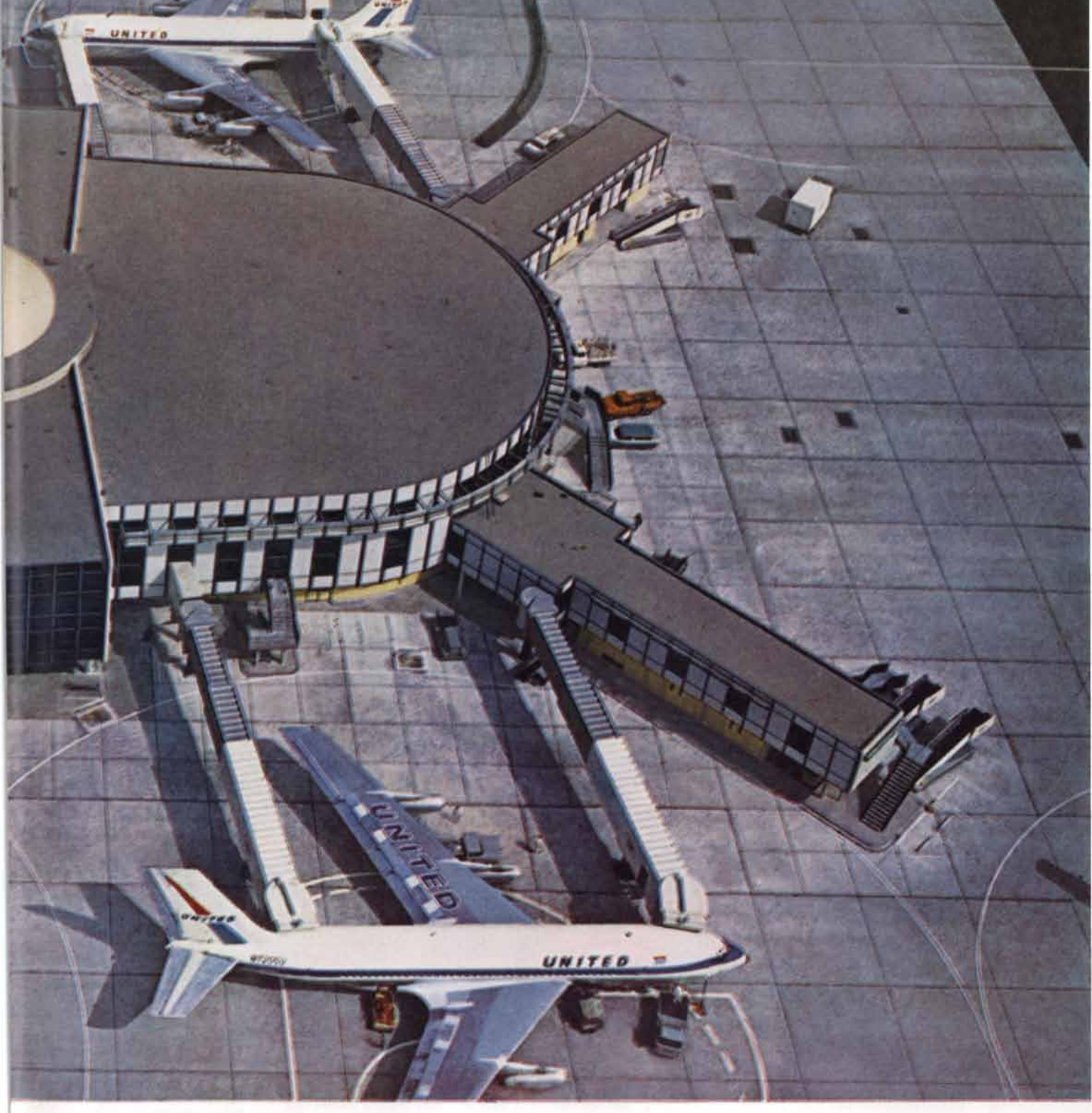

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BOOKS

A survey of mental health in New York raises important issues of methodology

by Ernest M. Gruenberg

MENTAL HEALTH IN THE METROPOLIS: THE MIDTOWN MANHATTAN STUDY, VOL. I, by Leo Srole, Thomas S. Langner, Stanley T. Michael, Marvin K. Opler and Thomas A. C. Rennie. The Blakiston Division, McGraw-Hill Book Company, Inc. ($9.95).

The sciences that study human beings are rapidly becoming more quantitative. In keeping with this development the various branches of public health have become more and more dependent on statistical surveys, particularly those concerned with the rates at which different types of illness occur in the population. Counting cases of illness is a complex procedure: it requires both clinical knowledge and the use of a wide variety of statistical techniques and of supplementary data on the size and characteristics of the population being studied.

One of the main sources of raw data on the frequency of a disease is the morbidity survey, a comparatively new fact-gathering device. A morbidity survey counts each member of a defined population, distinguishing each according to whether or not he has a specified disease. This count, if it is reasonably accurate and reasonably well designed, gives the frequency of the morbid condition in the enumerated population. The defined population can be regarded as being made up of several subpopulations—for example, of men and women, old and young, rich and poor. By comparing the frequency of the condition in each subpopulation one can ascertain whether it is more common among men or women, young or old, rich or poor. The morbidity survey is the most direct way to find out if a specified illness is more common at any moment in time (that is, more prevalent) in one part of the population than in another.

Studies of mental disorders are among the most common types of morbidity survey. At least two dozen such studies have been conducted, and the most recently reported, the occasion for this review, is in some ways the most sophisticated and in other ways the most cumbersome and awkward of the lot.

This book is the first of three projected volumes resulting from a morbidity survey of "Midtown," a residential section of Manhattan. The survey was initiated by Thomas A. C. Rennie, who was professor of social psychiatry at the Cornell University Medical School until his death in 1956. During the first years of the National Mental Health Act and the National Institute of Mental Health there was a rapid increase in interest in the community aspects of mental disorders, with the result that in the early 1950's a number of morbidity surveys were begun in the U.S. and Canada; Rennie was one of the leaders in this development. Like Alexander H. Leighton, who supervised the completion of this work after Rennie's death, Rennie was a product of Adolph Meyer's department of psychiatry at the Johns Hopkins School of Medicine. The first volume combines a partial report on the morbidity survey procedure used, the findings of the survey and the interpretation of those findings with a semipopular exposition of the methods developed and employed by the team.

