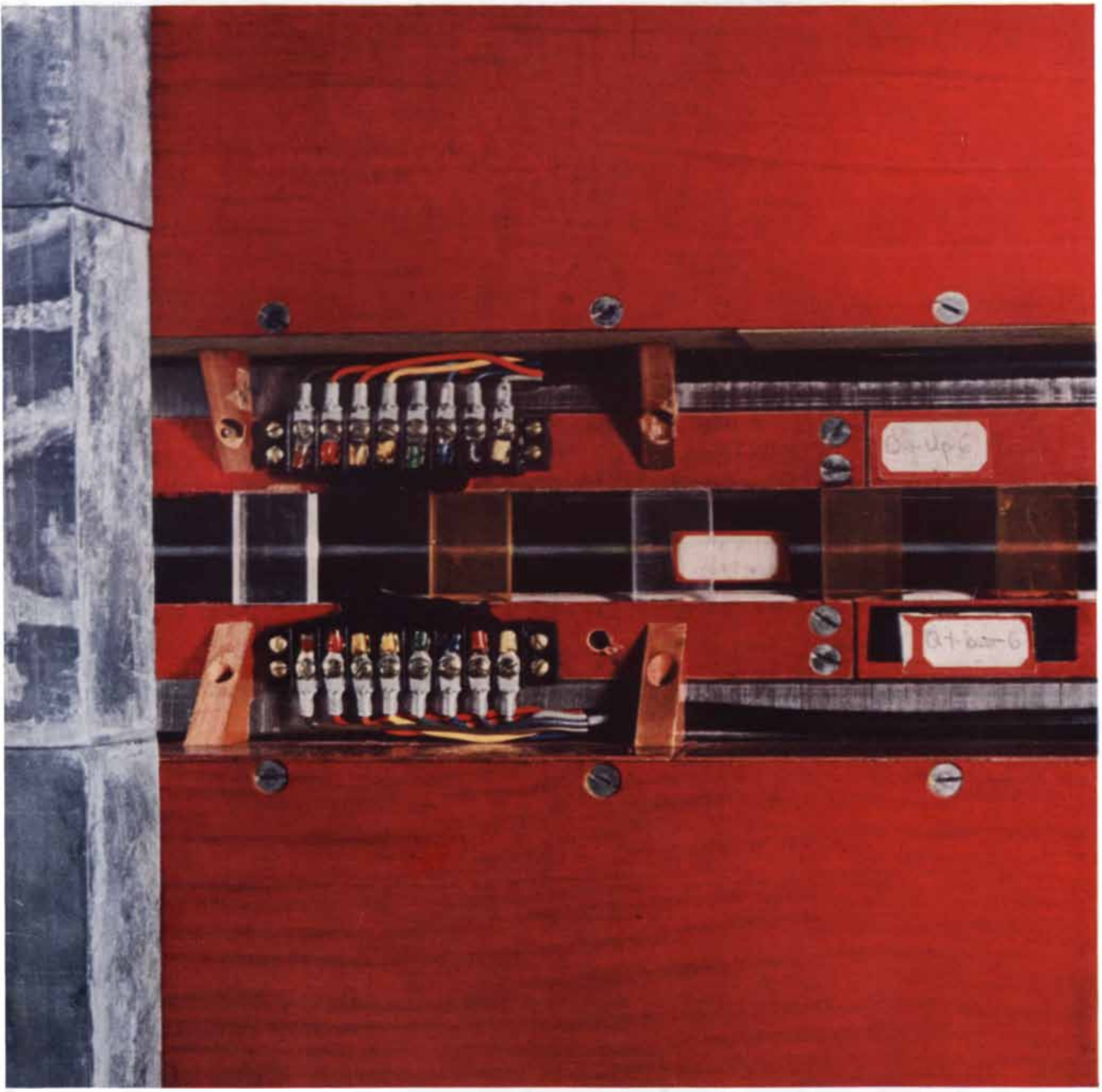
SCIENTIFIC AMERICAN



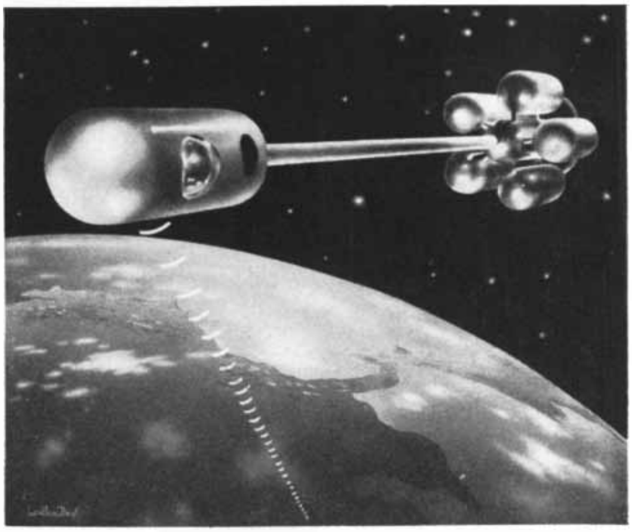
SYNCHROTRON BEAM

FIFTY CENTS

March 1958

Molecular model of ethylene oxide—one of the basic building blocks in Union Carbide's chemistry.

TEST INSTRUMENTS Bulova's rugged Tachometer Tester for all jet and reciprocating systems meets MIL-T-945A requirements—is accurate to 0.1% with engines on or off. Simple to operate and maintain, this field unit also serves in maintenance depots. Precise Bulova testers include the dual purpose Torqmeter—a dynamometer or calibrated torque source.



RECONNAISSANCE SYSTEMS Bulova-developed miniaturized sensor packages, geared to specific tactical missions, feed combat surveillance data to Bulova analysis and display systems. Camera, infra-red, TV and radar techniques, combined and integrated, aid decision-making on land and in space. Satellite applications? Unlimited!

Bulova's capability helps to solve today's most challenging problems

To conceive, develop and manufacture a broad range of advanced electronic and electro-mechanical devices...this is the Bulova capability.

Meeting the needs of defense and industry is an unusually creative group of scientists, engineers and technicians, backed by 80 years' experience in precision production.

With dynamic imagination, Bulova's capability has invaded the often uncharted technological areas to originate many modern-day miracles in miniaturized systems and components.

Here is a proven capability ready to assist you from concept to mass production. For full information, write Department G.I.S.-2.

BULOVA
watch company

BULOVA RESEARCH AND DEVELOPMENT LABORATORIES, INC.

BULOVA PARK — JACKSON HEIGHTS — NEW YORK

INFRA-RED COMPONENTS Bulova's advanced IR projects include mosaic cells that will automatically filter out unwanted wave lengths and picture targets clearly against any background. Bulova infra-red R&D covers lead selenide and lead sulfide cells, missile seeker cells, reticles, filters and thermistor bolometers...for defense and industry.

INFRA-RED SYSTEMS Bulova's IR illuminators put unseen spotlights on night objectives. Bulova's development capability extends to fire control systems that detect, track and automatically lock on target. Designed for accuracy and simplicity, these high resolution units will serve our nation's land, sea and air forces.

SEE US AT THE IRE SHOW BOOTH #S 1811-1813

Established 1845 **SCIENTIFIC AMERICAN** March, 1958 Volume 198 Number 3

ARTICLES

DEPARTMENTS

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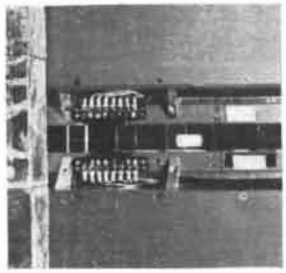

THE COVER

The photograph on the cover shows a section of the electron synchrotron (*see page 64*) at Cornell University. The luminous horizontal line in the middle of the photograph is light emitted by electrons as they speed around the tube of the synchrotron.

THE ILLUSTRATIONS

Cover photograph
by William Vandivert

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Largest Special Metals Company Formed

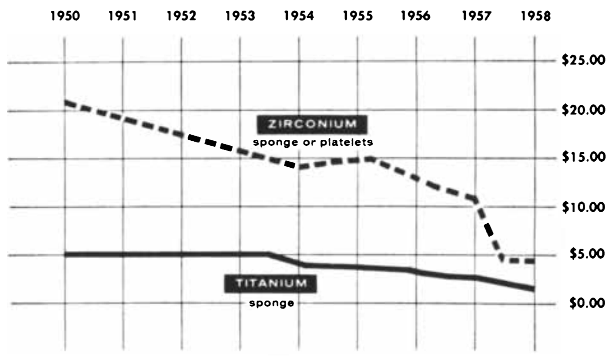
MALLORY-SHARON NOW INTEGRATED PRODUCER OF TITANIUM, ZIRCONIUM, SPECIAL METALS

Mallory-Sharon Titanium Corporation has broadened its scope in the special metals field with acquisition of all the titanium and zirconium sponge production facilities of National Distillers & Chemical Corporation, plus full ownership of Reactive Metals, Inc., formerly owned jointly by Mallory-Sharon and National Distillers.

Our new name is Mallory-Sharon Metals Corporation. Our products include titanium, zirconium, and hafnium in sponge form and in a broad range of mill products including sheet, plate, rod, bar, billets, etc. Planned for the future are other special metals.

LOW COST PROCESS—Now a fully integrated producer, Mallory-Sharon will use the new sodium reduction process for making titanium and zirconium sponge. This process is believed to be the lowest cost method developed to date for this purpose, and produces metal of unusually high ductility. It will contribute to making titanium and zirconium economically attractive in more and more applications.

WHAT THIS MEANS TO YOU—Mallory-Sharon's leadership in the special metals field will mean continuing improvements and importance to these metals. In addition to titanium's broad use in aircraft and missiles, and zirconium's in the nuclear field, both metals provide exceptional corrosion resistance—offering lower costs in a broad range of processing and industrial applications. Let us help *you* design ahead with these new metals.

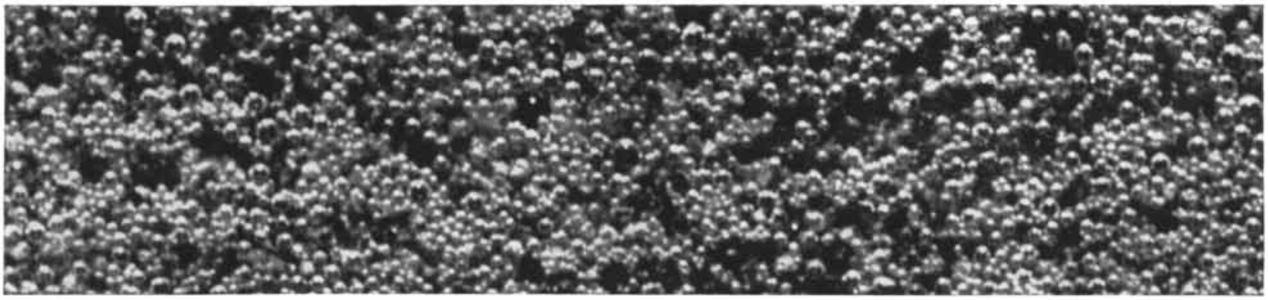


Regular price reductions in titanium and zirconium sponge have also been reflected in lower prices for mill products. This trend shows the wisdom of evaluating titanium and zirconium now for your new products.

MALLORY-SHARON

METALS CORPORATION • NILES, OHIO

Integrated producer of Titanium • Zirconium • Special Metals



"Microballoon" spheres are an exciting material on which to launch new creative ideas. Here they are shown magnified sixty times under a microscope. Read their story below and see if their successful applications may solve your research problems.

For new scientific discoveries . . .

Have you ever heard of "Microballoon"* spheres? Do you know what they have done, or what they may be able to do? Have you ever worked with these tiny spheres yourself?

What are they?

"Microballoon" spheres are the latest development in phenolic plastics. These hollow, unicellular spheres have an average diameter of only .0017 inch. Their density is 3 to 5 lbs. per cubic foot. They are resistant to hydrocarbons and acids. In bulk, "Microballoon" spheres look like reddish brown flour.

What have they done?

Used as a low density filler, these spheres which contain an inert gas, make it possible to control density and physical properties. Researchers tried them as fillers for plaster and paper. They found that the plaster would take a driven nail without cracking. Paper was found to be more opaque without being heavier.

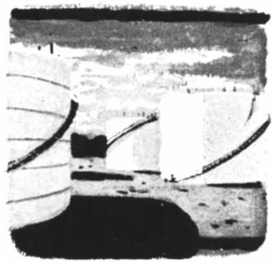
Crack-resistant plaster

"Syntactic foam" is another promising development. "Microballoon" spheres in an epoxy binder form a putty-like cellular substance that makes possible a type of controlled foam for on-the-spot installation in construction. After the binder cures the result is a strong sandwich core which has been used for boat hulls. Other advantages are light weight and insulating properties.

Though permeable to water, these hollow plastic spheres will float on crude oil. They form a blanket that reduces the evaporation of costly volatiles, and many oil companies have used them successfully on cone-roofed storage tanks for more than three years.

Opaque paper

Bakelite Company can help your research



Evaporation control

Your own investigation of this promising material may yield substantial rewards. As a start, learn more about "Microballoon" spheres first-hand. Bakelite Company's laboratory facilities, experience, and resources will help. Write for the latest technical information. Samples are available.

ADDRESS: Bakelite Company, Foam Division, New Products Engineering Department, 420 Lexington Avenue, Room 2840, New York 17, N. Y.

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BRAND
PLASTICS

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LETTERS

Sirs:

When allowance is made for scaling, the athletic performance of the grasshopper would appear to be relatively inferior among animals, and not superior as claimed by Graham Hoyle ["The Leap of the Grasshopper"; SCIENTIFIC AMERICAN, January].

Principles of scaling are familiar to physicists and are the stock in trade of people like naval architects and aerodynamicists who must often infer, from experiments with small-scale models, the predicted performance of the ships, aircraft or missiles whose full-scale versions may not yet have been built or that may be too large to fit into testing basins or wind tunnels. Not all biologists realize that animals, too, of varying sizes should be expected to conform to laws of scaling.

Imagine a sequence of cats, all similarly proportioned, and with all manner of sizes between some smallest cat that might be no larger than a mouse and some largest cat that might be as large as a lion. "Similarly proportioned" means that if one cat is half as long as another it will stand just half as high, and that each muscle or bone of the one will be just half as long, half as broad and half as high as the corresponding muscle or bone of the other. If all the cats are made of the same materials, it follows that their muscles will be able to exert forces proportional to their cross-sectional areas, and thus to the squares of their lengths. The weights of the cats will vary as the cubes of their lengths. Therefore the weight that a cat could lift (if a cat could be induced to lift it), divided by the weight of the cat, would vary inversely as the cat's length; and thus a cat three inches long could lift 24 times as many multiples of its own weight as could a cat six feet long. When starting to leap, a cat would accelerate with a number of centimeters per second per second that was inversely proportional to its length, since acceleration varies as force divided by mass; the distance through which the cat accelerated itself would vary as its length; the product of the acceleration and the accelerating distance would thus be a constant, independent of the length of the cat. Since the square of the velocity achieved varies as the preceding product, the velocity reached by jumping would be constant from cat to cat; and since the distance a cat can jump vertically or horizontally depends on its "launching" velocity, all the cats could jump equal distances vertically, and equal distances horizontally. They would all have equal athletic performances—not in cat-lengths but in meters.

Dr. Hoyle calls the grasshopper's jump one of the most remarkable performances in the biological world. It may be, indeed—but remarkably poor, not good. The feat of a grasshopper four or five centimeters long, in jumping only 45 centimeters vertically or a meter horizontally, merits little admiration because many other animals including cats, men and lions vastly out-jump the grasshopper.

A two-gram locust is said to exert a force of 30 grams with both legs together while accelerating. As we have seen, force varies as the square of length, or the two-thirds power of body weight, among similar animals. Thus, were the two-gram locust scaled up to a man's 80 kilograms, he could exert a force of 30 grams times the two-thirds power of 40,000, or about 35 kilograms. This performance is completely outclassed by that of an 80-kilogram man—the man outperforms the grasshopper twice without even trying, by merely supporting his own weight! Alternatively, imagine that a man, strong enough merely to support his 80-kilogram weight with bent knees, were scaled down to the two-gram weight of the locust. His two legs would together be able to exert a force of about 68 grams, as compared to the locust's 30.

The muscle of a grasshopper is said to be able to exert a force of 800 grams although it weighs only 1/25 of a gram;

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or 20,000 grams of force per gram of muscle weight. We have seen that this ratio scales inversely as the length of the animal, and therefore inversely as the cube root of the animal's weight. A man's muscle is stated to exert about 2,000 grams of force per gram of muscle weight. If an 80-kilogram man were scaled down to a weight of two grams, his muscles would then exert a force of 68,000 grams per gram of muscle weight, much excelling the 20,000 grams per gram exerted by the muscles of the grasshopper.

THEODORE E. STERNE

Harvard University
Cambridge, Mass.

Sirs:

Professor Sterne calculates that a sequence of cats of all sizes could jump equal distances vertically and horizontally. On the same basis a man-sized grasshopper should be able to jump as high and as far as the real one. But in another calculation Sterne finds that the grasshopper would be too feeble to support its own weight. Cats stay ever strong whilst 'hoppers just grow feebler! On looking into Professor Sterne's calculations one finds the reason for the anomaly. In making his comparison of cats of different sizes he has neglected to allow for the fact that whilst the cat is busy accelerating its mass it must also at the same time support its bulk against the inevitable force of gravity. Its strength is increasingly required for this purpose as its size increases. This factor must be added to the accelerating force. The weight can hardly be ignored in the case of a lion-sized cat. This creature would be a weakling. Yet a lion-sized cat (*i.e.*, the lion) exists in nature and it is a splendid athlete.

Imaginary scaling operations of this kind are misleading on all counts, for they do not take into account the complexity of muscles. The reason for the apparent weakness of the man-sized grasshopper is that its muscle fibers will have been increased in length by 34 times, so that they take up 34 times as much valuable space without being made any stronger. The lion exists because it has been able to increase the number of its muscle fibers per muscle to a greater extent than is possible simply by an increase of scaling, which allows only an increase in area proportional to the linear scaling for the insertion of additional muscle fibers. The lion has done much better than this by evolving extensive ramifications of the tendinous strands to which the still comparatively short muscle fibers are attached. A man-sized grasshopper, should it have existed, would have done the same thing.

The primary force developed by a muscle is determined by properties of the contractile protein actomyosin (in a few cases paramyosin), and it may be the same for all kinds of muscle. The force actually developed on a load attached to the muscle is determined by the properties of viscous-elastic elements in series parallel with the actomyosin. These secondary elements are very different in cats and grasshoppers. The ultimate force of actomyosin could only be realized in a thin sheet having no other elastic material in it at all. Its force would be thousands of grams per square centimeter or many millions of grams per gram. Such is the energetic material from which the muscle machinery has been built up; it is capable of forces and speeds far in excess of any which have yet been evolved. The limitation has been imposed by the weakness of the skeletal materials. Attenuation has been realized by the use of elastic material.

Muscles having different functions in the animal body require different aspects of their functioning to be emphasized: speed, force, extent of shortening, and so on. In comparing muscles we may use a variety of criteria, such as force per unit cross-sectional area, force per unit mass, extent of shortening, rate of shortening at maximum speed, rate of working per unit cross-sectional area, rate of working per unit mass, and so on. Two muscles with exactly the same shape and volume may be quite differently designed. Thus one may have long parallel fibers and be able to shorten over a great distance. The other may have ramifying tendons with short muscle fibers and only be able to shorten over a small distance. But the former would be able to lift only a much smaller load than the latter. If we are to compare the two muscles from the point of view of their *design* as instruments for developing *force* we must determine their maximum force per unit mass. This was the unit I chose. Felix Plateau and D'Arcy Thompson long ago debunked the notion that insect muscles are unusually *strong*, but in the units force per gram of muscle the grasshopper muscle is a winner every time.