The Midtown study found that four out of five people in the survey area had symptoms of psychiatric disorders—a startling figure to those who think such symptoms are very rare. It also found that the prevalence of subjects with symptoms was commoner among people who came from poorer homes. The validity of the findings depends on the validity of the techniques used. The efforts at popularization are less important than the survey findings, because, as I hope will emerge, the authors of the book have not been entirely successful in their own efforts to master the methodology they seek to explain to others.

In theory the morbidity survey is fairly simple. The objective is to count the frequency of a condition (some sort of illness) in the general population. A sample of the population is selected, each member of the population is screened by some method to see if the condition is present, the number of people with the condition is divided by the number of people put through the screen; in this manner the proportion of people with the condition is measured. When this scheme is applied to a malarial population (one way is simply to find out by feeling bellies how many people have enlarged spleens), it is a practical device for appraising the size of the problem, determining what part of the population has the most malaria (which provides clues to sources of exposure) and estimating the success of eradication programs. When the procedure is applied to a search for mental disorders, great attention must be paid to just what is counted and to the exact relevance of counted facts to mental disorders. When it is applied to a heterogeneous and migrating population such as that of the U.S., caution is required in selecting the population. When the population is divided into subpopulations and inferences are to be drawn regarding causes, scrupulous care must be taken to avoid bias.

The area selected for study by the investigators of the Midtown Manhattan Study had a population of some 110,000. Using a map of the area, the investigators sampled at random certain blocks, certain dwellings in those blocks and certain occupants of those dwellings. The process yielded a final sample of 1,911 people. These people were from 20 to 59 years of age and met certain requirements regarding residence. Of the 1,911 people selected, 1,660 answered a rather long questionnaire that elicited biographical details and information about any symptoms of mental illness, past and present. That no more than 251 (13.1 per cent) failed to respond to the questionnaire is proof of a conscientious and competent field job.

Having selected his population, the investigator must decide just what he

will count. Morbidity surveys have generally undertaken to classify the type of disorder present. Since World War II, however, psychiatry has again entered a period of uncertainty regarding the meaning of diagnostic classifications, while at the same time interest has been growing in the fluctuations and variations in both the intensity with which psychiatric disorders occur and the amount of disability experienced by patients. Indeed, there has been a tendency to think of mental disorders as being unitary, with the various diagnostic groups being merely superficially different manifestations of the same underlying defect in mental functioning. This unitary viewpoint is held by some well-known psychiatrists, but I believe it is a kind of primitivism that obscures the heterogeneity of mental disorders, inhibits sharp, specific thinking and avoids issues that can be tested empirically.

It is possible, however, to examine data produced by lumping together a large number of disorders without committing oneself to the notion that all subjects are sick for exactly the same reason. We do this in the case of physical illnesses when we look at national death rates or disability rates without attention to specific causes. It is useful, for example, to know that the U.S. does not have the lowest infant mortality rate in the world, even though we would want to know more details before deciding what can be done about it.

Hence the decision made in the Midtown study to look for people with the various symptoms of interest to psychiatrists makes some sense. Psychiatrists ordinarily know what symptoms they think are important in the instances of mental disorders they observe. Looking only for symptoms without worrying about diagnosis is an innovation introduced into mental morbidity surveys more or less simultaneously by this study, by Leighton and by me (in a survey of elderly people in Syracuse, N.Y.). The innovation makes certain types of survey easier to carry out but does not necessarily add to the value of the data.

The prevalence of symptoms can be studied from several points of view. One approach might be to recognize that certain characteristics common in sick individuals may also be prevalent in people who are not sick. Criminality, for instance, has been observed in some people with psychotic conditions, but field studies have shown that it is even more common in individuals without psychotic conditions. (In the Midtown report the possibility that some of the symptoms enumerated occur in the absence of mental disorder is not considered.) Moreover, the notion that certain physical illnesses are *ipso facto* evidence of psychosomatic conditions is very questionable. One might therefore try to determine to what extent certain "symptoms" are indeed symptoms of an illness. A second approach would be to assume that certain symptoms can be better understood if they are studied in all sorts of people without reference to the diseases present; this consideration would justify studies of suicide, alcoholism or insomnia, to give a few examples. Finally, one can simply take the presence of certain symptoms as a crude index of the presence of disorder. The Midtown study adopted this viewpoint; it counted the number of people classified as having a specified severity of symptoms and a specified level of impairment in social functioning.

Case-finding in morbidity surveys almost always involves a review of clinical records of the medical facilities that service the population. Fredrick C. Redlich and A. B. Hollingshead's work *Social Class and Mental Illness* was based entirely on clinical records of patients in psychiatric treatment. In their survey of Baltimore's Eastern Health District, Paul V. Lemkau and his colleagues searched social agency records and added independent appraisals of the significance of these records to the clinical records. Other steps can be taken to deepen the survey. The U.S. census of 1880 actually tried to count all the helpless people in the U.S., including the mentally ill and the mentally defective, by asking teachers, doctors and lawyers for nominees to the category. Some surveys used such nominations as the first screen and then went on to examine the nominees more intensively through direct contact. This method of case-finding has the appeal of a relatively inexpensive first stage (collecting nominations) and a relatively intense second stage. Investigators

SEVERITY OF SYMPTOMS	DIFFICULTY IN FUNCTIONING	"CONTINGENCY VALUE"	FINAL CATEGORY	DISTRIBUTION (PER CENT)	
NONE	NONE	4.3	WELL	18.5	
MILD	NONE	1.6	MILD SYMPTOM FORMATION	36.3	
MODERATE	NONE	1.8	MODERATE SYMPTOM FORMATION	21.8	
MODERATE	SOME	1.8	MARKED SYMPTOM FORMATION	13.2	IMPAIRED
SERIOUS	SOME	3.9	SEVERE SYMPTOM FORMATION	7.5	IMPAIRED
SERIOUS	GREAT	9.5	INCAPACITATED	2.7	IMPAIRED
SERIOUS	INCAPACITATED	45.0	INCAPACITATED	2.7	IMPAIRED

RATING PROCEDURE used in the Midtown study is illustrated by this table. Psychiatrists graded each subject on the scale in the two columns at left. The center column shows how well the clinicians agreed at each level. The two columns at the right give the distribution of the Midtown population among the six final mental health categories used.

MENTAL HEALTH CATEGORIES	AGE GROUPS			
	20–29	30–39	40–49	50–59
WELL	23.6	16.8	19.3	15.0
MILD SYMPTOM FORMATION	37.5	37.6	37.0	33.1
MODERATE SYMPTOM FORMATION	23.6	22.4	20.5	21.1
IMPAIRED	15.3	23.2	23.2	30.8
MARKED SYMPTOM FORMATION	(9.6)	(14.7)	(11.6)	(16.4)
SEVERE SYMPTOM FORMATION	(4.1)	(7.5)	(7.7)	(10.5)
INCAPACITATED	(1.6)	(1.0)	(3.9)	(3.9)
N=100 PER CENT	365	388	467	440

MENTAL HEALTH varied with age as shown in this table adapted from the Midtown report, which shows what per cent of each age group fell within each of the categories.

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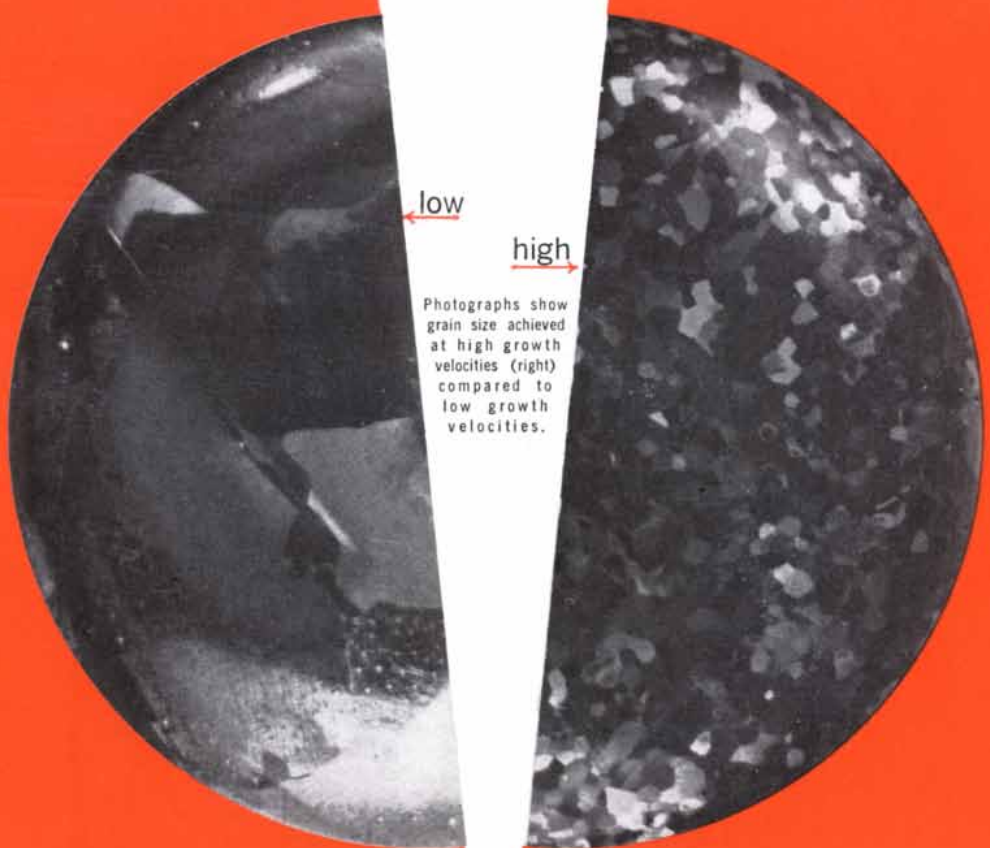

Photographs show grain size achieved at high growth velocities (right) compared to low growth velocities.

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end up with a discriminating set of conclusions about those identified as being sick. Among those who have used the method with success are Erik Strömgren, C. Burgger, Tsung-Yi Lin, Jan Böök and a number of others who have made psychiatric surveys. Two major disadvantages, however, attend the method. First, it is appropriate only in closely knit communities, where it is reasonable to expect every sick person to be known to at least one key informant and where the number of key informants is limited. It is manifestly inappropriate in a metropolitan complex; in Midtown, for example, the sample of 1,911 people might have called for interviews with several thousand key informants if one had set out to contact their physicians, pastors, schoolteachers and so on. The second disadvantage of the key-informant screen is that it does not require an explicit, equally intense scrutiny of each member of the population. The key informants review only the members with whom they are acquainted, and they are likely to give information only about those they know sufficiently well to describe as being possibly sick.

The obvious way to circumvent these disadvantages is to skip the nominating process and go directly to the whole sample population. This course has in fact been followed in at least two morbidity surveys in small communities in Sweden and Norway. A good example was a survey by Johannes Bremer, who was assigned as a young government physician to a small fishing village in northern Norway and who was obliged to extend his tour of duty by the German occupation. He helped to while away the years by conducting a morbidity survey of the entire village, every member of which he knew personally as well as professionally.

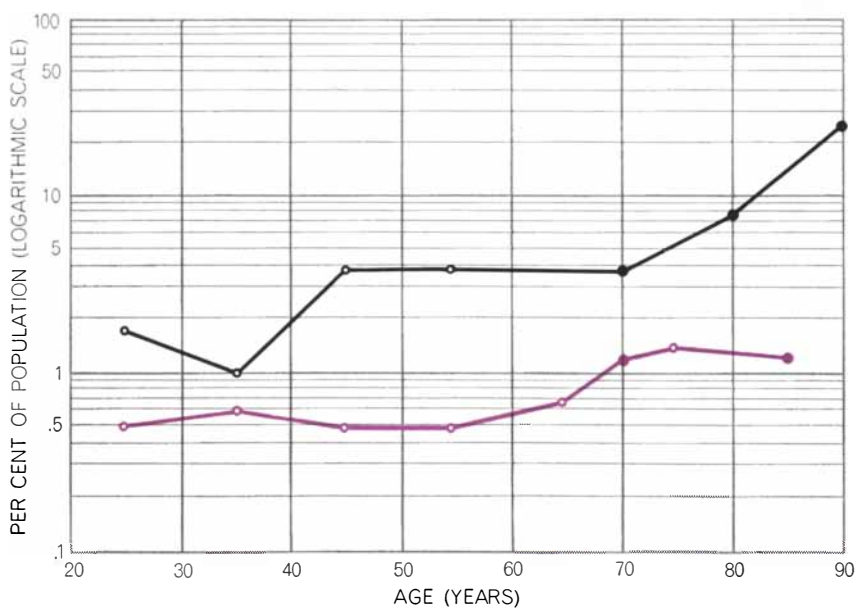
No such exploration in depth was open to the investigators of the Midtown study. Instead they worked with the specially created interview questionnaire that had been administered to the 1,660 respondents by highly trained nonmedical professionals. The questionnaire was structured and included questions regarding specific symptoms and attitude questions believed to be of clinical significance. The data from these interviews were then systematically reviewed by two psychiatric clinicians, who separately rated the respondents on the basis of the data, ranked each as to symptom severity and social impairment and ultimately placed each in one of six categories, as shown in the upper illustration on page 160.