GRAHAM HOYLE

The University
Glasgow, Scotland

FOR THE

NUCLEAR PROGRAM

Several divisions of the Norton Company are making important contributions to the field of nuclear energy. Some of the products that are proving helpful in furthering progress in nuclear energy are:

- **Ceramic fuel units, from sample lots to full core loadings.**
- **Reactor shield and control rod materials, particularly boron carbide, in a wide range of special shapes.**
- **Metallurgical refractories for processing and reprocessing nuclear fuel materials and other unusual alloys and metals.**
- **Source or intermediate materials, such as oxides or carbides, for use in producing zirconium and other materials for reactor construction.**
- **Diamond cut-off wheels for dicing or wafering — that eliminate waste and assure dimensional accuracy of the costly materials being cut.**

The Norton organization includes an engineering staff experienced in atomic development — available for cooperation where electric furnace products may be of interest. Facilities are available for the production of, or research in, classified items. For further facts, write to NORTON COMPANY, 542 New Bond Street, Worcester 6, Mass.

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to make your products better

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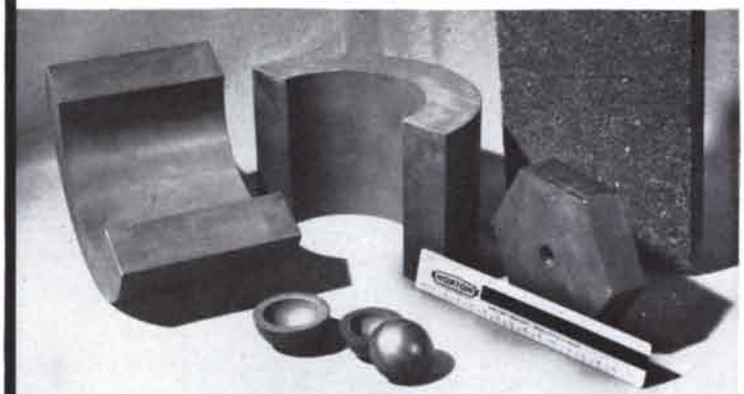
Grinding Machines • Refractories

BEHR-MANNING DIVISION
Coated Abrasives • Sharpening Stones • Behr-cat Tapes

Ceramic Fuel Pellets For Nuclear Reactors. Those illustrated are of a thorium-uranium oxide mixture. They are typical of the ceramic fuel element components available in a wide range of compositions made to exact specifications.



These Reactor Parts Are Made Of Boron Carbide, known as NORBIDE* — a hard, stable, lightweight material. They absorb neutrons without becoming radioactive. Besides the shields and other structural parts shown, Norton boron carbide may be molded into control rods, tubes, discs, segments, etc.

High Purity Refractories Vital To Metallurgy include crucibles, made of MAGNORITE* pure magnesia, zirconia and thoria, suitable for melting uranium, plutonium, thorium, etc. A special Norton laboratory devoted exclusively to nuclear problems is developing other unique ceramics for the atomic program.

50 AND 100 YEARS AGO

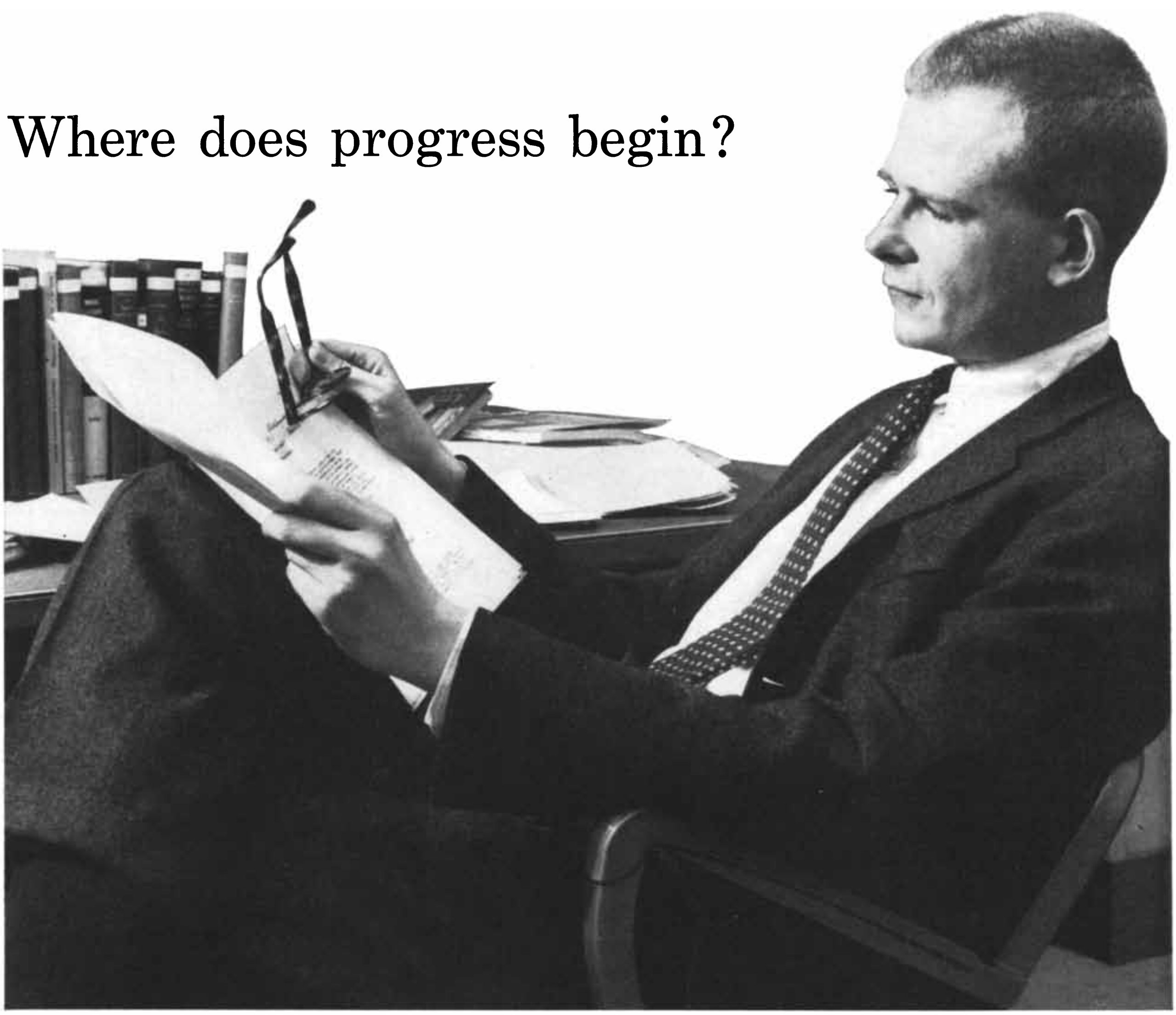
SCIENTIFIC AMERICAN

MARCH, 1908: "Dr. Alexander Graham Bell's gigantic man-lifting kite, the *Cygnet,* was sent up in December, 1907, both with and without a man. In it Lieut. Selfridge, of the U. S. Army, ascended to a height of 168 feet and remained in the air for over seven minutes. While Dr. Bell's ultimate object is to secure a flying machine that will support itself in the air at a moderate rate of speed, the experiments with the *Cygnet* have been mainly studies in stability. The wonderful steadiness of the tetrahedral structure championed by Dr. Bell is shown by the fact that the *Cygnet* descended from 168 feet to the water so slowly and evenly that the man aboard did not realize he was dropping until he found the kite in water. Dr. Bell's next step will be to put a powerful, light motor on a modified form of the *Cygnet.*"

"On February 25 there were opened with appropriate ceremonies the twin tunnels from 15th Street, Jersey City, to Morton Street, New York, which form the first section of the important system of tunnels designed to facilitate travel between Jersey City and New York. Two trains, carrying respectively Governor Hughes of New York and Governor Fort of New Jersey, started from New York and Jersey City, and met beneath the state line at the center of the Hudson. Here the governors shook hands from the front platforms of their respective trains; and thus was this great work placed at the service of the public."

"The motor omnibus made its debut in America last summer. It has entirely superseded the old horse stages that formerly supplied the only form of regular public vehicular conveyance on Fifth Avenue in New York City. The Fifth Avenue Coach Company has put into service 15 French De Dion buses of 1906 model. The bodies are of the double-deck type so popular in the large cities of Europe. They have seats for 34 passengers—16 inside and 18 on the upper deck. The prime mover is a De Dion gasoline engine having a French

Where does progress begin?



Kendall Preston Jr., S.M. in engineering from Harvard University . . .
graduate of the Laboratories' Communications Development Training Program.

Progress begins in the mind—in the perception and appreciation of new ideas. In the past the ideas that sparked progress too often had to wait on the random interest of genius. Today more and more new ideas come from men trained to an awareness of that which is yet to be accomplished.

At Bell Laboratories, communications science is entering upon its most challenging era in history. As never before, progress will depend upon men who have acquired the special training needed to think creatively in this exciting field.

Bell Laboratories provides the young college graduate with unique opportunities to develop his creative abilities. During his first two years, he spends two or three days a week as part of his job, taking postgraduate courses in basic mathematics, physics and electronics. This he does at a graduate study center which has been established at the Laboratories by New York University. As he gathers a broad fundamental knowledge which will enable him to tackle every type of communications problem, he also gathers credits toward advanced degrees. To round out his education, he spends a third year on special phases of communications technology.

By helping scientists and engineers to reach their top development, Bell Laboratories has helped to make your telephone system the world's best—and will keep it so.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT rating of 24 horse-power and an English rating of 28 horse-power. The cylinders are cast separately and have integral water jackets with brass caps. Solid rubber tires of American manufacture are fitted all around. The route covered extends from Washington Square to 90th Street, a distance of more than four miles. The buses run on a five-minute headway, and are allowed one hour for the round trip, including stops and a five-minute wait at each end. During the first six months of the new service it was found that the motor buses maintained their schedule."

"A telegram from the Lowell Observatory, Flagstaff, Ariz., recently announced the discovery that the atmosphere of Mars is very rich in water vapor. This information, gained by Mr. Slipher from a comparison of the spectra of Mars and the moon, is a notable contribution to our knowledge of water supply on the ruddy planet. At present the astronomical world is divided over the question of Mars and its canals. On one side we have Mr. Lowell and his followers, who by visual observations with the telescope and the recent photographs have discovered the presence of hundreds of thin line markings aggregating thousands of miles in length. The remarkable straightness of these canals, their systematic arrangement, and the changes that have been noted in their appearance at different seasons have proved to Mr. Lowell that these canals are the result of human ingenuity, and that their purpose is to irrigate the desert planet and render it fit for human habitation. Conclusive as these arguments seem to be to the observers at Flagstaff, the majority of the first-class astronomers in the world do not agree with them."

"A duplicate of the Farman prize-winning aeroplane, fitted with the regular Antoinette 50-horse-power water-cooled motor or with an air-cooled Renault or R.E.P. engine if the purchaser prefers it, can now be had in England for $6,000, or in America for $8,400, which includes the import duty of 40 per cent *ad valorem*."

SCIENTIFIC AMERICAN

MARCH, 1858: "In the transactions of the Royal Astronomical Society of London, lately published, Mr. Alvan

THE PEACEFUL ATOM

...can propel a ship one year without refueling

New Study Shows Nuclear Power May Be Practical and Economic for Merchant Ships

Some gray dawn in the early 1960's a heavily laden supertanker will shoulder her way through the steep Atlantic swells to a landfall in Delaware Bay. She'll be homeward bound for Philadelphia, 19 days out of Kuwait with nearly 40,000 tons of oil.

FOR SHIPS LIKE THIS . . .

No more dependent on thousands of tons of payload-stealing fuel oil, tomorrow's ships will range worldwide trade routes without refueling.

In the last twelve months she will have made eight trips to the Persian Gulf hand running. Now at last she is due for her annual refit . . . *and her annual refueling.*

Competitive at sea

A nuclear power plant for a ship of this type was the subject of a study recently completed by Atomics International for the Maritime Reactors Branch of the Atomic Energy Commission. Costs of building and operating a vessel powered by an Organic Moderated Reactor were compared with those for an oil-burning ship—a typical modern supertanker of some 38,000 deadweight tons.

Total costs for the OMR tanker, depreciated over 20 years, were only moderately higher than for today's conventional ship. But costs for oil-burners are on their way up, with steadily rising fuel prices seen from now on—whereas the cost trend for the OMR is downward, as nuclear technology is improved. An OMR tanker has greater cargo capacity because its fuel takes up little space. And it needs refueling less than once a year.

Bigger payloads, longer hauls, faster turn-arounds—this is the new pattern of operation. Shipowners can begin plans right now, for the Organic Moderated Reactor promises to put the atomic merchant ship on a sound commercial basis.

Versatile on land

The same features that make the OMR applicable for seagoing use are also in its favor for central power stations ashore. The basic simplicity and safety of this system point to economic nuclear electricity for many areas of the world today.

Plans are already underway to build an OMR plant in Piqua, Ohio, which will increase the city's electrical generating capacity by 12,500 kilowatts. Another OMR power station is planned for a Latin American country.

First OMR now in operation

All this stems from the results being achieved with the Organic Moderated Reactor Experiment, conducted by Atomics International for the Atomic Energy Commission. The Organic Moderated Reactor Experiment is being carried on at the AEC's National Reactor Testing Station in Idaho to establish the basic engineering data for this type plant. Atomics International is also operating the Sodium Reactor Experiment, a nuclear power project for the AEC. Another power reactor concept, the Advanced Epithermal Thorium Reactor, is under study for the Southwest Atomic Energy Associates. AI research reactors are now operating in Japan, Germany, Denmark, and the United States. Another is being built for Italy. ATOMICS INTERNATIONAL, P.O. Box 309, Canoga Park, Calif. Cable address: ATOMICS.

. . . ATOMIC ENGINES LIKE THIS

AI's Dr. A. B. Martin shows on this OMR tanker model how the compact power plant will free thousands of cubic feet of fuel space for revenue-producing cargo.

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

PIONEERS IN THE CREATIVE USE OF THE ATOM

Clark of Boston, Mass., celebrated for his skill as an astronomical instrument maker, is paid a high compliment by the Rev. W. R. Dawes for his astronomical discoveries, especially of new double stars. Regarding one of these, Dawes says, 'This star is about as difficult as the closest of the Poulkova catalogue, and, though on a fine night visible with the eight-inch object glass I now have in use, it would require the full power of a 15-inch refractor to divide it. That it attracted Mr. Clark's attention as a double star is sufficient to prove that his eye, as well as his telescope, must possess extraordinary power of definition.' This was accomplished by Mr. Clark with an object glass whose aperture is only seven and three-quarter inches."

"Samuel Colt, the famous pistol patentee, has presented a petition for the extension of his patent through Mr. Bishop, a member of the House, from Connecticut, and it is now in the hands of the committee, awaiting their action. Colt, it is known, has become immensely wealthy. He has undoubtedly one of the finest manufactories in the world for this particular kind of business, and is thereby enabled to manufacture his style of revolving arm quite as cheaply as, if not more cheaply than, any other establishment can do it. He is also able to put forth with great facility extraordinary efforts to prosecute his application before Congress or any other tribunal. There is, therefore, great danger that this pistol patent may be extended during the present session. Inventors, in most instances, are pushed forward by parties interested, who tell piteous tales of personal suffering. Such tales, whether true or false, are all the members hear in many cases, and are well calculated to move their sympathies; and, unless they can get behind the scenes and see all the actors, they are liable to be imposed upon themselves and to recommend measures which have no real merit to back them."

"It has been announced that the vessel which has recently sailed with the now celebrated Dr. Livingstone for the southeast coast of Africa has on board a peculiar steamboat provided by the British Government to enable the veteran traveler to prosecute his investigation of the Zambesi River. The vessel is a paddle steamer, her dimensions being: length, 75 feet; breadth, 8 feet; and depth, 3 feet. She will not draw more than 12 or 14 inches, so that she is expected to be able to navigate the shallowest parts of the river."

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New Sales Service Lab at Bartlesville is completely equipped with latest commercial processing machinery and research apparatus. Phillips experienced technical service staff will assist you in developing new products and processes using MARLEX plastics. Please make arrangements through your local MARLEX sales representative. Meanwhile, for complete data on MARLEX 50, send for our latest illustrated technical brochure.

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*MARLEX is a trademark for Phillips family of olefin polymers.

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Zirconium, the new atomic age metal developed because of its special value as a container for uranium fuel elements in nuclear reactors, now makes possible a remarkable new photo flashbulb produced by Sylvania Electric Products Inc.

Scarcely bigger than a thimble, the new M-25 zirconium filled bulb has a light output virtually equal to that produced by flashbulbs four times its size. New opportunities are opened up for improved flash photography by professionals and amateurs alike.

The zirconium used by Sylvania is one of the family of advanced materials made by the Carborundum Company. Originally so rare and costly that every pound was reserved for the nation's atomic program, zirconium is now available from Carborundum in sufficient quantities and at a drastically lowered cost that will permit its use in many commercial applications. High strength, extreme resistance to corrosion, transparency to thermal neutrons and other advantages suggest many uses in chemical and other industries.

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THE AUTHORS

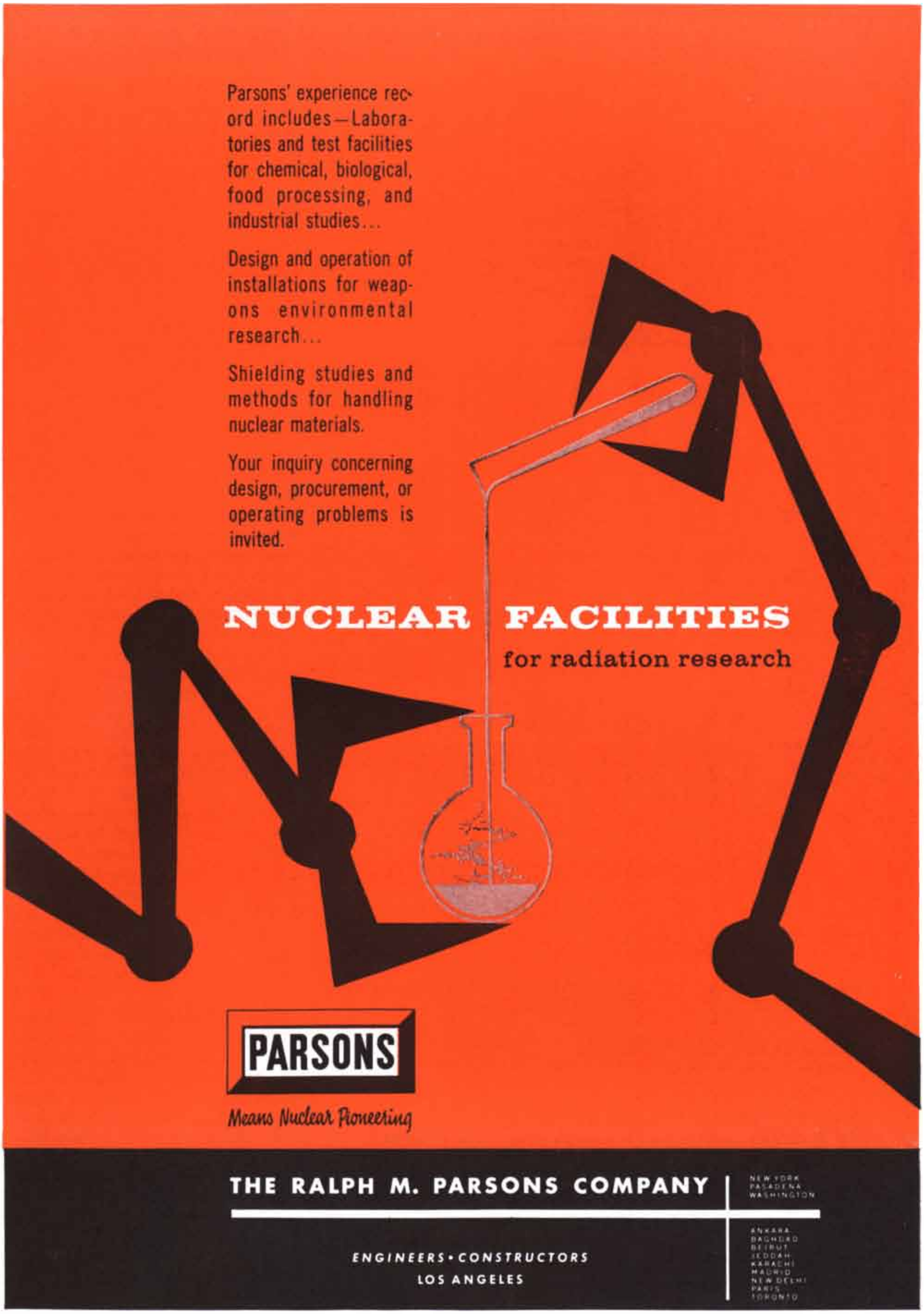
SIR CHRISTOPHER HINTON ("Atomic Power in Britain") directed the design and building of the atomic energy factories at Springfields, Capenhurst, Windscale and Calder Hall. The son of a Wiltshire schoolmaster, he left school at 16 to serve a five-year engineering apprenticeship in the locomotive works of the Great Western Railway Company. Eventually he became a draftsman for the railway. In 1923 he won a scholarship to the University of Cambridge where he took first class honors in mechanical sciences and received a prize for research on the vibration of railway bridges. He then went to work for Imperial Chemical Industries, becoming a chief engineer before the age of 30. During World War II the British Government put him in charge of the Royal Explosive Filling Factories. Sir Christopher was a member of Britain's Atomic Energy Authority until last year, when he became chairman of the Central Electricity Generating Board. He is a Knight Commander of the British Empire, a Fellow of the Royal Society and an Honorary Fellow of Trinity College, Cambridge.