This procedure of case-finding and identification involves problems of variability among interviewers and between the two raters as well as the validity of the ratings themselves. Interviewer variability can be estimated by two methods: a subsample can be interviewed repeatedly or each interviewer can be assigned a random subsample of the whole population and the distribution of findings derived from different interviewers or groups of interviewers can then be compared. The Midtown survey assigned interviewers in accordance with their presumed identification with particular groups in an effort to increase their rapport with different classes of respondents, and thereby it sacrificed an opportunity to estimate interviewer variability by the second method noted above. Nor was a subsample reinterviewed, but reinterviewing had been contemplated, and the report expresses the hope that knowledge of this plan acted as a damper on interviewer bias.

Rater variability is dealt with in the Midtown report both by the social scientists who analyzed the data (Srole and Langner) and by the psychiatrists who developed the rating methods and did the rating (Price Kirkpatrick and Michael). The variability is presented in terms of correlation coefficients and "contingency" probabilities for each rating. The upper illustration on page 160 gives the contingency values for each category—that is, the number of "times more often than would be predictable by pure chance" the two psychiatrists agreed on a rating.

The illustration makes it clear that the psychiatrists were in close agreement in rating people as being well or severely impaired. But they were much less consistent in discriminating among the middle three categories. Yet it was in precisely this area of the ratings that a major dividing line was established: Srole and Langner's analysis, without making any reference to the data on rater reliability, uses a cutting point for analysis between "moderate" and "marked" symptom formation. Those placed in the "marked" or "severe" symptom or "incapacitated" groups were lumped together as "impaired," and the bulk of the published data relates to "per cent impaired." In spite of these shortcomings the Midtown publication reflects a considerable advance in methods in that the available information on rater variability is at least presented.

The distribution obtained from the home interviewing and rating of 1,660 persons is shown at the right in the upper illustration on page 160. Does it adequately reflect the situation in Midtown? The definition of the population to be sampled excluded those living away in institutions. This was a disadvantage. It meant excluding not only people in mental hospitals—a treatment census was taken for the whole Midtown population but not for the surveyed sample—but also those in chronic-disease hospitals, in nursing homes, in prisons, in military service and at colleges away from home. This is a common practice in



MIDTOWN AND SYRACUSE findings on age distribution are graphed together. The black curve combines data for the "incapacitated" group in Midtown and people classed as "certifiable" in Syracuse. The colored curve is for patients in mental hospitals. In both curves the Midtown data are plotted as open circles and the solid circles are for Syracuse.

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both morbidity surveys and sociological surveys. The Bureau of the Census moves in the same direction. I believe these practices need to be re-examined, particularly with respect to mental morbidity surveys. In considering various rules for sampling defined populations it might be useful to ask this question: if every possible population were studied by this definition and this rule, would every person in existence be included in one or another of the populations? That is, if Midtown's rules for residence were applied to every geographic area in the country, would everyone in the country be included in one area (and in only one)? I am of the opinion that certain transients would not show up anywhere. Long-term prisoners and long-term hospital patients, for instance, would probably be left out. This means that our population-sampling devices need further refinement in this direction. (An extreme example is the National Health Survey, which ignores *all* people not living in a familial household.)

We may consider now the findings of the Midtown study as regards distribution in subpopulations. Morbidity and mortality data are conventionally first presented by age and sex. This is a standard way of dividing the population and has merit even though there is no particular logic in selecting these two dimensions. In the Midtown study the prevalence of "impaired" conditions rises with age, as shown in the lower illustration on page 160.

As I said earlier, I place most credence in the numbers rated as being severe and incapacitated, because here the psychiatrists exhibited a respectable amount of reliability. "Incapacitated" is a criterion meant to be comparable to morbidity intensities found in hospitalized people. The treatment census provided data on patients in mental hospitals. Both of these categories were also reported in the Syracuse survey, and it is interesting to graph the two sets of data together, as I have done in the illustration on page 162. These two curves show a marked rise with age in the prevalence of extremely sick people in two U.S. populations. This appears to be a reliable finding supported by data found elsewhere in similar morbidity surveys, and its importance cannot be overemphasized. Neither the Midtown nor the Syracuse study shows a significant variation between the sexes in these rates, but in certain other respects the sexes did vary in Syracuse, and I venture to predict that subsequent volumes of the Midtown data will likewise report some variations by sex.

Morbidity distribution by socioeconomic group, the next of the Midtown findings to be considered, was based on Srole's interpretation of each respondent's reply to these questions: "When you were about 18 to 19 years old, what kind of work was your father doing for a living?"; "At that time did he work for himself or others?"; and "About how many people did he have working for (under) him?" Replies to these questions were coded into a 27-category occupation code and were then collapsed into three blue-collar levels (skilled, semiskilled and unskilled) and three white-collar grades (high, middle and low). The categories were made approximately equal in size, although there is no justification for assuming that there are in fact any such equal-sized occupational levels. When mental health categories were distributed according to these socioeconomic strata, the results were as shown in the illustration below.

Earlier morbidity surveys of untreated populations have not made classifications of this kind by parental occupational status. The Midtown data are fresh and of considerable significance, although it should be noted that the variability in prevalence of cases does not show up between each step. There actually appear to be three grades rather than six, and the lowest white-collar occupational group is not very different from the highest blue-collar group in spite of the change in shirt color.

Again, in spite of the value of these findings, they are subject to criticism. My major complaint has to do with lack of age standardization. Health statisticians long ago found that many conditions occur more frequently at one age than at another—and the Midtown statistics quoted earlier bear this out. When one wishes to compare the rates at which such a condition occurs in two different populations, it is necessary to see if a difference in age composition of the two populations accounts for the observations. There are accepted methods for doing this. But the present study gives detailed information about the crude findings without providing the important necessary information about age-standardized rates. (For the arithmetically minded it might be worth pointing out that age standardization is a simple procedure that uses the principle of weighted averages. The actual proportions of people of each age group in the populations studied are viewed as an arbitrary weighting of the over-all rates. If the two populations have different age distributions, the resulting rates for the two populations have been produced by different weightings. Age standardization simply provides a technique of weighting that gives the effect of each age group the same weighting in both populations. Age-specific rates would be better still, but they are not subject to separate analysis unless much larger numbers are available than were present in this survey.)

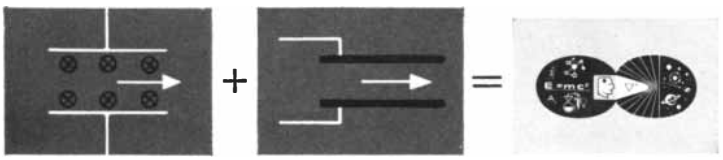
The data should all have been standardized for the ages of the population, but they were not. Instead Srole and Langner emphasize that the "well" per cent declines with lower parental socioeconomic status (SES) and the "impaired" per cent rises. The investigators then go on to invent an easier-to-handle index by dividing the number "impaired" by the number "well" in each group, which they call a "sick-well ratio." This shorthand ratio is, to be sure, then compared for each age group separately, and at each age it is higher for SES groups E + F than for SES A + B, with C + D at a more or less intermediate level. But this is an inadequate way to publish the material; the authors should be urged to publish separately and in greater detail a more conventional presentation of their findings.

The authors also assert that sex plays no part in these distributions, but they

MENTAL HEALTH CATEGORIES	PARENTAL-SES STRATA					
	A	B	C	D	E	F
WELL	24.4	23.3	19.9	18.8	13.6	9.7
MILD SYMPTOM FORMATION	36.0	38.3	36.6	36.6	36.6	32.7
MODERATE SYMPTOM FORMATION	22.1	22.0	22.6	20.1	20.4	24.9
IMPAIRED	17.5	16.4	20.9	24.5	29.4	32.7
MARKED SYMPTOM FORMATION	(11.8)	(8.6)	(11.8)	(13.3)	(16.2)	(18.0)
SEVERE SYMPTOM FORMATION	(3.8)	(4.5)	(8.1)	(8.3)	(10.2)	(10.1)
INCAPACITATED	(1.9)	(3.3)	(1.0)	(2.9)	(3.0)	(4.6)
N = 100 PER CENT	262	245	287	384	265	217

SOCIOECONOMIC STATUS groups varied in mental health, the Midtown survey found. This table from the book gives the distribution among symptom groups according to SES.

Physics Research at ALLISON



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THERMIONIC RESEARCH PHYSICISTS—Ph.D. with established reputation in field of thermionic energy conversion, or thermionic emission. As group leader, he must provide technical leadership in all areas related to development of practical thermionic converters (nuclear, solar, and chemical heat sources).

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give no data to support this statement. In view of their general failure to handle age in a satisfactory manner and the fact that the sexes can be expected to be affected differently by parental SES, I shall not be satisfied with their assertion without supporting data. In the Syracuse survey of older people the two sexes showed very different patterns of morbidity rates when contrasted with socioeconomic group.

Another point worthy of attention relates to distribution differences by generation groups. When the authors compare respondents born outside the U.S. with native Americans whose parents were born outside the U.S., they find no differences in the frequency of the "impaired" category. In this tabulation appropriate sex and age-standardization techniques were followed. But no such standardized data are given regarding the more reliable "severe" and "incapacitated" categories (although these data are given for the unstandardized populations, adding to the proliferation of useless figures at the expense of relevant data).

The investigators expected immigrants to have a higher prevalence of "impaired" states. Because the findings did not confirm their assumptions they looked more closely at their data and decided that immigrants of a new kind were present: people who move from urban setting to urban setting rather than from peasantry to urban setting. When they broke down their foreign-born group into these two parts and standardized for age, they found the expected differences in the "impaired" per cent between peasant immigrants and native-born respondents.

Any survey that seeks to interpret variations in the prevalence of morbidity among subsections of a surveyed population involves a number of difficulties. Let us examine some of these and see how well they have been surmounted in the Midtown study.

Each apparent observation of a variation in prevalence requires a separate search for possible bias respecting that variation in case-finding or case-identifying procedures. Since no survey can reach 100 per cent efficiency in case-finding and therefore a certain part of the defined population always remains unscreened, each type of variation in the findings requires its own examination of the "unknowns"—that is, people included in the sample but not screened in the search for cases. The present investigators went to some length to look for bias regarding socioeconomic status in the raters and handled this in an ingenious manner. They have not been so successful regarding age and sex, and they acknowledge this fact. Perhaps the Syracuse survey of older people did better on age (which was a datum withheld from the raters, just as SES information was in the Midtown study), but it too did not have a good way of looking for bias with respect to sex.

I believe the Midtown investigators may have allowed bias to creep into their analysis of SES differences: in accordance with their decision not to count transients they specifically excluded hotels and clubs. But lower SES transients do not live in hotels or clubs to the extent that wealthier people do; as a result some low-SES transients may have been counted, and there is ample evidence that transient populations are high in prevalence of mental disorders. This is the sort of error that can vitiate findings, although my guess is that more caution in dealing with this particular source of bias would not have eliminated the findings regarding the effects of age and socioeconomic background.

Having found that the prevalence of mental morbidity varies in a certain way —that it rises with age, for example— one has then to look for a possible mechanism by which such a change in prevalence could be produced. If, as the discussions in this first Midtown volume frequently imply, a mental disorder once present in an individual always remains, prevalence of such a disorder will inevitably rise with age (unless it is associated with an excessive mortality rate or an excessive net emigration rate of sick people).

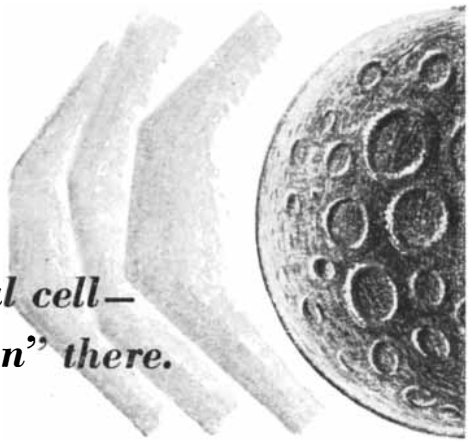
As some of the data reported here and much other evidence make abundantly clear, however, mental disorders do terminate. (In fact, Michael refers to this in one of his discussions.) So the rise in prevalence rates with age must be accounted for by at least one of three factors: (1) more new cases arise with each year of life than terminate (incidence more than terminations); (2) sick people die earlier than other people; (3) the proportion of out-migrants who are sick is less than the proportion of in-migrants who are sick. In practice it is almost impossible to get direct estimates of these possibilities from a single cross-section picture of a population. Several modifications of the usual data-gathering patterns of morbidity surveys make it easier to know about these events. For example, if data are gathered regarding the duration of residence in the studied population, information can be obtained on the prevalence of morbidity among in-migrants. But even this leaves the out-migrants unknown. A follow-up in a year or two makes possible estimates of incidence and terminations and of in-migrants and out-migrants. It is a curious fact that no one ever seems to do this.