EDWARD O. WILSON ("The Fire Ant") was born 28 years ago in Birmingham, Ala. After acquiring a B.S. and M.S. from the University of Alabama, he went to Harvard University, where he held a National Science Foundation fellowship and later a junior fellowship in the Society of Fellows. He received his Ph.D. from Harvard in 1955, and was appointed assistant professor of biology in the following year. He now teaches courses on evolutionary theory and devotes his research to the evolution of ants. "The imported fire ant was among my earliest acquaintances," reports Wilson, who has been studying it since his undergraduate days. However, it is only one of over 1,500 species of ants which he has collected and observed in the U. S., the West Indies, Mexico, Australia, New Guinea and Ceylon.

BRIAN HOPE-TAYLOR ("Norman Castles") is a successful painter, wood engraver, book illustrator, writer and lecturer as well as a professional archaeologist. Archaeology, however, has been his ruling passion since childhood. As an archaeologist, Hope-Taylor specializes in the delicate methods required to reconstruct the pattern of ancient wooden buildings. In addition to Norman castles he has recently excavated the palaces of the Anglo-Saxon kings of Northumbria at Yeavering in Northumberland. Hope-Taylor is archaeological consultant to the Ministry of Works of Great Britain and secretary of the Medieval Research Committee of the Council for British Archaeology.

ROBERT R. WILSON ("Particle Accelerators") moved so many times in his childhood that his school record lists seven grammar schools and five high schools in various parts of Wyoming, Colorado and California. This resulted in poor grades which made it difficult for him to enter college. Yet before joining the freshman class of the University of California he had already built a rudimentary laboratory in which he made high-vacuum pumps of his own design. Wilson majored in electrical engineering, but a near-failing grade in freshman physics challenged him to study physics instead, against the advice of his teachers and in spite of the handicap of poor health. By his senior year he was doing original research in gaseous discharges under Ernest O. Lawrence, and had discovered an original way to study the time lag of the spark discharge. As a graduate student at Berkeley Wilson turned to nuclear physics and was the first to work out the theory of the cyclotron. In 1940 Wilson joined the faculty of Princeton University. There he invented a way to separate uranium isotopes, with the result that at the age of 28 he found himself in charge of a $500,000 project employing 50 people. Wilson and his staff were soon moved to Los Alamos, where he led the cyclotron group. Eventually he became head of the Experimental Nuclear Physics Division and mayor of the community. Since World War II Wilson has taught at Harvard University and Cornell University. At Cornell he built the first strong-focusing synchrotron and has experimented with thermonuclear reactors, none of which have worked so far. He is one of the founders of the Federation of American Scientists. In his spare time he likes to carve sculptures in wood.

ECKHARD H. HESS ("'Imprinting' in Animals") is associate professor of psychology at the University of Chicago. The work on imprinting which he carries on there is a part of his larger campaign of research on the experience of infant animals and how it affects their behavior. Hess was born in Germany, graduated from Blue Ridge College and acquired M.A. and Ph.D. degrees from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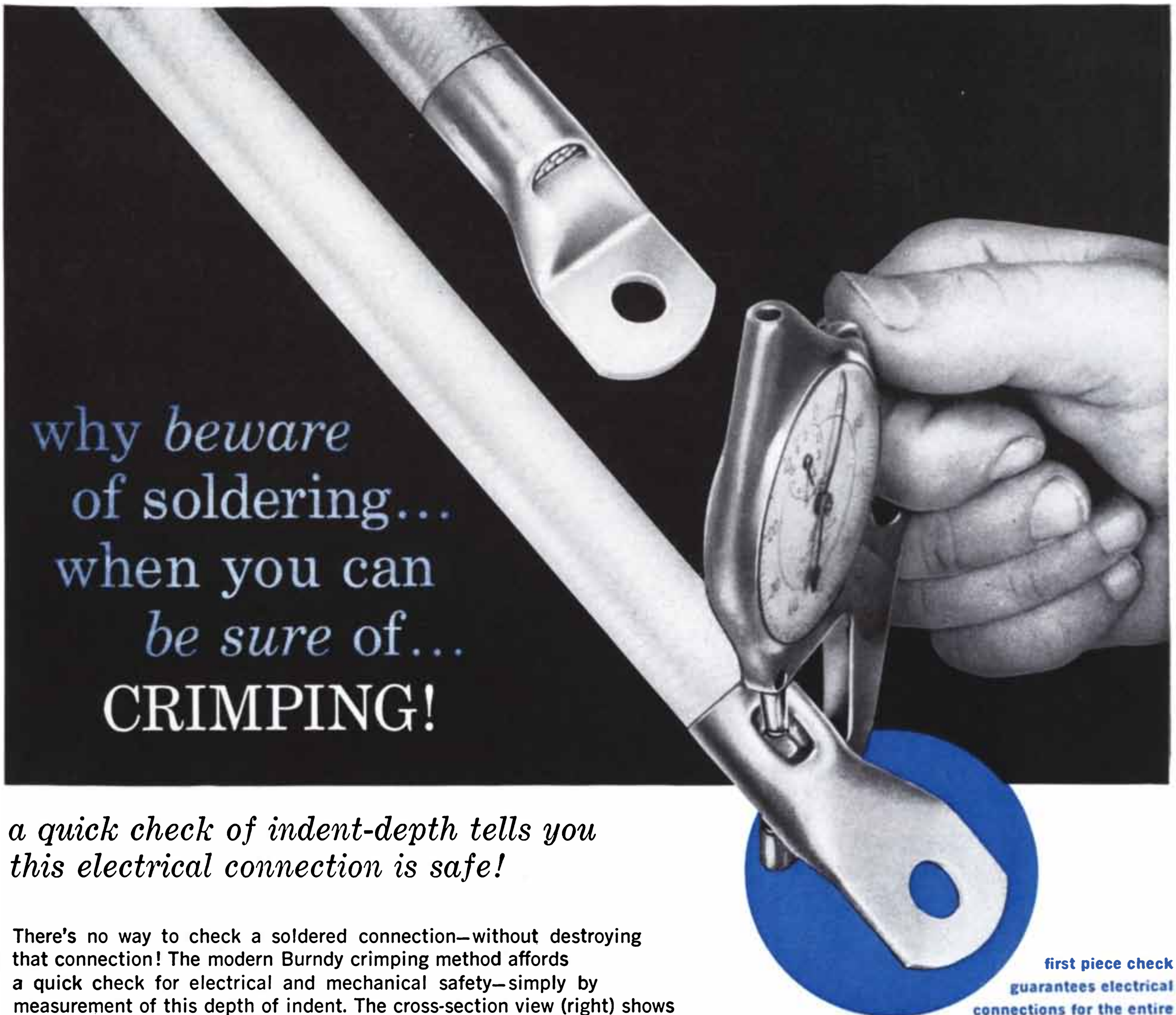
the Johns Hopkins University. He is the author of "Space Perception in the Chick," which appeared in the July, 1956, issue of SCIENTIFIC AMERICAN.

A. C. CROMBIE ("Helmholtz") lectures on the history and philosophy of science at University College London. In addition he edits *British Journal for the Philosophy of Science.* He is the author of two books: *Augustine to Galileo* and *Robert Grosseteste and the Origins of Experimental Science: 1100-1700.* Crombie recently spent a year as visiting professor of philosophy at the University of Washington. His interest in Helmholtz is a part of his concern with the history of the reduction of life phenomena to physicochemical terms.

RAYMOND J. HOCK and BENJAMIN G. COVINO ("Hypothermia") both studied the adaptation of animals to cold at the Arctic Aeromedical Laboratory of the Air Force in Fairbanks, Alaska. Hock is now chief of the physiology department of the Laboratory. He graduated from the University of Massachusetts, and received a Ph.D. in zoology from Cornell University in 1949. As a graduate student he observed homing birds from an airplane over the Gaspé Peninsula with Donald R. Griffin, and later studied the body temperatures of birds at the Arctic Research Laboratory in Point Barrow, Alaska. After a stint of teaching at the University of Arizona, Hock returned to the north to become a biologist on the staff of the U. S. Public Health Service Arctic Health Research Center at Anchorage, Alaska. Thus Hock has served in all three of the U. S. Government's Arctic laboratories. Covino was born in Lawrence, Mass., and earned a Ph.D. in physiology from Boston University. He served at the Arctic Aeromedical Laboratory as an Air Force research physiologist. Now he is assistant professor of pharmacology at Tufts College School of Medicine.

PAUL C. ZAMECNIK ("The Microsome") heads the executive committee of Harvard Medical School, where he is Collis P. Huntington Professor of Oncologic Medicine. He graduated *magna cum laude* from Dartmouth College in 1933, and received his M.D. from Harvard three years later. Since then he has pursued his career at Massachusetts General Hospital and Harvard, with a year out for study in the Carlsberg Laboratory in Copenhagen and another two years as a research fellow at the Rockefeller Institute for Medical Research in New York.



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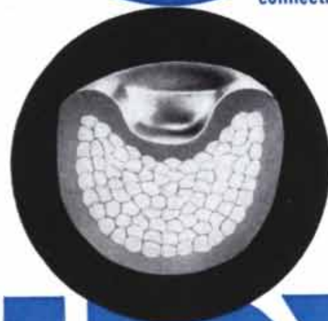

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a report by LINDSAY

A few months ago, in one of these reports, we presented this table of high purity rare earth and yttrium oxides. We anticipated inquiries, of course, but the flood of letters requesting detailed information really startled us.

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We have expanded our production facilities to keep up with demand and now have more than 100 ion exchange columns in continuous operation. Quantities are large enough to assure you a dependable source of supply. Prices are low enough to make their use on a production basis economically sound.

Most of the high purity rare earth and yttrium oxides are available for prompt deliveries in quantities of an ounce to hundreds of pounds.

We can't tell you how to use high purity rare earths in your production operations, nor can we promise that one of them may be the missing element in new process or product developments on which you are working. We *can*, however, supply you with data which you will find interesting, revealing and quite possibly of immediate importance to you.

TYPICAL MAXIMUM IMPURITIES IN LINDSAY PURIFIED RARE EARTH AND YTTRIUM OXIDES

ATOMIC NO.	OXIDE	CODE	PURITY	% RARE EARTH MAXIMUM IMPURITIES AS OXIDES
57	La_2O_3. LANTHANUM OXIDE	528 529	99.99 99.997	0.01 Pr, 0.001 Ce. 0.0025 Pr, 0.0005 others
58	CeO_2. CERIC OXIDE	215 216	99.8 99.9	0.2 (largely La + Pr + Nd). 0.1 (largely La + Pr + Nd).
59	Pr_6O_{11}. PRASEODYMIUM OXIDE	726 729.9	99 99.9	1 La + Nd + smaller amounts of Ce and Sm. 0.1 Ce + Nd.
60	Nd_2O_3. NEODYMIUM OXIDE	628 629 629.9	95 99 99.9	1-4 Pr, 1-4 Sm, 0.5-1 others. 0.1-0.4 Pr + 0.1-0.4 Sm + 0.5 others. 0.1 (largely Pr + Sm).
62	Sm_2O_3. SAMARIUM OXIDE	822 823	99 99.9	0.2-0.7 Gd, 0.2-0.6 Eu, and smaller amounts of others. 0.1 (largely Nd + Gd + Eu).
63	Eu_2O_3. EUROPIUM OXIDE	1012 1011	98-99 99.8	1-2 Sm + smaller amounts of Nd + Gd + others. 0.2 (largely Sm + Gd + Nd).
64	Gd_2O_3. GADOLINIUM OXIDE	928.9 929.9	99 99.9	1 Sm + Eu + trace Tb. 0.1 Sm + Eu + trace Tb.
65	Tb_4O_7. TERBIUM OXIDE	1803 1805	99 99.9	1 Gd + Dy + Y. 0.1 Gd + Dy + Y.
66	Dy_2O_3. DYSPROSIUM OXIDE	1703 1705	99 99.9	1 (largely Ho + Y + Tb + small amounts of others). 0.1 Ho + Y + traces of others.
67	Ho_2O_3. HOLMIUM OXIDE	1603 1605	99 99.9	1 (largely Er + Dy + small amounts of others). 0.1 Er + Dy + traces of others.
68	Er_2O_3. ERBIUM OXIDE	1303 1305	99 99.9	1 Ho + Dy + traces Yb and Y. 0.1 Ho + Tm.
69	Tm_2O_3. THULIUM OXIDE	1405 1403	99.9 99	0.1 Er + Yb + trace Lu. 1 Er + Yb + trace Lu
70	Yb_2O_3. YTTERBIUM OXIDE	1201 1202	99 99.9	1 Er + Tm + trace Lu. 0.1 Tm + trace Lu + Er.
71	Lu_2O_3. LUTETIUM OXIDE	1503 1505	99 99.9	1 Yb + Tm + traces of others. 0.1 Yb + Tm + traces of others.
39	Y_2O_3. YTTRIUM OXIDE	1112 1115 1116	99 99.9 99.9+	1 Dy + Gd + traces Tb and others. 0.1 Dy + Gd + traces Tb Approx. 0.05 Dy + Gd.

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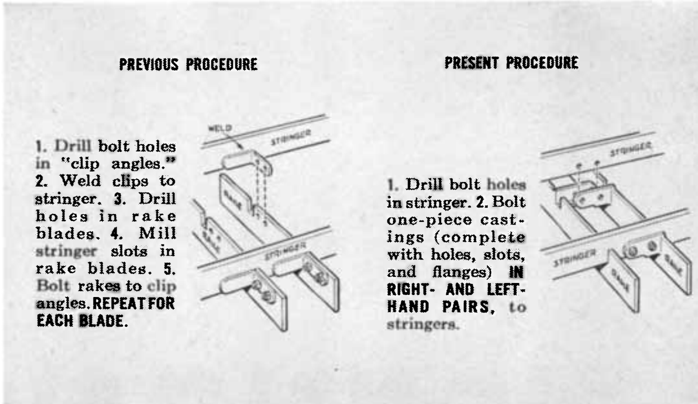
How to cut costs, improve product design with stainless steel close-tolerance castings

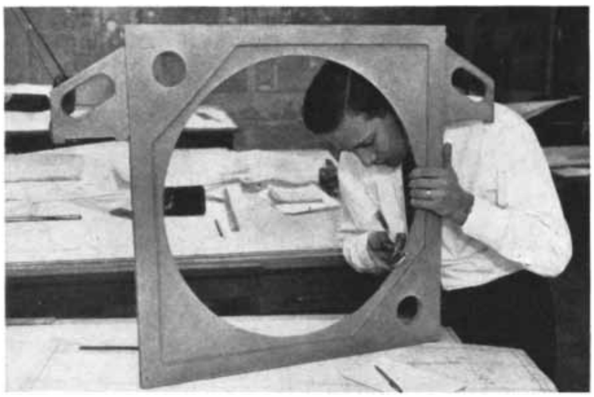
Cooper Alloy design collaboration with advanced casting techniques can simplify your fabrication, cut your costs. Here's how:

Casting of intricate parts: Jet engine afterburner component, cast for Pratt & Whitney Aircraft by Cooper Alloy, is a tangle of projections and cavities. Required, however, were the most precise dimensions to make for automatic precision machining. Shellcast® shell coring and CO_2 process cut down rejection and machining costs.

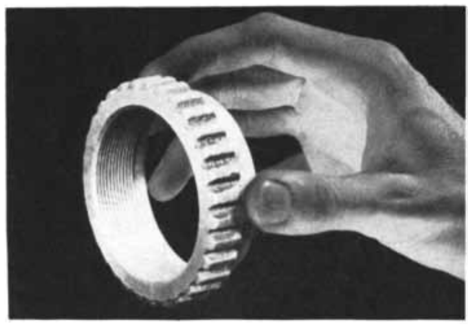
Strength and quality: Castings stronger than forgings! These Cooper Alloy nuclear service fittings possess high-temperature yield strengths 20% higher than minimum code specifications. Tough quality requirements have been met and bettered on a regular repetitive quality basis.



Part redesigned, simplified, assembly costs lowered. Classifier rake blade, Shellcast® by Cooper Alloy for Dorr-Oliver Inc., was originally made by welding cast and machined elements. Close-tolerance, smooth-surface shell castings made possible design change to one-piece cast unit, eliminating welding and much of the assembly costs.



Casting of thin-walled close-dimensioned parts. Tennessee Eastman filter frame plate previously required a good deal of careful milling on thin inner web. Combined use of shell core in a sand mold held tolerances, eliminated milling operation.



Product improvement: Gear lugs on adjusting ring for Manning, Maxwell & Moore pressure safety relief valve, formerly sand cast, are now being produced directly by Shellcast® process. Dimensional accuracy possible with shell castings permitted redesign of part to give more lugs, finer adjustability in use.

If you haven't looked over your fabrication and assembly costs lately, check the unusual cost-saving techniques listed in the capsule stories shown above. They are typical of Cooper Alloy advanced casting know-how. Many parts and assemblies that you probably haven't even considered as makable by castings, can be now by Cooper Alloy, specialists for over 35 years in casting *only* stainless steel.

Want more information? To learn more of how Cooper Alloy know-how can help cut *your* manufacturing costs, write for our free 16-page booklet, "Cooper Alloy—Pioneering in Stainless Steel." Also available, information on the other problem-solving Cooper Alloy products listed below.

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Established 1845 SCIENTIFIC AMERICAN March, 1958 Volume 198 Number 3

Atomic Power in Britain

With the Calder Hall reactors feeding into its national power grid and several other stations nearing completion, Britain leads the world in the peaceful application of atomic energy

by Sir Christopher Hinton

On October 17, 1956, Her Majesty the Queen officially opened the nuclear power station at Calder Hall when she switched electrical power generated from its reactors into the distribution mains of the Central Electricity Authority. She was making history, for this was the first time anywhere in the world that nuclear power had been used to generate the electricity used in factories and homes. The weather during the week preceding had been dismal: on the day before the opening ceremony the clouds were right down on the power station. During the night a gale blew in from the sea and flattened a refreshment tent, but on the morning of October 17 the clouds had blown away and the ceremony was performed under a blue sky with a fresh wind whipping the flags and bunting on the stands. The weather was appropriate to the occasion, for on that day the United Kingdom atomic energy program, which had been through a good deal of depressing weather, broke through into the sunshine of international prominence.

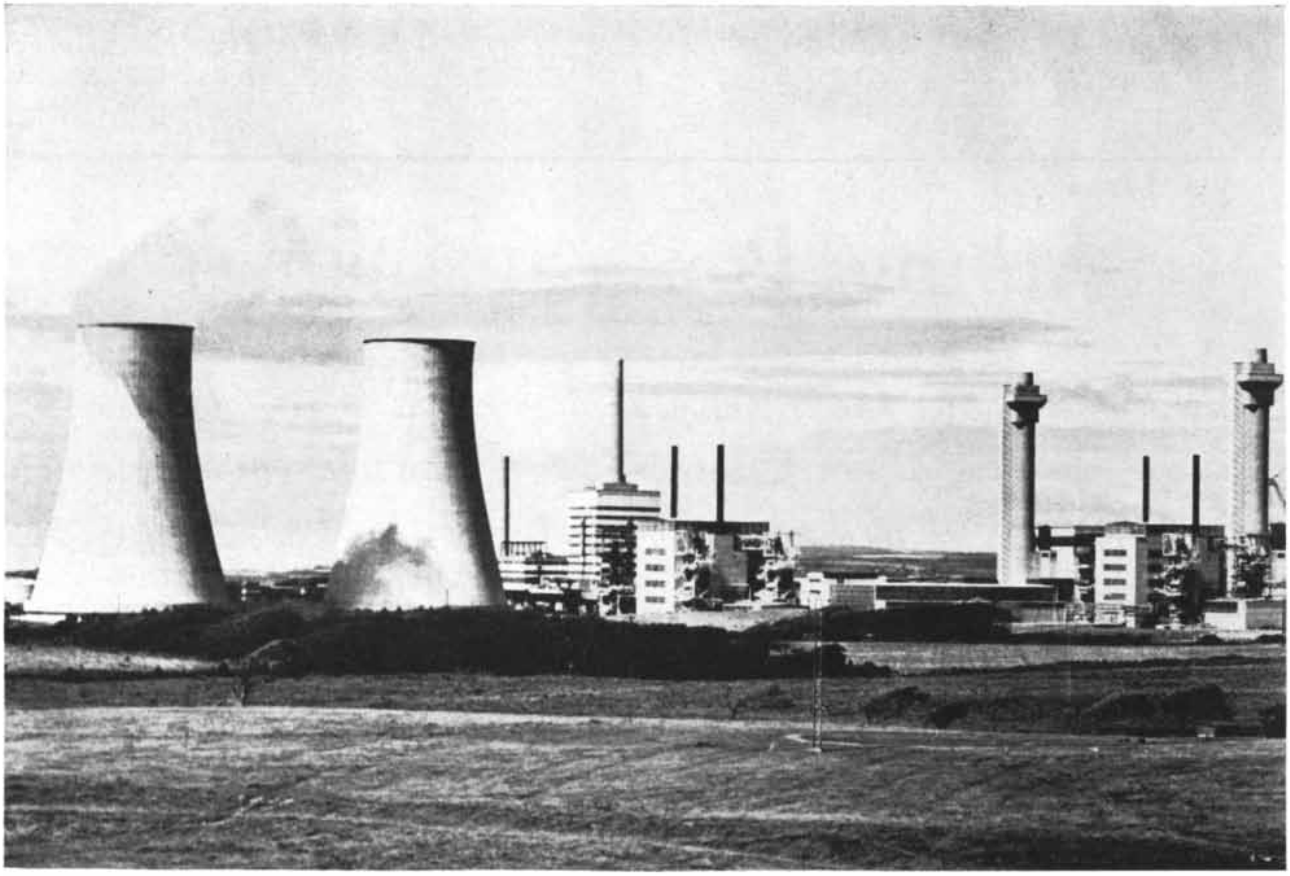
We had undertaken our atomic energy developments at the end of the war with little help from the great wartime research and industrial program in the U. S. A few of our scientists had worked in that program; a larger number had been on the team that developed the immensely successful research reactor that was built at Chalk River in Canada. But we had only one or two engineers who had experience in nuclear work and no management staff which had operated factories. The MacMahon Act denied us access to U. S. information.

Toward the end of 1945 the decision was taken to build a nuclear research station at Harwell, and in December of that year I was asked to set up an organization to design and operate industrial atomic-energy establishments. Our office at Risley was opened on February 6, 1946, with a total staff of 18, including clerks and typists. Our first tasks were to design a research reactor for Harwell and at the same time to construct a plant to process the uranium ore and manufacture the fuel elements required for that reactor and for the larger reactors needed for plutonium production.

It was at first intended that these large reactors should be of a design similar to those at Hanford in the U. S., *i.e.*, thermal (slow) neutron reactors, graphite-moderated and water-cooled. But at that time it was not possible to build reactors of this type with inherent stability. During operation they might become supercritical and disperse radioactive fission products over a fairly large area of the countryside. The reason is that the coolant which surrounds the fuel elements in a water-cooled thermal reactor acts both as a moderator and as a neutron absorber; that is to say, it serves the useful function of helping to slow neutrons down, but at the same time it has the undesirable characteristic of capturing them so that they are no longer available to cause further fissions. The net effect of the water is to slow down the chain reaction. Now if the flow of cooling water is suddenly stopped, and if the control rods fail to operate, the heat of fission will vaporize the water and eject most of it from the reactor. The neutrons which had been absorbed by the water become available to cause fissions and so increase the activity of the reactor. If the automatic control devices operate satisfactorily, the reactor is safeguarded, but they cannot be completely infallible. If they fail, the activity may build up so quickly as to cause the fuel elements to vaporize and disintegrate. Today it is possible to avoid this instability in graphite-moderated, water-cooled reactors, but in 1946 we did not know how.

The recognized instability of the Hanford reactors had led the Americans to locate them remotely in barren country. In large and thinly populated nations like the U. S. it is reasonably easy to choose sites having the necessary degree of isolation. In the United Kingdom, however, the problem of finding a site sufficiently remote to comply with the safety distances which had to be observed was extremely difficult.

We realized that if we could cool our reactor with gas instead of water we should achieve inherent stability and could then place our reactor in a comparatively accessible site. Gases such as carbon dioxide absorb very few neutrons but do act as moderators. Hence their net effect is to accelerate rather than



CALDER HALL STATION appears at the left in this photograph. In the foreground are the cooling towers for the two reactors, which are housed in the buildings in center. At right can be seen the plutonium factory at Windscale, across the River Calder.

slow down the chain reaction. So if the coolant is lost from a gas-cooled reactor, the activity of the reactor will diminish and it will tend to shut itself down.

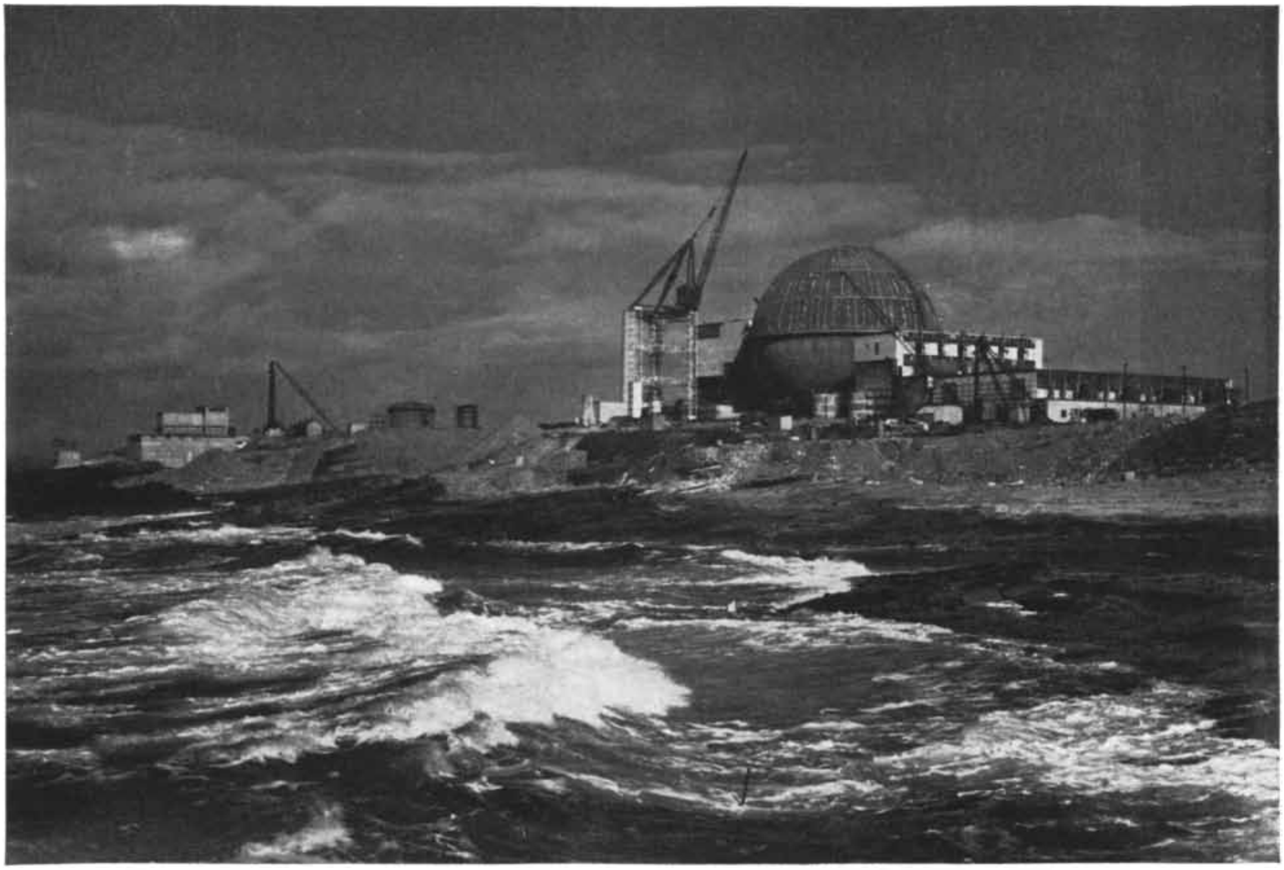
We knew that during the war the Americans had wished to build a large gas-cooled reactor, but were discouraged by the difficulty of obtaining the huge blowers that were required. The attractions of gas cooling were, however, so great that we started an intensive study of the problem. We came to the conclusion that, by putting cooling fins on the fuel-element cans and compressing our coolant gas, we could design gas-cooled, graphite-moderated reactors which would not only produce plutonium but would at the same time generate electrical power. Power could not be generated, however, unless the temperature of the gas leaving the reactor was reasonably high, and the problems of achieving these temperatures involved more research than we had time for. We realized that by temporarily sacrificing our objective of generating electrical power and by using air at atmospheric pressure as our coolant we should be able to build a reactor for the production of plutonium which would be inherently safe and which would not need to be built in a remote locality.

In the autumn of 1947 we began the construction of two such reactors at Windscale; they were completed during the first half of 1950. They are cumbersome and extravagant plants, but they had the great merit of enabling us to produce plutonium at the date which had been demanded. They also gave us invaluable experience.

Meantime we continued to work on the problems of developing a gas-cooled reactor for the production of useful power. By 1953 we had arrived at a practical scheme. In that year there was an additional demand for plutonium for defense purposes, and we decided that this requirement should be met by building graphite-moderated gas-cooled reactors which would produce electrical power as a by-product. We already owned a site opposite the Windscale works on the banks of the River Calder. The site was part of an old estate called Calder Hall Farm, which gave its name to the reactor now known throughout the world. We initially planned to build one reactor, but a few months after the work had been started the defense demands were increased and a second reactor was begun. Three years later the plant was again extended by two more reactors, and a second plant of identical design was inaugurated at Chapel Cross in southern Scotland.

The first reactor "went critical" in May, 1956, and by July of that year was developing electrical power which was used at the Windscale works. By October, when power was turned into the distribution network of the Central Electricity Authority, the reactor was working practically at full-rated capacity.

In the Calder Hall reactors the heat of fission is removed from the fuel elements by cooling them with pressurized carbon dioxide gas instead of with atmospheric air, as in the Windscale reactors. The uranium fuel elements are arranged vertically in the mass of the graphite moderator, and the whole of the reactor core is enclosed in a steel pressure vessel which is more than 40 feet in diameter. Hot gas leaving this vessel is passed through ducts to the heat



FAST-BREEDER REACTOR is being built at Dounreay, on the north coast of Scotland. The spherical structure is a pressure vessel surrounding the reactor. This experimental device will be fueled initially with enriched uranium, and ultimately with plutonium.

exchangers in which it gives up its heat to water and so generates steam which is used in conventional turbogenerators to make electric power. The carbon dioxide gas cooled down in this way passes through other ducts to the blowers which force it back once more into the nuclear-reactor core.

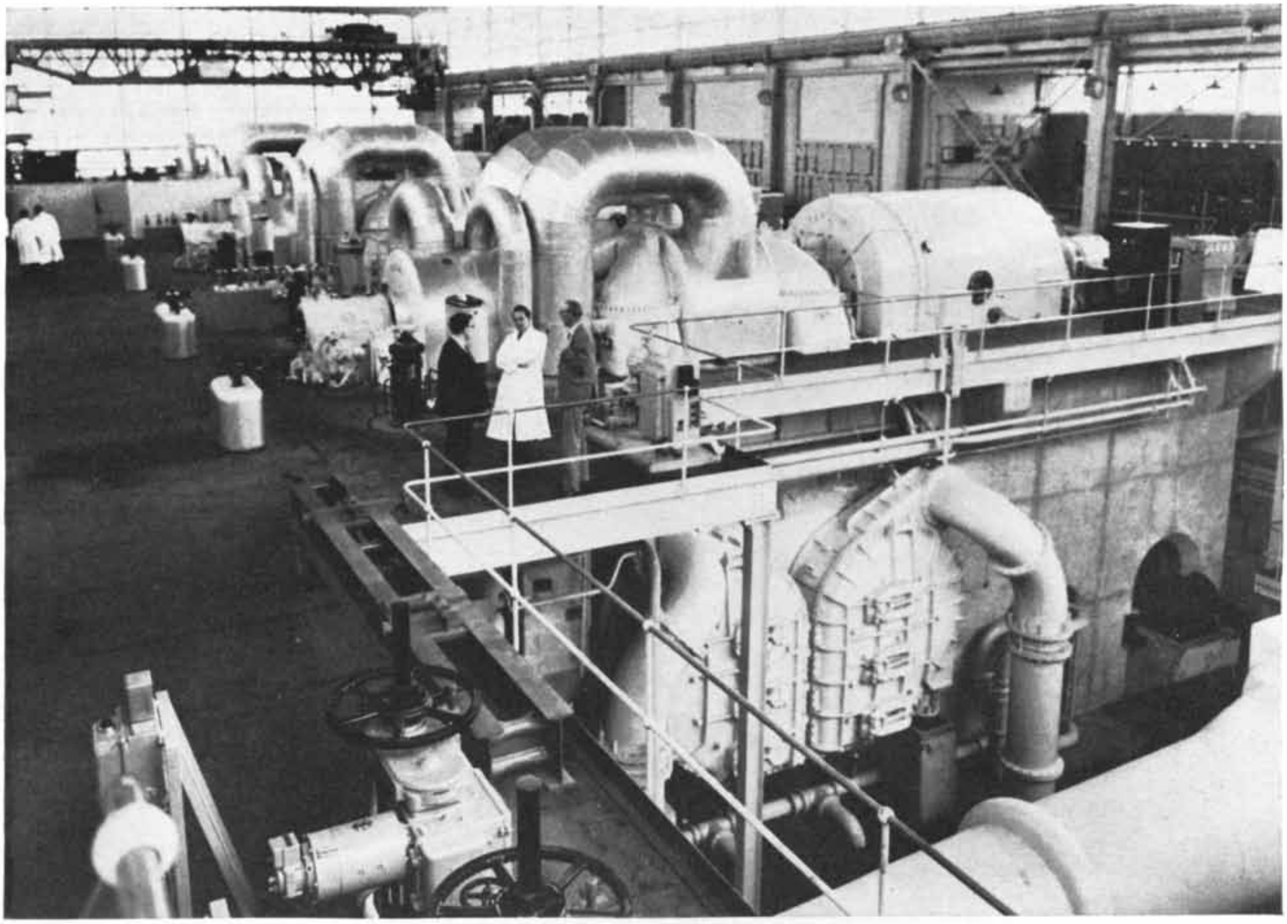
In the middle of 1954, when the construction of the first Calder Hall reactor was only in its early stages, we felt quite certain that it could form the basis of a national program for the large-scale development of nuclear power, and we produced a report which set out a long-term scheme for this development. In preparing this scheme we realized that nuclear power could not, in its early stages, compete with conventional power unless some industrial use were found for the by-product plutonium. Our scheme therefore envisaged the use of this plutonium as fuel in reactors of more advanced types.

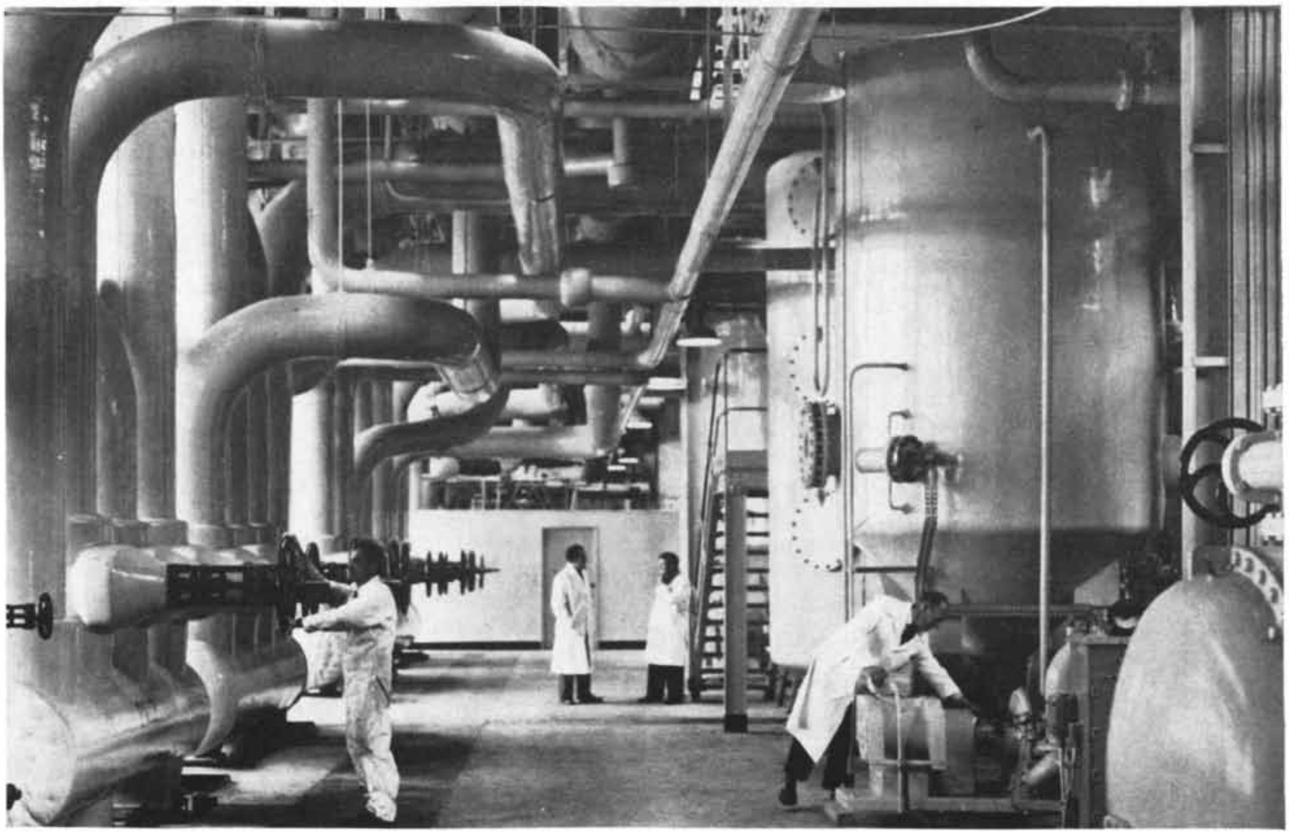
Our long-term plan envisaged the construction of 12 stations by 1965 which would have a capacity of between 1.8 and 2 million kilowatts, an electrical output equal to that from five to six million tons of coal a year. Further construction would then increase nuclear power capacity to the equivalent of 40 million tons of coal a year by 1975.