The appendix note on "incidence" (the number of new cases arising in a population in unit time) and "prevalence" (the proportion of a population sick at a given time) is poorly conceived. It treats these two measures of morbidity frequency as competitors in a popularity contest; it is as if geographers had debates on whether length or breadth were a better measure of size or hydrodynamicists debated whether rate of flow or duration of flow had a greater effect on the volume moved. Prevalence of a condition in a population is the simple product of incidence and the average duration of the cases.

Confusion on this issue is compounded because the book is not clear as to the time dimension of the initial case-identification procedure. Some items used in the questionnaire seem to refer to the respondent's current functional state, other questions are of the "Have you ever...?" variety and still others refer clearly to childhood without reference to the present. Whether or not the raters made any explicit effort to distinguish present from past symptom patterns is not clear. As a result they end up by measuring something called "lifetime prevalence," which presumably means the proportion of the population studied that has at any time displayed any of the symptoms being counted. This particular measure is one of the new gimmicks that are being introduced these days into a field of mensuration that has enough real troubles without being further burdened by unhelpful tricks. Lifetime prevalence measures are of no visible usefulness. They depend not only on the limited reliability of present case-finding and case-identifying techniques but also on the distant memory of respondents. Even if the questions had been explicit in distinguishing the past from the present (which they were not), the reliability of information regarding past symptoms is even less than that regarding the present. When data regarding past and present are fused, it becomes almost impossible to handle the data in a productive fashion. It is not possible to guess intelligently how many of the observations reported may be due to such factors.

In this situation, moreover, the issues regarding in-migrants and out-migrants become even more complex and urgent. The distinction between present preva-

When it Comes to Colonizing the Moon...



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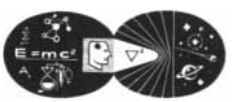

Energy Conversion Is Our Business

lence and recent and past incidence becomes vital. The factors likely to produce illnesses and the factors likely to perpetuate them may or may not be the same, but without separate data no one will ever find out.

Perhaps the basic trouble is that those who have been responsible for completing the analysis and publication of this study since Rennie's unfortunate death following the field work have been tempted to make too much of the data they have. There is really no substitute for the morbidity survey as a technique for measuring the distribution of disease prevalence in different populations. Beyond this, it can portray the distribution of disease prevalence in the population it studies within the limitations of its methods. Sometimes it can even give insight into the factors that determine variations in prevalence, but it should not be expected to go that far. The factors producing variations in disease prevalence must be studied by other methods that include measures of incidence and deal with differential mobility and mortality of the sick and the well.

This book is one of a growing group of studies of mental morbidity in the community. It contains many useful contributions for the specialist along with much speculation and digression. For some reason it has not been presented as a technical monograph but as a hard-cover commercial book offered at a high price to both the specialist and the interested reading public. If any research workers have been tempted to withhold their findings from the technical literature in order to provide meat for a general book, they should read this result and be discouraged from such a course. I believe that the two goals are incompatible in a single publication and that this volume is a good demonstration of the fact.

Short Reviews

UNPUBLISHED SCIENTIFIC PAPERS OF ISAAC NEWTON, chosen, edited and translated by A. Rupert Hall and Marie Boas Hall. Cambridge University Press ($11). In the Cambridge University Library there reposes an immense amount of manuscript material by or relating to Isaac Newton. These manuscripts, known as the Portsmouth Collection after the Earl of Portsmouth, who presented them to the university, deal with every aspect of Newton's extraordinarily wide-ranging labors and interests and include all manner of documents, scribblings and memorabilia as well as letters and copies of letters. Although the correspondence is being collected and published for the first time in full (reviews of the first three volumes of H. W. Turnbull's superb edition of the letters have already appeared in these columns), the other manuscripts have been little explored by scholars, and it is this material that the Halls have undertaken to sample—partly for its intrinsic interest and partly in the hope of encouraging others to extend their effort and erect a suitable monument to Newton in the form of a complete edition of his writings. The Halls admit, to be sure, that it might be futile to print the whole of the Portsmouth Collection because Newton kept so much, because most of his papers have been preserved and because many items are of trivial significance. There are "pages of laborious computation whose purpose is indiscernible, detached sentences noting the opinion of some early Father on a doctrinal question, drafts in four or five different versions of passages in Newton's printed works," advertisements, pamphlets, posthumous papers relating to Newton, papers concerning his family and his work at the Mint, complimentary letters and so on. Nevertheless, there is much material that deserves to be printed, particularly if what is offered here is a fair sample. In his most energetic and creative years Newton apparently allowed no scrap of paper that came to hand to escape before he had covered every blank portion of it with his scribblings. He jotted down anything and everything that occurred to him, sometimes in orderly and coherent fashion, sometimes simply helter-skelter. That he continued this practice even in later life is shown in a manuscript leaf reproduced in this volume. At the top are calculations on motion in a resisting medium, probably relating to the second edition of the *Principia;* in the center is a note on currency in Brandenburg and France; at the bottom is a theological note. Pity the editor confronted with such a mishmash and required to make sense of it; envy him too, of course, for the fascinating byways of his journey and for the unexpected discoveries he may make.

The Halls' selections throw fresh light on Newton's development as a scientist and on his ideas of the world that science explores. The first section, devoted to mathematics, consists of a tract ("To resolve Problems by Motion") that is probably Newton's first attempt at a finished exposition of new mathematical procedures involving his method of

fluxions. Newton th ught of a curve "as the line produced by a point moving with an arbitrary velocity, so that the co-ordinates x and y of the point also change with a corresponding and varying velocity, dependent upon the equation to the curve. Similarly, the algebraic expressions denoting the slope of the tangent to the curve at the point, the area enclosed under it, and so forth, have their appropriate velocities of change. Just as the distance moved in a straight line by a point is calculated as a product of velocities and time, so Newton calculated such algebraic expressions from their velocities of change, themselves derived from the rates of change of the co-ordinates." This approach led to his methods of differentiation and integration. His notation and technique were clumsy and more difficult to handle than Leibniz', but he had forged a new and powerful tool. Although he did not make much use of this tool in writing the *Principia* itself, having resolved in that work to publish his theories and findings in geometrical form, there is evidence that he tackled many problems by fluxional analysis before devising the synthetic geometric proof of the truth of a solution.

The Halls' book includes also a manuscript "On the Gravity and Equilibrium of Fluids," short papers on the laws of motion and the elements of mechanics and a disquisition on the theory of matter. There is a beautifully precise and lucid paper, later in date than the *Principia*, describing "The Mechanical Frame of the World," apparently a more or less popular synopsis of the content of the *Principia*, with some additional observations—not found in that work—on, for instance, the gravitational force exerted by the stars. There are manuscripts related to the *Principia*, among which are early drafts of propositions in mechanics, a partial draft of the preface and a draft of the conclusion, and papers on education and other topics.

The Halls have performed their editorial function in exemplary fashion. The manuscripts are given in the original Latin and in English translations by the editors. Each section has a critical introduction that sets the manuscripts in perspective and discusses their implications. These introductions will be helpful to both the specialist and the general reader not only because they clarify the meaning of the manuscripts but also because they enable one to follow the remarkable development of one of the foremost intellects of all time. Not for a long time has such a distinguished

contribution to the history of science appeared.

LETTERS OF THE LEWIS AND CLARK EXPEDITION, WITH RELATED DOCUMENTS, 1783–1854, edited by Donald Jackson. University of Illinois Press ($10). In this thick, well-made volume are collected 428 letters, memoranda and other documents, more than half of which have never before appeared in print, that touch on all aspects of the memorable expedition. When Lewis and Clark turned their boats against the current of the Missouri and set out "under a jentle brease," they were to become, as Jackson says in his foreword, "the writingest explorers of their time. They wrote constantly and abundantly, afloat and ashore, legibly and illegibly, and always with an urgent sense of purpose." The letters and documents deal with such matters as authorization, preparation, outfitting, finances, Indian policy, foreign reaction and Lewis' violent death, and they include biographical data about other members of the expedition and evaluations by contemporary zoologists, botanists and geologists of the expedition as a scientific reconnaissance. Among other items that help to re-create the setting are an address of welcome by Thomas Jefferson to a party of Osage Indians; a bill from a Philadelphia storekeeper named Robert Barnhill to the War Department for $10 for a pair of pocket pistols with "secret triggers"; a report from the artist Charles Willson Peale on the health of a prairie dog, and a letter from him to Jefferson reporting on some "sadly deseased" Indians who while tasting the high life of Philadelphia in 1807 "had been with the women of bad fame in the lower part of the town and contracted the venerial disease." This is an engrossing volume of history, whose major entries, curiosities and trivia combine wonderfully to shed fresh light on the expedition.

OUR SYNTHETIC ENVIRONMENT, by Lewis Herber. Alfred A. Knopf, Inc. ($4.95). There are any number of ways a man can do himself in but until comparatively recently it was assumed that mankind as a whole would have a hard time committing suicide. The advance of science and technology, however, has considerably improved these opportunities. The large-scale use of atomic weapons is the obvious method, but there are others that, while slower, are no less deadly; in fact, the way may be open for clever men to exterminate not only the entire human population

but also all forms of life on earth. This book gives a better than average journalistic account of what is known today about this distressing subject. Herber discusses, among other things, the hazards to man and wildlife created by agricultural chemicals, the destructive effects on health of overurbanization, the dangerous use of chemicals in food processing, the chemical carcinogens and the effects of radiation and fallout in the nuclear age. The author's thoughtful observations on questions of human ecology make his book more than a catalogue of horrors. The obvious but rather nice moral is that either we will have to learn to live in the world—to respect the right of other creatures to live in it, from earthworms and ferns to robins and human beings, to maintain the purity of our atmosphere and to cultivate rather than plunder our planet—or we will have to pack up and find another world to destroy.

CALCIPHYLAXIS, by Hans Selye. The University of Chicago Press ($25). Selye, director of the Institute of Experimental Medicine and Surgery at the University of Montreal and widely known for his work on the effects of stress on the human organism, here introduces a new biological concept: calciphylaxis. In a long series of experiments in his own laboratory, which are fully described, he demonstrated that tissues can be made particularly sensitive to calcification and that when tissues are in this state, pathological calcification can be induced by stimuli, or "challengers," as "harmless as plucking a few hairs, pinching the skin or administering such a common and seemingly innocuous substance as the white of an egg." Little is known as yet about the biological significance of calciphylaxis, but the phenomenon, Selye states, "appears to be essentially a defense reaction that—as many other homeostatic responses, including serologic immunity and the General Adaptation Syndrome—may become pathogenic under certain circumstances. It remains to be seen to what extent calciphylaxis plays a role in physiology and pathology and whether it can be used for therapy."

INTERNATIONAL BIBLIOGRAPHY OF THE SOCIAL SCIENCES: SOCIOLOGY, POLITICAL SCIENCE, ECONOMICS, ANTHROPOLOGY. Prepared by the International Committee for Social Sciences Documentation. Aldine Publishing Co. ($35). These four volumes are part of the general program of the International Committee for Social Sciences Docu-

mentation, set up in 1950 with the help of UNESCO for the purpose of encouraging the development of all bibliographical and documentary activities relating to the social sciences. The volumes noted cover all scientific publications in the four disciplines published during 1960. The bibliography is presented in bilingual form (English and French) and includes both author and subject indexes and a list of the periodicals consulted, with their official abbreviations.

THE BIRDS OF THE BRITISH ISLES: VOL. X, by David Armitage Bannerman. Oliver & Boyd, Ltd. (63 shillings). This admirable work continues in its stately and spacious way to describe the birds of the British Isles, both those that are common and those that are rare. In the present volume are covered the remainder of the sandpipers not covered in Vol. IX, yellowlegs, redshanks, plovers (including the sociable plover *Chettusia gregaria*), the lapwing, stilt, avocet and oyster catcher. Twenty-three color plates by the late George E. Lodge.

THE EYE: VOL. I, edited by Hugh Davson. Academic Press, Inc. ($14). The first of four volumes that are to provide an integrated account of the physiology of the eye, with the emphasis on function. A wide variety of scientific disciplines are employed. For example, the present volume on the vegetative physiology and biochemistry of the eye discusses such topics as electron microscopy of the vitreous body and cornea, active-transport mechanisms involved in the functioning of the aqueous humor, vascular circulation in a semirigid cavity and the metabolism of avascular tissues. Still to appear are volumes on the visual process, muscular mechanisms and visual optics, and the optical space sense. Photographs and diagrams.