Up to that time all of our nuclear power plants had been designed, built and operated by the British Atomic Energy Authority. It was now decided to bring industry into the program. The four largest British manufacturers of conventional electricity generating plants were therefore approached. It was suggested to them that they should associate themselves with other firms in the field to form combines which would be trained in the design of nuclear power plants. These combines could undertake the design and construction of the industrial nuclear stations required both in the British program and in the export market we hoped to develop. Engineers from these combines were put through extended training courses by the Atomic Energy Authority. It was further decided to turn over the operation of the nuclear power plants in England to the Central Electricity Authority, and in Scotland to the South of Scotland and North of Scotland electricity boards. Engineers from these three nationalized concerns were therefore given training courses also.

On December 13, 1956, the Central Electricity Authority placed orders with the industrial combines for the first two industrial nuclear power stations. One of the stations is at Bradwell on the Thames estuary while the second is at Berkeley on the River Severn. These two plants are now well advanced. Six months after the first orders the South of Scotland Electricity Board placed an order for its first station, and its construction is now proceeding on the Ayrshire coast; the Central Electricity Authority placed an additional order a few weeks later for the largest station of all, which has just been started on the north coast of Somerset. The total value of all of these orders amounts to around 200 million pounds; the capacity of the stations is approximately 1.4 million kilowatts.

We had originally expected that the capacity of each station would be around 150,000 to 200,000 kilowatts, but engineering developments by the four industrial combines showed that far larger





TURBOGENERATORS AT CALDER HALL are driven by steam produced in the heat exchangers of the two reactors. At top is the turbine room itself; at bottom is the basement in which can be seen the pipe system bringing steam from one of the reactors.

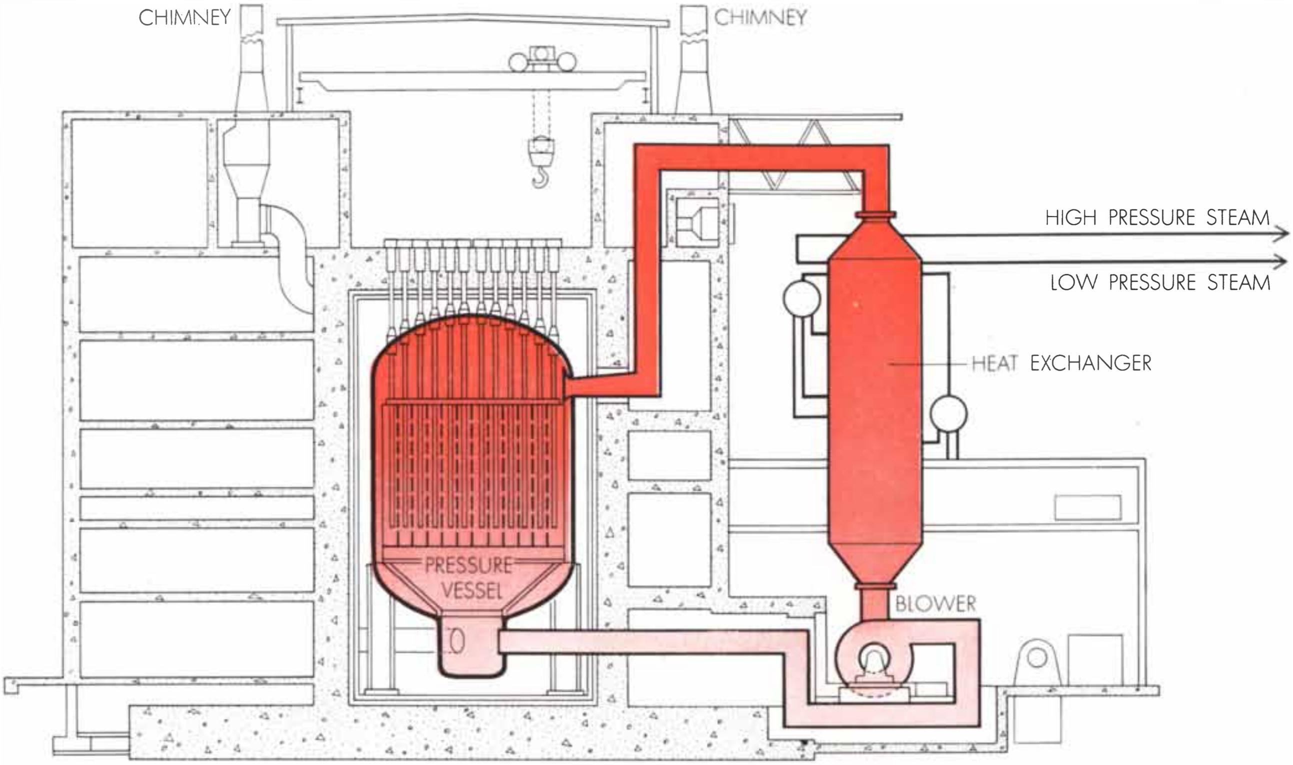
stations were possible, and that such stations would have a great advantage in economy of construction cost. As a result it was decided that the program could be enlarged without materially increasing the number of stations to be built in the first 10-year period. The present plan calls for the construction of between five and six million kilowatts capacity by 1966.

It must be realized that Calder Hall was built essentially for the production of plutonium, and that electrical power is generated only as a by-product. It would therefore be unrealistic to attempt to estimate the cost of nuclear power by a direct calculation of the cost of the electricity which is produced in the reactors there. The cost of nuclear power can, however, be assessed from the capital cost of the plants which are being built for the electricity authorities and by analogy with the operating experience at Calder Hall. Such analysis shows that the cost per kilowatt-hour of electricity sent out will be of the order of .66 pence. This is about 10 per cent more expensive than the price at which electrical power can be produced in the most modern conventional plants. However, the cost of coal in the United Kingdom has risen steadily in terms of real money values. Although this upward trend may be diminished by the extensive plans of the National Coal Board to mechanize coal mining, it appears most probable that it will not be entirely halted. This rise in the price of coal will naturally improve the competitive position of nuclear power, and, with improving technology, the cost of producing electricity in the nuclear stations will certainly come down.

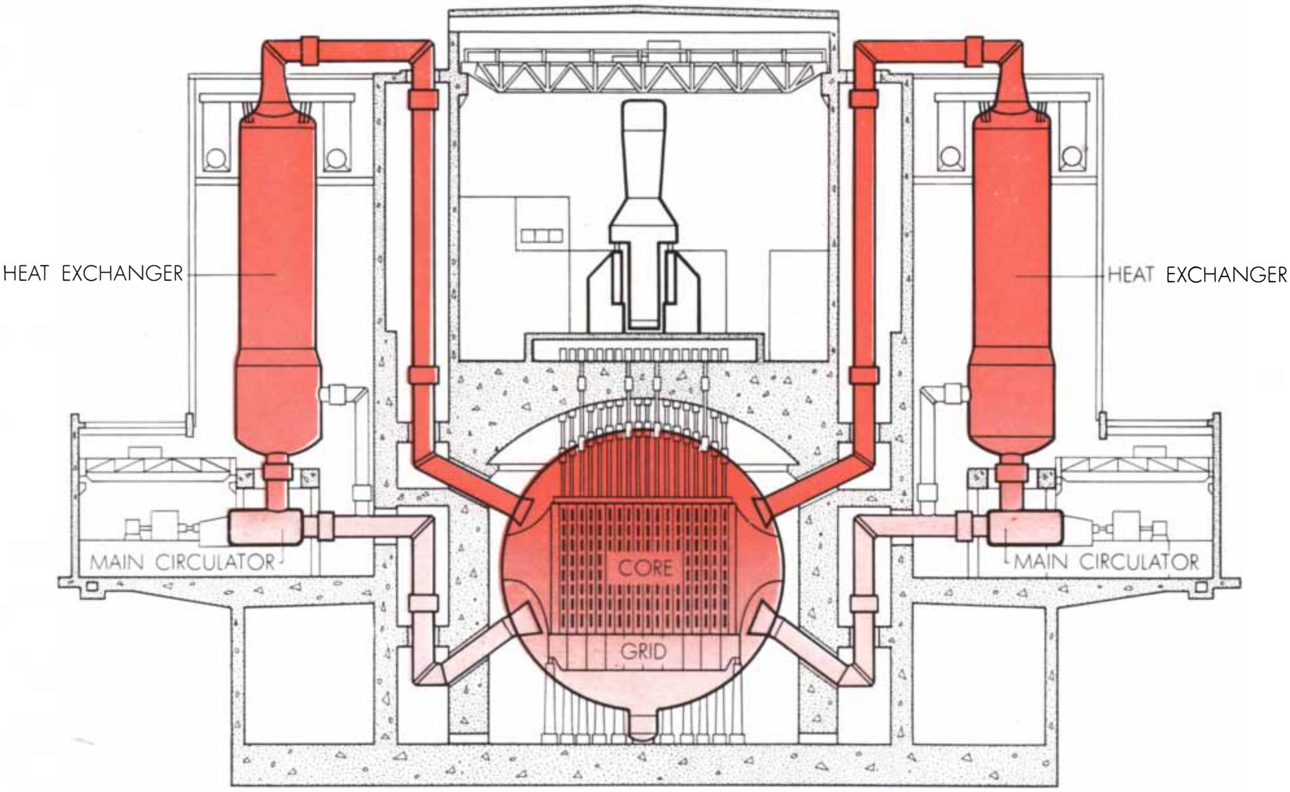
In a conventional power plant about one third of the cost of each unit of electricity sent out is accountable to capital charges, the other two thirds arising from coal and operating costs. In a nuclear power plant this proportion is roughly reversed: only one third of the cost of each unit sent out is accountable to fuel and operating costs, and two thirds arise from capital charges. Conventional power plants can be built in Great Britain today at a cost of between 40 and 50 pounds per kilowatt sent out. The capital cost of the first nuclear power plants ordered was of the order of 140 pounds per kilowatt. In the later plants this figure is more nearly 120 pounds per kilowatt, and there is every indication that the downward trend in capital cost will continue.

Up to now the decrease in capital cost has been achieved largely by the straightforward engineering development of the Calder Hall plants. The combines which are designing the new plants have found it feasible to use thicker plate for the pressure vessels and better techniques for the manufacture of the heat exchangers. This has made it possible for them to design units of greater capacity and, as always happens, this higher capacity has reduced the capital expenditure per kilowatt. There is, however, a limit beyond which these purely engineering improvements are unlikely to go, and in the long run reduction in capital cost of nuclear power plants must arise (as it has in the case of convention-

ATOMIC POWER STATIONS will soon be scattered over much of Great Britain. Map shows locations of these sites and of experimental installations mentioned in this article.



COOLING CYCLE of the Calder Hall reactors is shown in color. Cool gas (*light color*) enters core at bottom and is blown through ducts around the fuel rods. Hot gas (*dark color*) emerges at top and passes to an exchanger where its heat is used to make steam.



BRADWELL REACTOR, here diagrammed in cross section, is one of the power plants being built by industrial groups in Britain. Its design is basically like that of the Calder Hall reactors, but it will produce more power. The cooling cycle is in color.

al power plants) from the use of higher temperatures in the gas cycle.

Fundamentally the problem lies in the fuel elements. In existing reactors the fuel elements are bars of uranium approximately one inch in diameter. These are enclosed in magnesium-alloy cans to protect them from oxidation and to contain the fission products. The melting point of magnesium is around 600 degrees centigrade; this sets a definite limit to the temperatures that can be achieved. To go higher it will be necessary to use canning materials other than magnesium. Beryllium appears to be suitable, but it is expensive and its use in reactors cannot be afforded unless the specific rating of the fuel element is increased; that is, unless the amount of heat released from each ton of fuel elements is far higher than in present reactors.

But as we try to take more heat from the fuel elements we run into difficulties within the uranium itself. The heat of fission must be conducted from the center of the fuel element to the surface from which it is removed. This requires a temperature gradient within the metal, and with high ratings the difference in temperature between the center of the fuel element and its surface is considerable. If we attempt to achieve higher ratings while using fuel elements of the present form, we find that the temperature in the center of the uranium is dangerously high. To avoid this we have to use elements having a smaller cross section; this is unfavorable from the point of view of nuclear physics and demands the use of enriched uranium. This again increases the price of the fuel elements and cannot be justified unless high burn-ups are achieved, that is to say, unless the fuel elements can be left in the reactor for considerable periods of time. It is unlikely that we shall be able to achieve these high burn-ups with metallic uranium; in all probability we shall have to go to uranium in a ceramic form, which further increases the cost. However, all these expenses will be justified if they lead to the higher temperatures which make possible improved thermal efficiencies and more compact units of lower capital cost.

Reduction in capital cost is essential. Nuclear power has been given a temporary advantage which it cannot hope to hold indefinitely. These early nuclear plants are being used as base-load stations, that is, they are operated continuously. Obviously when a power plant has a high capital cost and a low fuel cost it is most economical to keep it in operation on full load for as many hours as possible during the year. The initial plants will generate electricity at all times except when they are shut down for repairs. By 1965 it will be impossible to give this advantage to the nuclear power plants. Then the total installed capacity of nuclear power will be such that nuclear stations will have to carry a share of the peak loads, and it will be impossible to run them steadily at their designed capacity. This will result in an increase in the capital charges per unit sent out, and unless the capital and operating costs of nuclear plants have been brought down they will no longer be able to compete with conventional plants. It is at that date that nuclear power will have to meet its second crisis. Its first crisis occurred during 1956, when the operation of Calder Hall had to establish that our plans were well founded.

Nuclear power engineering in the United Kingdom has not been confined to the development of reactors of the Calder Hall type. We have studied various other forms of thermal reactors, including the pressurized-water reactor (which is the preferred type in the U. S.), the sodium-graphite reactor and others. Our studies suggest that for the United Kingdom these reactors offer no advantages over the gas-cooled type. In the thermal-reactor field we have thought it worthwhile to concentrate our resources on the further development of gas-cooled systems, which appear to us to be the most promising.

It has already been pointed out that these first-stage reactors can only be economical if a buyer can be found for their by-product: plutonium. It would be possible to use this by-product as fuel in thermal reactors, but there is a serious disadvantage in doing so. Plutonium absorbs thermal neutrons to form higher isotopes which are not fissionable and which capture neutrons; these higher isotopes act as "poisons" in the reactor. On the other hand, plutonium will not absorb neutrons which have not been slowed down in a moderator. Thus it is more effectively and economically used as a fuel in a fast-neutron reactor. Even before ground was broken for the Calder Hall reactors, we had begun to develop a fast reactor. We realized that in the long run it would almost certainly form an essential part of an integrated power program, and that the technological and scientific problems involved were extremely complex and would require a long time for their solution. This fast reactor is now about to go into operation at Dounreay in the north of Scotland. It should not be regarded as anything more than a large experimental prototype. Many years of work probably lie ahead before we can say whether its design is sound. But certainly the reactor at Dounreay is giving invaluable information on the problems involved not merely in the design of fast breeder-reactors but also in the design of highly rated reactors of all kinds.

The first land-based reactor for the generation of appreciable quantities of power from nuclear energy in the U. S. went into operation at Shippingport, Pa., in December, 1957. The Calder Hall reactors have now been in steady operation for more than 18 months. It would therefore seem reasonable to say that, starting from nothing in 1946, the British are, temporarily at any rate, ahead of the U. S. in the industrial-reactor field.

I hope it will not be taken amiss if I attempt to analyze the reasons for this. To attribute it to any deficiency in research on atomic energy would surely be wrong. From the information available to us we have the impression that U. S. basic research has been a little more advanced than ours. To attribute it to an alleged lack of American ability to bridge the gap between scientific research and industrial achievement would also be wrong. That ability was handsomely demonstrated by the wartime atomic-weapons program and by the outstandingly successful work on the nuclear propulsion of submarines.

The real reason for the present relative positions of the U. S. and the United Kingdom in the industrial application of nuclear power seems to lie in the well-known relation between necessity and invention. British supplies of coal are running short. All of our oil is imported. From the outset we realized that we would need nuclear power and need it soon. Our organization was compact, and the collaboration between scientists and engineers was first-class. Above all, the program was carried through with relentless singleness of purpose and with the conviction that failure was unthinkable. The competition among industrial engineers increased the rate of progress.

There is no reason to believe that Americans could not have organized with equal success, but you did not have the same need. Now that your first industrial reactor is in operation, we look forward to competition and collaboration, not merely between teams working in the United Kingdom, but between teams working in our two countries.

THE FIRE ANT

An imported species of this insect has become a serious pest in the South. It is studied both to find means to control it and to learn how a species adapts itself to a new environment

by Edward O. Wilson

"Fire ant" is the common name of many ant species distributed throughout the tropical and warm temperate regions of the New World. The sting of these ants causes a burning sensation, hence the name. Three species of fire ant are native to the southern U. S.; a fourth (*Solenopsis saevissima*) was introduced from South America around 1918. For 10 years the imported fire ant lived within the city limits of Mobile, Ala.; then it began to spread. It has now become a dominant species over a large part of the South, and has developed into a serious pest.

It is not only a serious pest but a versatile one. In South America the normal diet of the fire ant appears to consist mostly of seeds, the flesh of insects and "honeydew" gathered from living insects such as aphids. But its dense

FIRE ANTS swarm out of a fire-ant mound which has been broken open. These ants are workers, which sting fiercely. The mound is honeycombed with passages. It is built by the workers out of tightly packed particles of soil; thus it has considerable strength.

populations in the U. S. have extended this diet to include, to the grief of farmers, the seedlings of several important food crops and the newborn young of poultry and livestock. Nesting fire ants build large mounds, numbering up to 50 an acre, which hamper plowing and harvesting. Moreover, worker ants swarm aggressively out of the nests at the slightest disturbance, making manual labor in infested fields painful and difficult. Some farmers who have heavily infested land are unable to hire sufficient help, and are forced to abandon land to the ants. In two counties of southern Alabama the crop damage caused by fire ants was recently estimated at more than $50,000. The total agricultural loss in the South probably extends into millions of dollars.

The onslaught of the fire ant has reached such proportions that the Federal Government has undertaken to conduct a special control program. Last spring Congress appropriated $2.4 million to the Department of Agriculture for this purpose. The Department's plan, which is being put into effect now and is scheduled to last for several years, calls for the spraying of 20 to 30 million acres with Dieldrin, a hydrocarbon insecticide many times more toxic than DDT. The Dieldrin will be distributed both from the ground and from airplanes.

This unhappy tale has a special interest for the student of organic evolution. A fundamental problem of evolution is: How does a species adapt itself to a new environment? The problem is dramatized by the special case of animals and plants transported by man to areas far from their native ranges. Some transplanted species are immediately successful, building up huge populations until they become dominant members of the local fauna and flora; related species completely fail to establish themselves. Still other species follow a more baffling pattern. For a time they maintain a limited and precarious "beachhead"; then suddenly and unpredictably they explode into a phase of rapid expansion. The imported fire ant occupies the last category.

Like most other ants, fire ants are dispersed by the nuptial flights of males and winged virgin queens. During the flight a queen may travel as far as five miles from the colony of her origin. After she mates with the male she descends to earth, excavates a simple burrow in the soil, and over a period of several days lays approximately 100 eggs. The

FIRE-ANT MOUNDS dot a field in Mississippi's Lowndes County. The mounds interfere with plowing and harvesting. The ants also infest the seedlings of several important crops.

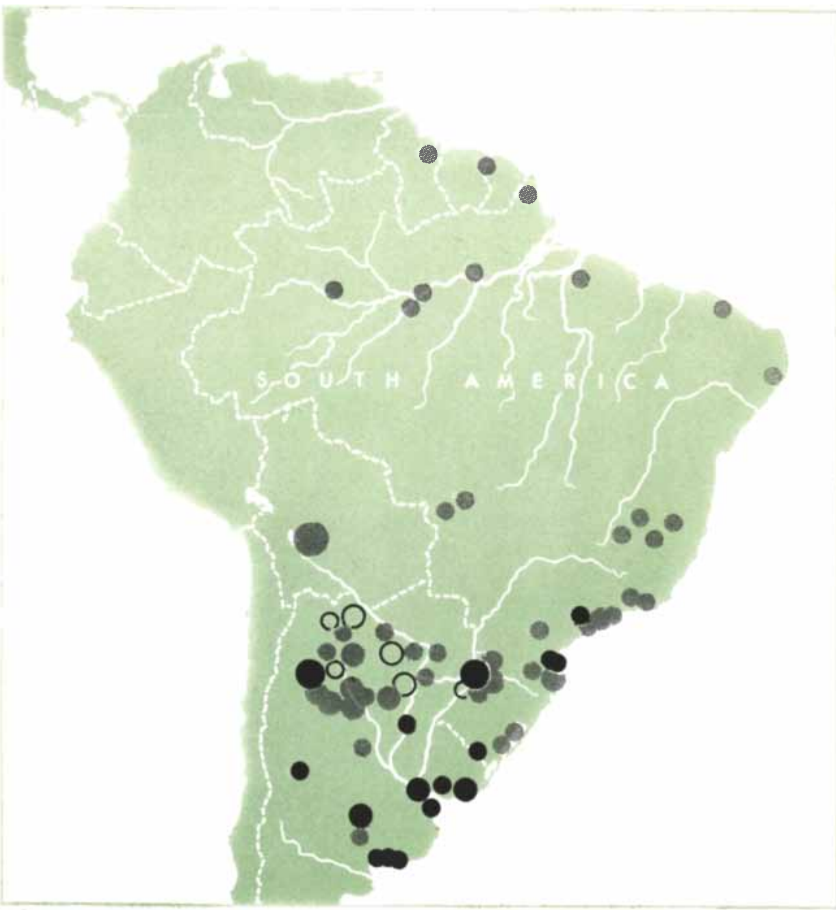
INFESTED FIELD in Lowndes County is sprayed with insecticide in a water emulsion. One treatment is capable of eliminating the ant from a field for as long as three years.

first brood of worker ants then develops very rapidly. The eggs hatch in about nine days, the larvae change to pupae after about the same period, and adults emerge from the pupae about a week later. Often small groups of queens cooperate to found colonies. Later, however, the first emerging workers execute the surplus queens so that only one remains. Once established, the young colony grows with startling speed. Within four or five months it contains over 1,000 workers. In a year it seethes with tens of thousands of workers and has reached sexual maturity; that is, it has begun to produce the winged males and queens which start the life cycles of new colonies.

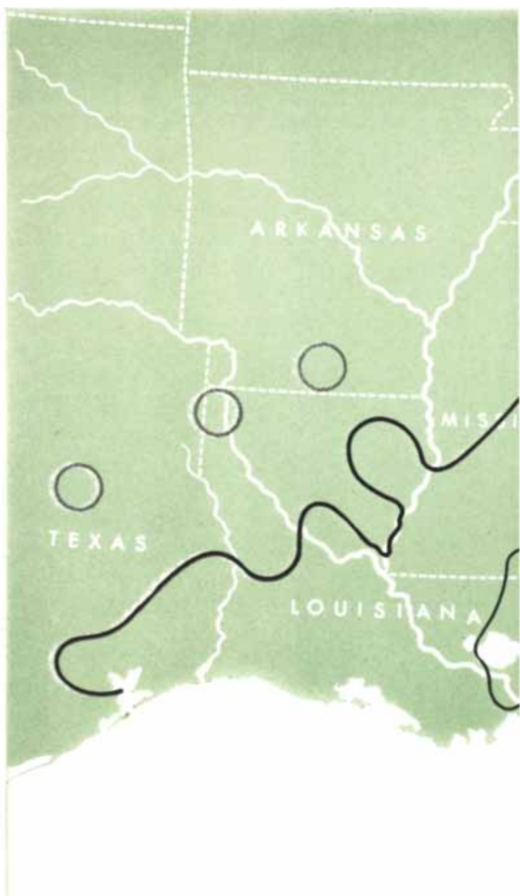
Given this means of dispersion, exactly how did the imported fire ant spread in the U. S.? As I have indicated, the imported population was at first quiescent and then exploded. We now know that at the beginning of the explosive phase an important change in the genetic structure of the population occurred. In the 1920s, following the introduction of the colony into Mobile, it consisted entirely of a relatively large, blackish-brown form that corresponded exactly to the southernmost race of the mother population in South America. The range of this race is northern and central Argentina and part of southern Uruguay. The founding colony (or colonies) may have come from Buenos Aires or Montevideo in ships. Once established in Mobile, the dark form was not notably successful. William S. Creighton, a Harvard University graduate student in entomology who studied the population in 1928, found it limited to Mobile and the suburban community of Spring Hill. There was no inkling of the explosion to come.

Sometime in the 1930s a second form of the imported fire ant made its appearance in the Mobile area. It was reddish-brown in color, smaller in size than the original immigrant, and it built smaller nests. Its origin is not positively known. Three possibilities have been considered: (1) that the second form was introduced from another part of South America, (2) that it was a mutation of the original dark form, (3) that it represented a recombination of genes already present in the dark form. Several lines of evidence point to the first alternative. Where light and dark colonies meet we find colonies of many intermediate colors. This suggests that the variation in color is controlled not by one gene but by several. Moreover, the light and dark forms differ in characteristics other than color, and these characteristics vary independently of one another; thus they are probably controlled by different groups of genes. So it seems unlikely that mutation or recombination can account for the sudden appearance of the complex genetic structure of the light form.

Furthermore, recent studies have shown that the light form, or its close equivalent, occurs abundantly in certain parts of northern Argentina and southern Bolivia. Perhaps like the dark form it was introduced into the U. S. in cargo shipped out of Buenos Aires or Montevideo. Whatever the origin of the light form, the significant fact is that it



FIRE-ANT SPECIES imported from South America is widely distributed there. Black dots represent the dark form of the species; circles, the light form; gray dots, all other forms.



SPREAD OF SPECIES began about 1918. Black lines show the limits of the central appeared at just about the time that the population as a whole began its rapid growth in all directions out of Mobile.

When I first began to study the imported fire ant in 1949, I noticed that the two color forms were distributed around Mobile in a curious and significant pattern. The dark form was very rare within the city itself, despite the fact that it had been the predominant or exclusive form when Creighton studied it there 20 years earlier. Now it was limited to a few isolated localities concentrated mostly along the southern periphery of the range [*see map at right below*]. Everywhere else in the Mobile area the teeming colonies were composed of the light form. To the north, in the Mississippi towns of Meridian and Artesia, there were small secondary populations consisting entirely of the dark form. Investigation showed that these localities had been colonized by ants from the Mobile area during the 1930s, probably while the dark form still predominated in the primary population. Other isolated populations were found at Thomasville and Selma in Alabama. These consisted entirely of the light form. As one might have predicted, it was subsequently disclosed that these light-form populations were quite recent in origin, being no more than five years old in 1949. Compared to the dark-form populations of Mississippi, they were remarkably successful and fast-growing. The Selma population, in fact, already exceeded in size both Mississippi populations taken together.

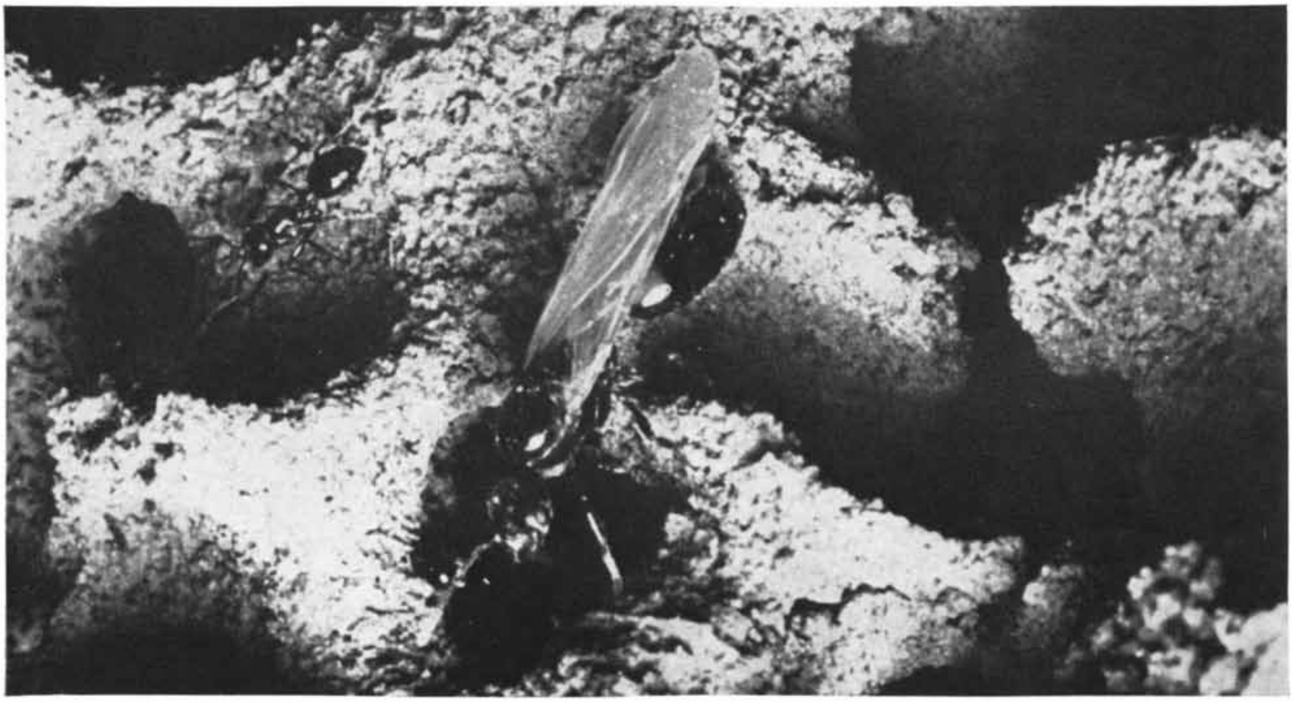
All this information clearly indicated that the imported fire ant was in the midst of a rapid evolutionary change. The conclusion seemed inescapable that the light form, which had originated in the Mobile area sometime after the introduction of the dark form, was adaptively superior to the dark form and was replacing it over most of its range. Additional field studies conducted by William L. Brown and myself in 1956 and 1957 have corroborated this interpretation. We found that in the interval between 1949 and 1957 the dark form had continued to decline in the center of the main population, while the growing edge of the population had come to consist almost entirely of the light form. In some areas where the dark form had been abundant in 1949 it was now absent; only the light form persisted. By 1957 the dark-form population at Meridian had been engulfed by the northward-expanding main population, and the light form was quickly rising to predominance there. The Artesia population, 70 miles to the north of Meridian and still isolated, remained uniformly dark in composition, but its rate of spread had been far less than that of nearby light-form populations.

These most recent studies indicate that replacement of the dark-form genes is proceeding not only by genetic "swamping" but also by direct conflict between colonies. The dark form appears to be losing out in the struggle because its nest-founding queens and young colonies are destroyed by the fiercely aggressive mature colonies of the light form. Young dark-form colonies are

population by years. The gray lines indicate the limits of secondary populations in 1957.

DARK FORM OF SPECIES comprises more than 20 per cent of population in dark areas; 20 to 5 per cent in heavily hatched areas; less than 5 in light hatched. Dots are small colonies.

WORKER ANTS remove larvae from exposed part of nest. When the nest is disturbed, workers rush out to sting the interlopers. The sting is not so painful as that of a honeybee or a wasp, but it is extremely effective when delivered by large numbers of ants.



YOUNG QUEEN ANT shown in this photograph is winged, as is the male. When the male and the queen make their nuptial flight, they may travel as far as five miles. Four or five months after they have mated, the new colony contains more than 1,000 workers.

very rare today in areas where mature colonies of the light form exist in any number. To look at it another way, the dark form appears to be declining because, under competitive pressure from the light form, it is unable to reproduce itself adequately.

The future of the imported fire ant in the U. S. is difficult to predict. Energized by the highly adaptive genes of the light form, its rapidly growing populations may within the next 10 or 20 years come to cover all of the southeastern states. As a warm temperate-zone species that nests exclusively out-of-doors, it may never succeed in pushing north much beyond its present limits in Alabama and North Carolina, but within this range it will undoubtedly continue to wax as one of the most noxious of all insect pests.

The Department of Agriculture of course hopes to deal a lasting blow to the fire-ant population. But there are many potentially hindering complications in a program as broad as the one proposed. The possibility always exists that the natural enemies of the fire ant, including its various predators, parasites and competitors, will be hit harder by the Dieldrin insecticide than the ant itself. The subsequent relief of this form of environmental pressure on the ant may result in its rapid resurgence a few years after the spraying, perhaps to population densities even higher than those before the spraying was started. Another drawback lies in the generally poisonous nature of Dieldrin. Officials of several conservation organizations have recently joined in opposing the Government program on the ground that Dieldrin is extremely toxic to animals other than ants and in sufficient quantities is even dangerous to man. Indeed, field studies on the effects of Dieldrin have produced some alarming information. While evaluating the biological results of the sand-fly control program in Florida's St. Lucie County, R. W. Harrington, Jr., and W. L. Bidlingmayer of the Florida State Board of Health found that a pound of Dieldrin per acre of marshland destroyed the entire fish population of more than 30 species! Virtually all crustaceans also succumbed, and for a short period of time the only larger animals left alive in the treated water were mollusks. Thus a large and vital part of the aquatic fauna had been wiped out in one stroke.

It is probably too soon to judge whether similar detrimental side-effects will follow from the fire-ant control program, but it is at least clear that long-range control of such vast insect populations is going to be a very complicated matter. It is likely that biological control—the introduction of new parasites and predators which attack the fire ant—will have to be attempted. This technique, which has been so effective in stopping other insect pests, has not yet been investigated with respect to the fire ant. Finally there is the ironic fact that the fire-ant infestation, if left alone long enough, would probably abate by itself. A general characteristic of introduced populations is that in time native elements adjust to them and eventually reduce their density. But the period of adjustment could take years or decades, and continued research on control measures seems economically imperative. Meantime the imported fire ant will provide valuable clues as to the kind of genetic processes that underlie the adaptation of animal species to new environments.

WORKERS TEND APHIDS (small white objects) on the underside of a leaf. At certain times of year the fire ant feeds on the "honeydew" secreted by aphids and similar insects.

NORMAN CASTLES

When the Normans invaded England in the 11th century, their first fortresses were made not of stone but of wood. Recent excavations have shown what these wooden castles looked like

by Brian Hope-Taylor

". . . and they filled the land full of castles. They cruelly oppressed the wretched men of the land with castle-works; and when the castles were made they filled them with devils and evil men. . . ."

These bitter words, written in the 12th century by an anonymous Saxon monk, describe one of the principal weapons with which William the Conqueror and his barons had secured their conquest of England. The Norman cavalry overran the country. The Norman castles held it. At the time the monk's lament was written, moreover, similar castles had been built by petty warlords who had seized power during a breakdown of the central government.

In the mind's eye a "Norman castle" conjures up something out of *Ivanhoe*—massive stone battlements and a grim masonry tower. The Normans did indeed build castles of this sort during the later stages of the Conquest. From their crumbling remains we have learned much about the way in which the invaders consolidated their rule and exploited their new lands. But the first Norman castles, erected in the campaign that began in 1066, were made of wood, not stone. They could be built quickly to provide strong points from which the invaders could keep the surrounding countryside under surveillance and control until the inhabitants were pacified.

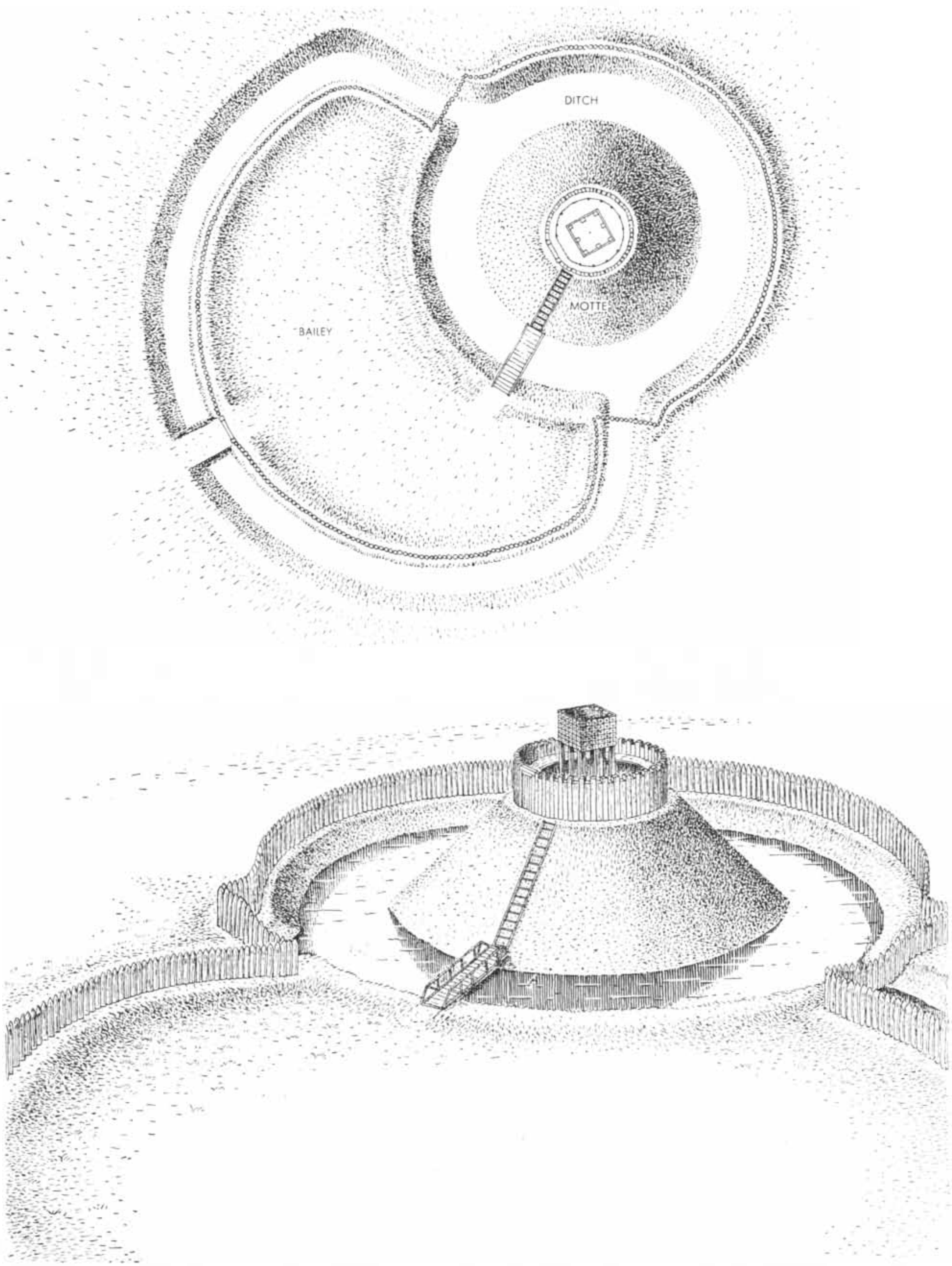
All that remains of these castles today are the great flat-topped mounds of earth on which their wooden structures stood. Such earthworks, shaped like inverted washtubs and long since overgrown, are to be seen not only in England, but also in Wales and Scotland and even in northern Ireland. Most of those originated in the internal conflict and external land-grabbing which accompanied the establishment of feudalism in Britain during the two centuries after 1066. But some of them are true monuments to the Conquest itself.