THE PREHISTORIC CHAMBER TOMBS OF FRANCE, by Glyn Daniel. Thames and Hudson (70 shillings). An illustrated survey of the megalithic chambered tombs of France: their location, their different shapes and forms, their chronology. Daniel, who has been interested in this branch of archaeology for almost three decades, visited most of the chamber tombs of France, and he presents in addition to his own descriptions a summary of the extensive field surveys and researches of others. A feature of the book is a 40-page bibliography.

THE NATURALIST ON THE RIVER AMAZONS, by Henry Walter Bates. University of California Press ($2.45).

A soft-cover reprint of a record of the South American adventures of Henry Walter Bates, who, beginning in 1848, spent some 11 years in Brazil and there collected 14,712 species of animals, of which no less than 8,000 proved to be new to science. The first two years Bates traveled and collected in the company of Alfred Russel Wallace; then they parted and Bates continued his field explorations alone, encountering many adventures and hardships and earning many rewards. All this is delightfully described in his book, the attractions of which are further enhanced by numerous quaint and curious illustrations reprinted from an earlier version.

Notes

THE PSYCHOLOGY OF INSANITY, by Bernard Hart. Cambridge University Press ($1.25). A paper-backed reissue based on the fifth edition (1957) of a well-known and often reprinted account of modern notions of insanity.

THE FALL OF THE RUSSIAN MONARCHY, by Sir Bernard Pares. Vintage Books ($1.45). A paper-backed reissue of Pares' chronicle of the causes and outbreak of the Russian Revolution, first published in 1939. Pares was himself in Russia during most of the events he describes, and his book, informed by understanding and sympathy, is a first-rate performance.

POLYAMINO ACIDS, POLYPEPTIDES, AND PROTEINS, edited by Mark A. Stahmann. University of Wisconsin Press ($8). These 36 papers from an international symposium held at the University of Wisconsin in 1962 represent the views of investigators in many disciplines and from this country, England, France, Germany, Israel and Japan.

CHAUCER'S WORLD, compiled by Edith Rickert. Columbia University Press ($2.95). A paper-backed reprint of Miss Rickert's exceptionally entertaining selection of materials concerning Chaucer's era and surroundings. Many illustrations.

VIRUSES, by K. M. Smith. Cambridge University Press ($3.75). A relatively jargon-free, illustrated primer of our knowledge of viruses: how they differ from other agents that cause disease, how they can be isolated and crystallized, what they look like under the electron microscope, how they are transmitted and the nature of the diseases they cause.

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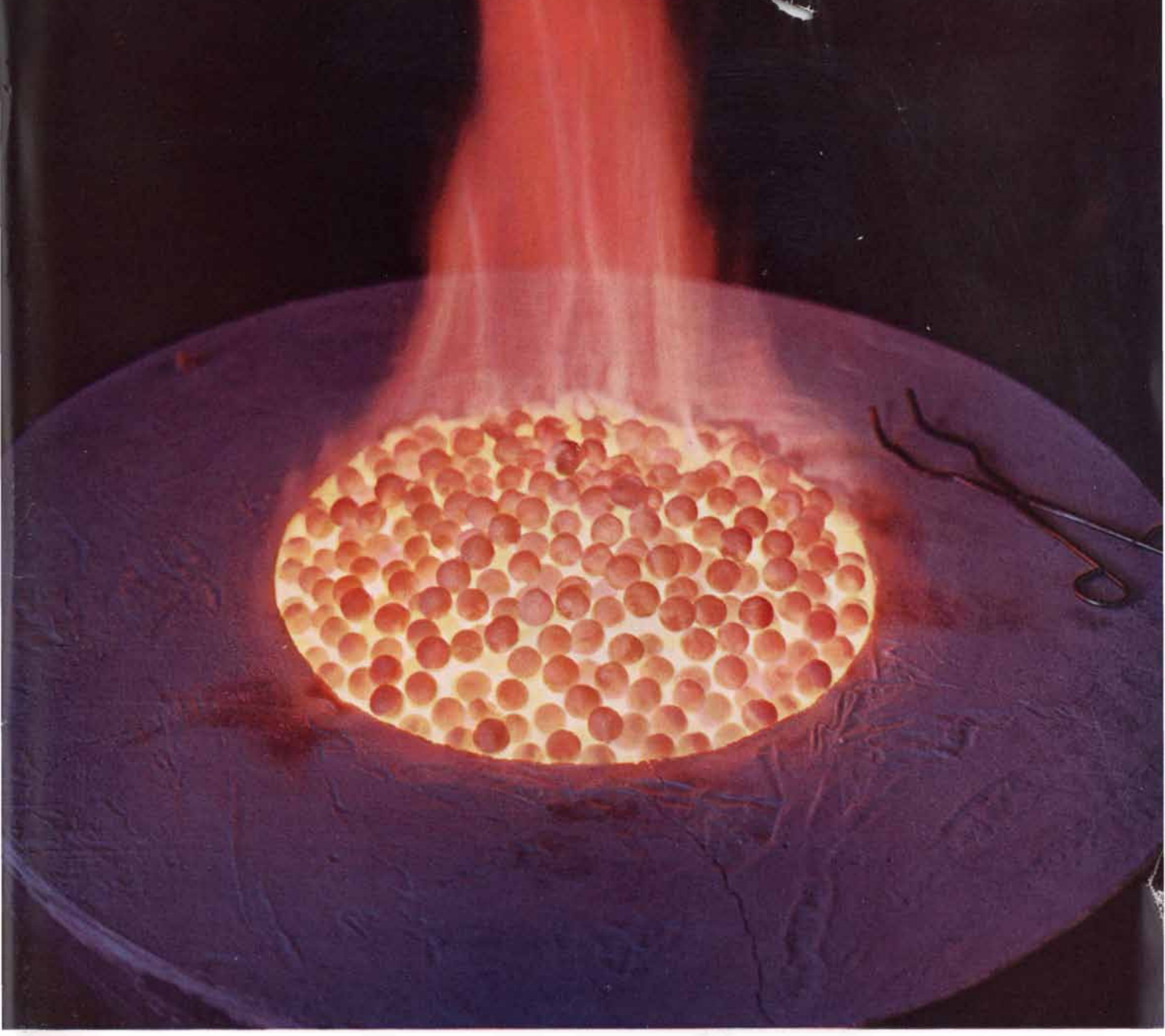

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