To oppressed Saxons like our anonymous chronicler these wooden castles may well have seemed the work of devils. An island people with no interest in foreign conquests, they had little experience with such sophisticated military devices. Their society had no need of feudal castles. The typical Saxon fortification was a communal affair: a town enclosed by a ditch or palisaded earthen bank, not unlike the primitive defensive stockades of prehistoric Europe. England's Saxon kings gave the nation a well-knit administration, encouraged religion, the arts, trade and agriculture, but neglected to modernize the country's defenses. Edward the Confessor, whose death opened the way to the Normans, was a pious but a weak king. While allowing his Norman favorites—a potential fifth column—to build private castles in England, he concentrated on the building of Westminster Abbey.

The Normans, by contrast, were dominated by an aristocracy of landowning warriors under a warrior duke. Their conquests, ranging from the British Isles to Palestine, made them quick to adopt and develop military devices; the feudal structure of their society filled their lands with private strongholds. In their businesslike exploitation of the lands they seized, they remind us of the Romans, and in William's ruthless generalship we can see something of Julius Caesar. But William was an unlettered Caesar and left us no commentaries on his wars, no manual of military method to explain his prowess and success. Indeed, though the Norman Conquest is one of the most familiar events in English history, our knowledge of its first and purely military phase is sparse and generalized. Documents like *Domesday Book*, William's famous tax survey of his English lands, give us a vivid and detailed picture of the Norman as a landholder and administrator. But the Norman soldier in action is represented only by sketchy accounts in the chronicles of the time, by a few scenes in the famous Bayeux Tapestry, and by the overgrown mounds of earth on which his wooden castles stood.

The wooden castle typically surmounted a fortification that combined two elements, the "motte" and the "bailey." The bailey, a relatively large area in which the garrison was lodged, resembled the primitive defensive stockade; it was surrounded by a deep ditch, the earth from which was heaped in a rampart along the inner edge and topped by a sturdy fence or palisade. The motte was the steep-sided mound of earth, heaped up from a formidable ditch that encircled it. On its flat top stood the castle proper.

When the castle had served its purpose, it was dismantled, burned or left to rot. At sites of permanent strategic importance the wooden castles were replaced by stone buildings. The Conqueror's motte at Windsor, for example, is crowned by the ancient stone Round Tower. Nothing remains of the wooden buildings but traces buried in the mottes. In theory this should present no great problems to the archaeologist. The soil should hold traces of the vanished timbers, if only as differences in color and texture, and from this it should be possible to map out the plan of the structure. In fact, the archaeologist finds that erosion and rabbits, tree-roots and treasure-seekers, have left more of a



WOODEN CASTLE at Abinger was reconstructed from excavations. The bailey, although characteristic of this sort of fortification, is conjectural; no traces of it survive at Abinger, possibly because of centuries of plowing. A typical bailey enclosed residential structures and other buildings. At Abinger the bridge, supported by an underwater causeway, could be removed in case of attack.

BAYEUX TAPESTRY shows a motte castle at Dol in Brittany. The ditch, shown in cross section, is spanned by a flying bridge. The checkerboard pattern on the tower probably indicates "armor plating" of lead or hide squares, each with a large nail in its center.

mark on the motte than have its buildings. But despite these hazards the first systematic attempt to recover the plan of the timberwoods on a motte was wholly successful.

In choosing a site for our excavations we rejected those where the wooden castle had been replaced by stone buildings. At such sites the original surface is either sealed by masonry or so disturbed by rebuilding as to leave no coherent traces of the wooden structure. We chose a grassy mound near the manor house at Abinger, a village about 24 miles southwest of London. The manor house itself stands in what was probably the bailey. Though there are now no traces of surrounding earthworks, there is evidence of many later disturbances which could have removed them. The motte, however, has escaped damage. It proved an ideal subject for investigation. For one thing, the sand of which it is composed is a sensitive medium for revealing traces of timbers. For another, it is relatively small: it stands about 20 feet high and has a flat top about 35 feet in diameter. Mottes with relatively small tops were typical of the earlier history of these fortresses in England; it was only later that they were required to carry halls and residential structures.

Before excavating the motte itself we decided to investigate the surrounding ditch. We expected to find evidence which might help us to date the structure. Though this motte is of the same type as those of the Conquest, we knew there was no reason why one of these should have been built at Abinger. It seemed more likely that it was an illegal stronghold of the first half of the 12th century, when a struggle between two claimants to the throne threw England into anarchy. From the centuries of rubbish and silt which filled the ditch almost to the brim we hoped to get not only a date but, equally important, clues to the events which had affected the castle on its top. In our delicate excavations on the motte top we had to be ready for signs of repair or rebuilding.

Trenches dug across the ditch exposed a thick layer of 19th-century rubbish, and below it three feet of silted sand. We found that the sand had been deposited over a period of more than 600 years; halfway down were pieces of pottery from the time of Henry VIII, and at the base of the layer was a delicately made 13th-century jug. Below the sand the deposits changed in character, becoming damp and water-stained. The 13th-century jug thus gave us the approximate date when the ditch had become choked and dead [*see drawings on next two pages*]. These water-stained deposits, along with other evidence, showed that the ditch had been water-filled from the beginning. The motte's builders had deliberately located it so that the ditch would be fed by a spring. This is the earliest example in Britain of a castle with water defenses.

Our excavations went deeper yet, but still we saw no sign of the more intensive rubbish deposits which would mark a period of activity on the motte above. Then, at a depth of seven feet, there was an almost dramatic change. The silt became black charcoal thrown in from ancient fires. Among traces of decayed bones of ox, sheep and pig we found large fragments of soft, brown, unglazed cooking pots. The shape and finish of these pots were typical of the period around 1150. Here, indeed, was evidence of activity. Several large fragments of oak suggested that the motte's timberworks had been repaired or rebuilt at this time, a point to be remembered during the later digging. But we had not yet reached the bottom of the ditch.

At last the virgin sand of the ditchbed gleamed through the oozing water. On its surface we uncovered cooking pots of a different kind. These were almost globular and made of well-fired sandy ware. Their outer surfaces, below their flaring rims, were covered with swirling patterns of fine, parallel scratches, resembling an enlarged photograph of several superimposed fingerprints. This surface treatment, perhaps intended to give a surer grip to the carrier's hands, is characteristic of the period 1080-1140. A later date within this range seems most likely, since other evidence so clearly establishes the Abinger motte as a product of the 12th-century anarchy.

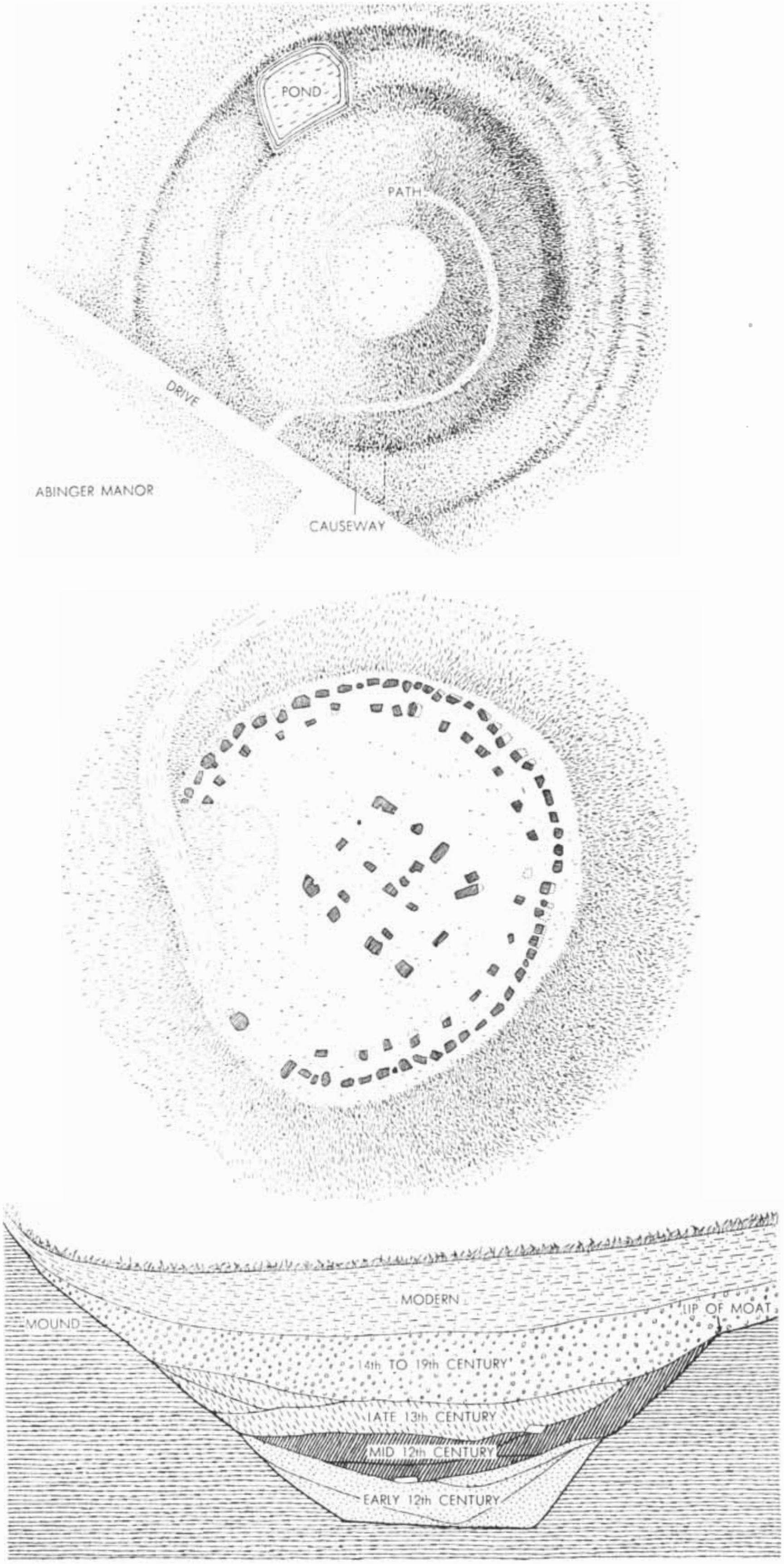
In addition to dating the motte, our excavations in the ditch uncovered an interesting and quite unexpected structure. This is a massive causeway of hard, undisturbed sand lying across the ditch. We had supposed the ditch to be an uninterrupted circle, and so it would have seemed to a medieval attacker, for this causeway was cunningly contrived. It was shaped rather like an executioner's block, with two rectangular humps at either end, obviously designed to bear a light wooden bridge. The humps were low enough, however, to lie out of sight below the surface of the water. With the bridge removed, like a ship's gangplank, the water in the ditch would have presented an unbroken surface.

We were now ready to begin the second and more difficult stage of the excavation, on top of the motte. The ancient bits of wood found in the ditch had been preserved by waterlogging. We could expect to find no such tangible relics in the dry sand of the motte, but only faint discolorations in the sand. Stripping the modern turf from the motte's flat top, we uncovered a layer of ash and clinker placed there in recent times to level the surface. Immediately below this layer we came upon the ancient deposits. The clean break between ancient and modern layers indicated that at some point the mound had been shaved down, by at least a foot.

Delicate skimming with bricklayers' trowels exposed the grayish-yellow sand which had been heaped up into the original mound. When every particle of the overlying ash had been removed with hand brushes, faint variations in the tone and texture of the sandy surface became visible. As our excavations spread across the motte top, these faint discolorations multiplied and formed a pattern. We recorded the markings in careful detail for later dissection, including those that suggested more recent disturbances by man and nature. As these various features were dissected we could distinguish the deep, cylindrical pockets of slightly dirty sand that were ancient postholes from the shallow, darker and more irregular stains caused by later tree roots. When this work was finished, we were able to draw up the first complete plan of a medieval timber castle [*see drawings on page 43*].

Around the edge of the motte was a ring of closely set postholes. About three feet within was another ring of postholes, shallower and more widely spaced. The first ring represented a stout palisade; the second, the supports of a walk or fighting platform along its inner side. Two deep postholes bounded a gap in the palisade—probably a gate. The plan thus far suggested little by way of departure from earlier methods of fortification.

In the center of the motte top, however, we found evidence of a structure to which all the rest was merely auxiliary. It was a free-standing wooden tower only 12 feet square. The depth of its corner postholes and the small area it covered showed that it was built for height, not capacity. This tower was the structure that the motte, and others of its type, existed to support and protect. Sentinels posted on its top could survey a wide area for the approach of enemies. If the manor were attacked, the tower



ABINGER MOTTE **is shown as it exists today (*top*). The spiral path is a modern addition. Excavation of the motte top revealed the plan of the palisade and tower (*middle*). Deposits in the ditch, shown in cross section (*bottom*), contained pottery which dated the structure.**

would become a vantage-point from which defending archers could pick off attackers who were floundering across the ditch.

The tower and its associated palisade actually belonged to the second phase of activity indicated by the fragments of oak in the ditch. Further excavation revealed traces of an earlier tower and palisade of a very similar plan. The original tower had been dismantled, probably because the newly built mound had settled and made it unstable. About 1150, judging from the first pot fragments we had found in the ditch, the motte had been heightened and leveled by the addition of a thick layer of sand, and the new tower had been erected. Though the accession of Henry II in 1154 brought stable government once more, the second fortress was not dismantled but left to rot.

Our excavations were finished, but our researches into wooden castles were only beginning. At Abinger, we soon realized, we had found a key to some of the more cryptic portions of the Bayeux Tapestry. This remarkable embroidery, made soon after the Conquest, shows the course of that struggle in a richly colored decorative frieze. It is so highly conventionalized, however, that its details have needed clarification from other sources. Our excavations show that many seemingly obscure features of the Tapestry are fairly plain statements of fact.

Some scenes, for example, center around structures once thought to be towns. We now know that they must be mottes, for the correspondence between these scenes and the structure at Abinger is conclusive. The Tapestry's picture of the scene at Dinan shows a washtub mound with its encircling ditch boldly drawn in cross section [*see illustration on page 44*]. A sturdy palisade crowns this motte, and above it looms a tower. In only two respects does the illustration depart from the Abinger evidence. First, it shows a fighting platform outside the palisade; this may occasionally have been a feature of the motte fortress. Second, the Dinan motte is reached by a flying bridge springing directly from the outer edge of the ditch to the palisade gate. All the Tapestry's castles have flying bridges of this sort. Doubtless this more permanent bridge could safely be used in the more important castles with strongly defended baileys. The Abinger castle had at best a weak bailey, and thus needed a bridge which could be removed if the bailey fell to the enemy.

The close agreement between the

structure we uncovered at Abinger and the castles pictured on the Bayeux Tapestry encouraged me to take up a new line of inquiry which now promises to explain how the motte originated. Historians and archaeologists have assumed that this type of fortification was a Norman invention. Since so little was known about its timber structures, they took the mound to be its central feature and credited the invention to the Normans because no such large mounds from pre-Norman times have been found. Further researches have convinced me, however, that the really distinctive element of the motte was not the mound but the tower. It was, I believe, a tower of a special type, which originated centuries before the Norman Conquest. Let us see if, from the Abinger remains and other evidence, we are able to reconstruct its history.

We know that the Abinger tower occupied a considerable portion of the small motte top. If it was boarded in from top to bottom it would certainly have hindered the defenders from moving freely about the fort. If, however, the tower was a sort of box on stilts, its defenders could have moved about on the motte between its supporting posts, while the enclosed top would shelter the soldiers there against arrows. Our excavations, though they suggested this picture of the tower, could not confirm its above-ground details.

Was there, perhaps, some clue in the Bayeux Tapestry, some small and hitherto-unnoticed detail? Indeed there was. The Dinan scene shows a soldier who is fighting apparently at the foot of the tower. His arm passes behind one of the cornerposts and reappears on the other side. This can only mean that the lower part of the tower was open and that the soldier was actually engaged in fighting underneath it.

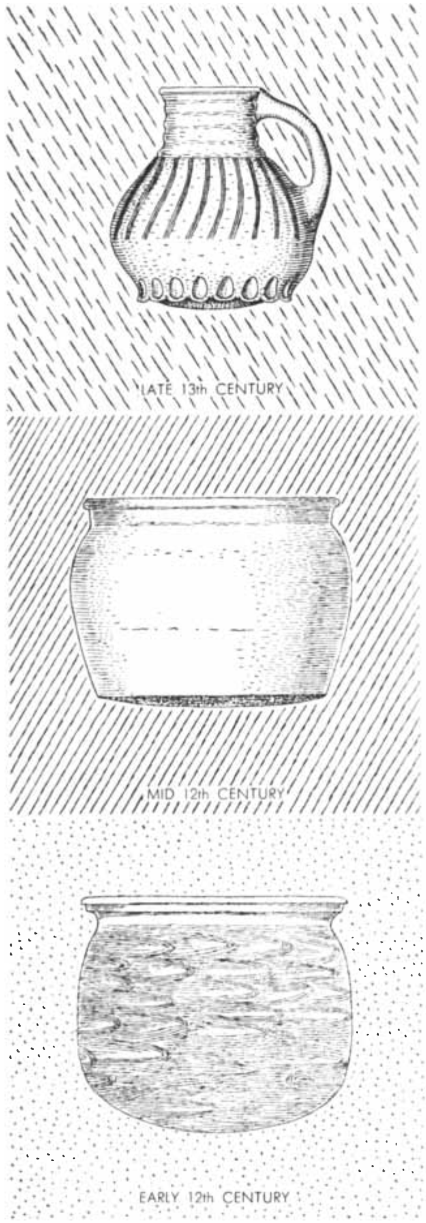
Once one knows what to look for, the meaning of evidence which has long been overlooked almost leaps at one. I soon found further confirmation in a carved stone capital from the original building of Westminster Hall, which dated from the generation after the Conquest. (The immediate successor of this building still stands near Westminster Abbey.) The carving shows a stilted tower of the same type as that in the Tapestry. Beneath it crouches a soldier, chopping at one of the great cornerposts with an ax.

The tower in the Westminster carving is firmly tied to the castles of the Bayeux Tapestry by another significant element. The enclosed upper portion of the tower is covered with small, carefully carved rectangles, each with a raised edge and a dimpled central boss. These rectangles must indicate pieces of hide or lead nailed to the tower, an early form of armor-plating. The appearance of a raised rim would be given by rows of nails about an inch from the edge of each plate. A single, large-headed nail hammered through the center of the plate would produce a central boss. This same treatment of the tower surface appears on the castles of Dol and Dinan in the Bayeux Tapestry, the alternate rectangles being embroidered in contrasting colors to form a gay checkerboard pattern. In every case the central boss is represented by a carefully stitched ring. There is no doubt, then, that both carving and tapestry depict the same type of stilted tower which we excavated at Abinger.

We are now ready to consider the question of whether the mound or the tower came first in history. A tall free-standing tower, built on natural ground, will need deep cornerpost holes for stability, and the posts must fit tightly in their holes. Using only pick and shovel, it is almost impossible to dig a hole which is both narrow and very deep, as anyone who has tried it knows. The trick of setting posts in concrete was not included in the techniques of ancient builders in timber, nor did they have pile-drivers capable of driving tall posts into the ground. A tower built on natural ground, then, would soon become unstable. In correcting this weakness the early builders, in my opinion, endowed their towers with a new strength, for it was this which seems to have led to the development of the motte.

As a first step in stabilizing a tower, its builders might well dig a ditch around it and heap the excavated earth inward around the cornerposts. Success will encourage the throwing-up of mounds around towers as soon as they are built. The importance of the postholes dug in the ground will diminish. Eventually the towers will be supported by temporary frameworks while ever-bigger mounds are heaped up and rammed solid at their base. Meanwhile the military advantages of this method will have become apparent, for the higher mound and deeper ditch will themselves offer a formidable obstacle to enemies attacking the tower.

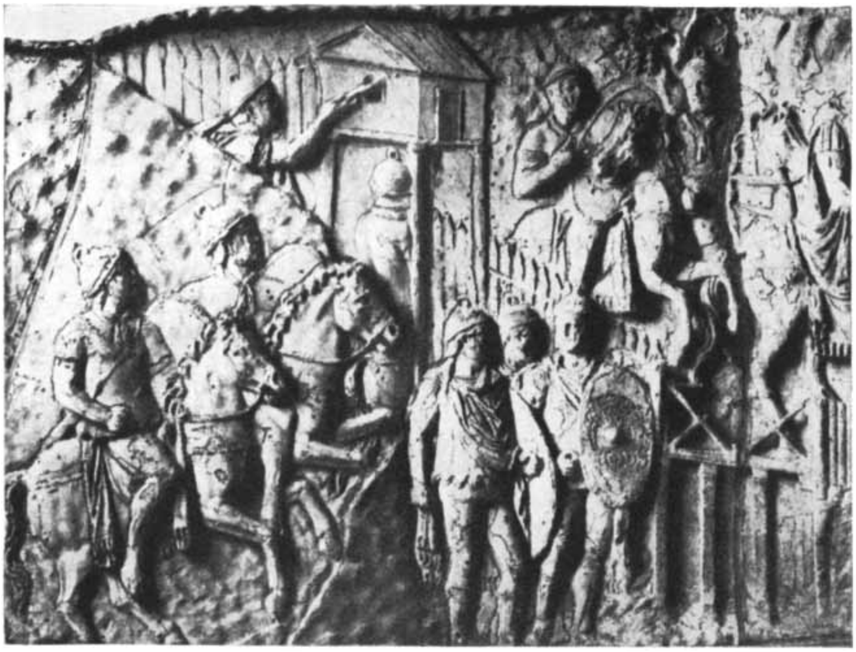
This line of deduction is also confirmed by the Bayeux Tapestry. It pictures a castle under construction at Hastings and shows workmen shoveling up



TYPES OF POTTERY from the Abinger ditch make it possible to set approximate dates for various phases of motte's history.

an earthen mound around an already-constructed tower framework. But we have even more concrete evidence. When Hans Stiesdal of the National Museum of Denmark excavated a small motte in eastern Jutland a few years ago, he discovered that the tower's cornerposts had run through the entire mound. At ground level they had rested on a bed of stones. Stiesdal agrees with me that the mound must have been built around the tower. As further evidence we have later medieval documents which refer to such "prefabricated" towers being transported by land and sea.

Clearly, then, the story of the motte begins not with the mound but with the



WATCHTOWER ON STILTS in Dacia (modern Rumania) is depicted on Trajan's Column in Rome. The Dacians may have borrowed this type of frontier fortification from Romans.

STONE CARVING from the original building of Westminster Hall shows a tower covered with carved squares, indicating the "armor-plated" structure depicted in the Tapestry.

stilted tower. How did such a distinctive structure originate? The most likely answer is that it began as a platform or guardroom over the gateway of a prehistoric fort. Later the elevated platforms would be used separately, as a means of supervising an area of open country. Roman sculptures show structures of exactly this kind—small timber towers, each based on four stout cornerposts [*see top photograph on this page*]. Long lines of timber watchtowers were erected along the frontiers of the Empire. Excavation of several examples in Germany has shown that the earth from a circular surrounding ditch was thrown inward to form a low, flat-topped mound at the base of four cornerposts set in the ground. Here, surely, is the prototype of the motte, with all its essential features. One of these Roman proto-mottes is even set within a bailey-like earthwork enclosure. And the Romans, as did the Normans centuries later, often replaced the original timber towers with stone ones.

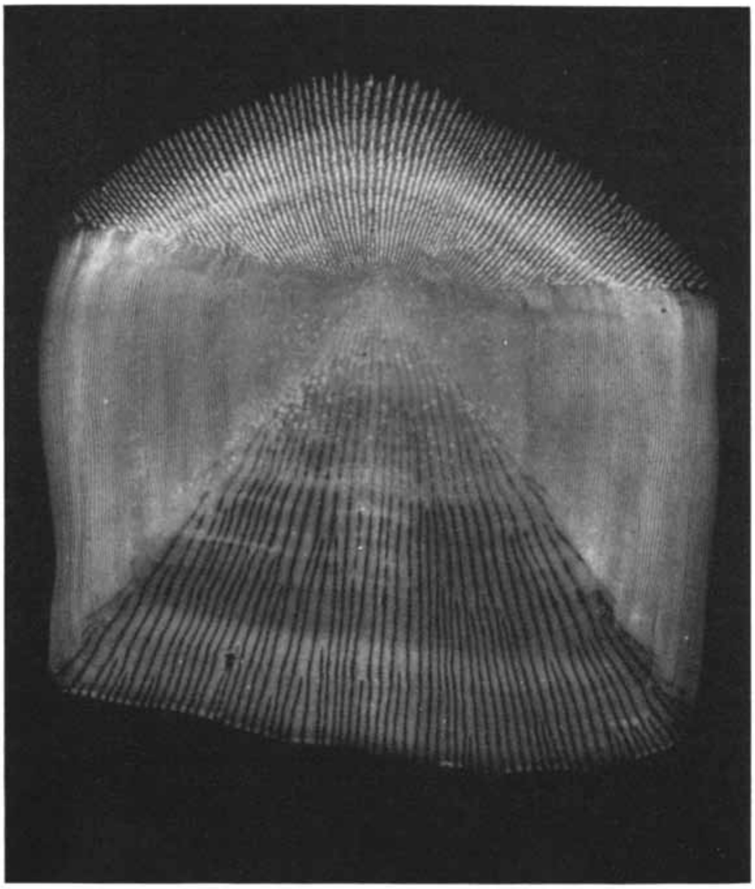
We can now summarize the history of the wooden castle. It begins with the banding together of families and tribes to build communal fortresses. Later a stilted tower is built over the fortress gate. As tribes coalesce into states and empires, the tower is detached from the fortress and becomes a frontier watchtower. Used extensively by the Romans, it is probably passed on by them to the Franks and by them to the Normans. In the Norman conquests, from Sicily to Scotland, the tower, now set firmly in a motte, reaches the climax of its history. But the story does not end with this blare of victorious trumpets. The motte begins to lose its martial character, turning into the "residential motte," with the lord's dwelling on the mound and the garrison in the bailey below. A few scattered fragments of a once-great tradition survive for centuries as a lingering anticlimax.

There is, however, an epilogue. The motte never reached the New World, but the palisade stockade—a sort of bailey—played an important part in the conquest of North America. And in the blockhouse we find a far-off echo of the motte tower.

Now, of course, the wooden castle is as extinct as the dodo. In our time we have seen castles in the air become reality, along with floating fortresses. So we beat our wooden palisades into newsprint, whereon we record the appearance of weapons which reduce all castles to ivory towers.

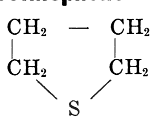
Kodak reports on:

a fish story with a picture to prove it . . . pressure from the gas company



This is a microradiograph of a striped bass scale. In microradiography one passes low-voltage x-rays through a specimen to a special fine-grain photographic emulsion in intimate contact with it. The resulting photographic image then becomes a subject for conventional photographic enlargement or photomicrography. If you already know that much, there is then some point in requesting of Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y., information about an improved material for this work which we hope to have available in the near future. The same source can also provide a recently updated bibliography on results and techniques with microradiography. But don't ask us about striped bass and the lessons to be learned from their stripes or scales. Ask the Fish and Wildlife Service of the U. S. Department of the Interior in Washington.

Tetrahydrothiophene



We had an inquiry from a gas company for tetrahydrothiophene. Feeling a little glum that day and aware that we cannot be expected to make 10 grams of each of the half-million-plus organic compounds that have been proved capable of existence, we politely declined the gas company's offer. Back they bounced for a second try, asking for 100 grams or $100 worth, whichever would be less. That constituted pressure. It also showed we were dealing with a party who understands the facts of life. We forgot the $100 limit and shot the works.

We took a lot of *1,4-Dichlorobutane* (Eastman 5658) and sodium sulfide and put them into a solvent chosen by experience. We heated to a temperature and for a time, both chosen by experience. By steam distillation we separated the oily product from the solvent and the sodium chloride formed. The water-insoluble material was then decanted and purified by distillation to BP 118-119 C. The job went rapidly, and the yield was excellent, amounting to five pounds of tetrahydrothiophene. It smells something like indene. The five pounds cost us only $A. Five grams might well have cost the same.

Only in form was this transaction the sale of a certain chemical at a meaningless $B per pound. In reality our persistent customer was buying a service which would either find the right reaction solvent, time, and temperature to produce what he wanted or else would silently take the loss if the entrepreneurs' judgment or execution proved faulty. Furthermore, we didn't even make him pay the whole shot but undertook to market *Tetrahydrothiophene* as Eastman 7516, searching for other buyers (as we do by these very lines) to share the cost with him. The list price is $18.55 per 100 grams.

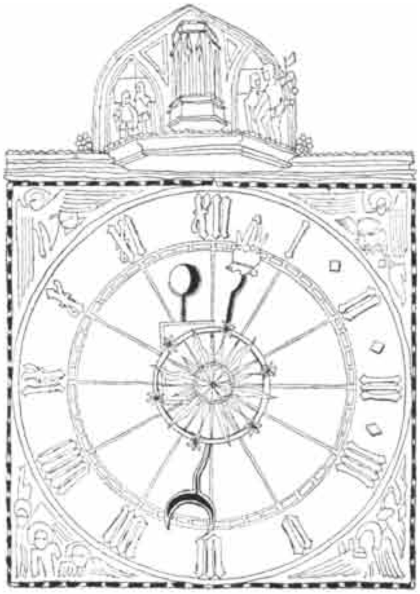
If A were given, you could compute B/A, a ratio that most widely held corporations disclose only for the business as a whole. A copy of our 1957 Annual Report will gladly be sent by Eastman Kodak Company, Public Relations Department, Rochester 4, N. Y. Tetrahydrothiophene, *along with some 3600 other Eastman Organic Chemicals, is sold by the division called Distillation Products Industries, Rochester 3, N. Y.*

Research organics and special materials for relatively obscure laboratory methods like microradiography are rather small business compared with Kodachrome Film, Brownie Starflash Cameras, *or* Chromspun Yarn. *We console ourselves for their disproportionate drain on technical manpower with the thought that for public relations with certain segments of the public this activity might be almost as impressive as flush brochures and statements to the press. We caught on to this approach long before it was widely accepted that the good will of those segments—whether employed by gas companies, fisheries institutes, or astronomical observatories—is important.*

Prices quoted are subject to change without notice.

Kodak
TRADEMARK

SCIENCE AND



Fusion Power Progress

The possibility of obtaining useful power from controlled thermonuclear reactions has now been demonstrated. This seemed the unanimous reaction to last month's joint announcement on thermonuclear-power research by Great Britain and the U. S. There were varying appraisals of the actual experiments, which were reported in the British *Nature;* but, said Lewis L. Strauss, chairman of the Atomic Energy Commission, as to the long-run feasibility of thermonuclear power, "today there are almost no skeptics."

Perhaps the chief question at this stage is whether a true thermonuclear reaction has yet been achieved. A number of experiments with very hot, ionized gases (plasmas) have yielded neutrons which come from the fusion of deuterium nuclei. But whether the fusing atoms obtained their necessary speeds from local accelerations in the complex electrical fields of the plasma, or whether their energy came from a general heating throughout the gas—the condition for thermonuclear reaction—has been moot. Now Sir John Cockcroft of Britain's Atomic Energy Authority declares he is "90 per cent certain" that the English device known as ZETA has produced thermonuclear neutrons.

ZETA (for zero-energy thermonuclear assembly) is an aluminum doughnut, three meters in central diameter with a one-meter bore, in which deuterium gas is heated and "pinched" by a strong electric current [see "Fusion Power," by Richard F. Post; SCIENTIFIC AMERICAN, December, 1957]. The British report that they have operated with currents of 200,000 amperes and heated the gas to five million degrees centigrade. A ring-shaped magnetic field running parallel to the axis of the tube helped overcome the tendency of the pinched body of plasma to destroy itself by writhing into the walls of the tube. The discharge was stabilized for periods of two to five thousandths of a second, and some three million neutrons were emitted on each pulse. The number and distribution of the neutrons, the experimenters say, are what would be expected from a thermonuclear reaction at that temperature.

Even if all the neutrons came from a thermonuclear process, the power released by the reaction was a completely negligible fraction of the power needed to produce it. To achieve a self-sustaining fusion reaction in deuterium will require a temperature of some 400 million degrees and a discharge lasting several seconds. (A deuterium-tritium fusion would become self-sustaining at 40 million degrees.) It is expected that ZETA's operating temperature will be increased to 25 million degrees this year.

A theoretical analysis of the ZETA experiments by Lyman Spitzer, Jr., of Princeton University indicates that the behavior of hot plasmas is still not completely understood. The rate of heating (speeding up) of the deuterium nuclei was measured by adding a few heavier atoms, which are not wholly ionized, and observing the Doppler shifts in the spectra they emit. According to Spitzer, the heating proceeded at a faster rate than can be explained by collisions between plasma electrons and ions, the only known means of acceleration. He concludes that "some unknown mechanism would appear to be involved."

Another British pinch experiment was reported by a group at Associated Electrical Industries, Ltd. In an aluminum doughnut called Sceptre III, about one third the size of ZETA, the industrial researchers have achieved a four-million-degree temperature in bursts lasting a few millionths of a second. The designers expect to raise the temperature to 12 million degrees soon, and they are building a larger device in which they hope to reach 40 million degrees, the break-even point for deuterium-tritium fusion.

U. S. papers told of experiments with two straight pinch tubes called Columbus II and Columbus S-4, and with a ring-shaped device, the Perhapsatron. Columbus II has produced one-microsecond bursts of 10 to 100 million neutrons, which appear to be thermonuclear in origin. The other machines have demonstrated an ability to form "highly reproducible" and "well-stabilized" pinch currents. The Perhapsatron has operated at temperatures of six million degrees during pulses lasting two microseconds.

Another apparently successful experiment was announced later from Japan. Workers at the University of Osaka reported that they have achieved controlled thermonuclear fusion for one microsecond at a temperature of one million degrees, with the release of five million neutrons. Their apparatus was said to be similar to ZETA but smaller.

Publication of the U. S. and British papers represents a substantial relaxation of the secrecy which has surrounded thermonuclear research. However, according to Strauss, "certain areas . . . must remain classified in both countries at this time." Commenting on the security restrictions, the British magazine *The New Scientist* attributed them to "American fears" that neutrons from thermonuclear reactors could be used to manufacture fissionable plutonium from U-238. In this way, "small nations could quietly set about making atomic bombs," and they "would no longer be dependent on the U. S. or the Soviet Union for enriched fuel elements for more advanced types of [fission] reactors." Many U. S. scientists connected with the thermonuclear power program stated that secrecy had not hampered research. There were some dissents. Morton A. Levine of the Air Force Cambridge Research Center, one of the early workers on stabilized pinch discharges, attributed a lack of interest on the part of physicists in general to the secrecy surrounding the project.

Fission-Power Progress

A substantial advance in the economics of nuclear-fission power was announced last month by workers at Argonne National Laboratory. They have souped up their experimental boiling water reactor (EBWR) to the point where it puts out 50,000 kilowatts of heat instead of the 20,000 kilowatts for which it was designed. If the extra heat were used to drive a generator (the turbine now attached to the EBWR is too small), the cost of the electricity produced would be an estimated 32 mills per kilowatt hour. This is the lowest figure for any U. S. reactor, representing a 40 per cent reduction from the present 52-mill cost of electricity from EBWR.

The increase in rating was achieved without changing the design of the reactor, simply by pulling out the control rods farther than was envisaged in the original operating specifications. This makes the water surrounding the core boil faster, thus increasing the rate of circulation and the rate at which heat can be extracted. The reactor responded so well that Argonne designers now contemplate a revised version that might cut costs to about 20 mills. Such a figure would be economical even today in some areas. In 10 years or so, the engineers believe, it should be possible to build a boiling reactor to produce electricity at 10 mills per kilowatt or less, which would be competitive with conventional power over much of the U. S.

As the name implies, a boiling-water reactor is one in which the cooling water is converted directly to steam in the reactor core and used to drive a turbogenerator. In other designs the coolant is not allowed to boil, but transfers its heat *via* an exchanger to a secondary water circuit in which the steam is raised.

Number Three

"Explorer," the third artificial satellite, was launched by the U. S. Army at 10:48 p.m. on January 31. It carries equipment for three geophysical experiments. Cosmic rays are recorded by a Geiger counter; temperatures at the outside surface and within the satellite are measured by their effect on the electrical resistance of strips of zirconium oxide; the impacts of micrometeorites are detected by a series of external wire meshes and by an interior microphone which picks up the sound of their collisions with the skin. The readings of these instruments are relayed to the ground by radio. There are two transmitters, one sending a 60-milliwatt signal at 108.03 megacycles and the other a 10-milliwatt signal at 108 megacycles. All countries participating in the International Geophysical Year have been informed of the telemetering code used in the transmissions.

The satellite, together with the case of its final rocket stage, is a cylinder 80 inches long and six inches in diameter. It weighs 30.8 pounds, of which instruments, radios and batteries account for 11 pounds. Explorer was launched from Cape Canaveral, Fla., in a southeasterly direction at an angle of about 33 degrees to the Equator. Its orbit, as established by early radio observations, takes it around the earth in 114.95 minutes, passes within 219 miles of the ground at the closest approach and reaches a maximum height of 1,587 miles.

Having the brightness of a star of the fifth or sixth magnitude, the satellite is not easily visible to the naked eye. Initial tracking was done entirely by Minitrack radio stations. A receiving system designed especially for Explorer, called Microlock, can pick up the signal of a one-milliwatt transmitter at a distance of 20,000 miles.

The four-stage rocket assembly which put the satellite into its orbit was reported to weigh 65,000 pounds at takeoff. The first stage, a liquid-fueled Redstone rocket, developed 78,000 pounds of thrust and boosted the assembly to a height of 53 miles before exhausting its fuel and falling away. At this point the remaining stages had enough speed to coast to 200 miles. Then the last three stages, consisting of clusters of small solid-fueled rockets, were fired by remote control from the ground. They gave the satellite the necessary horizontal speed, about 18,000 miles per hour, to go into a stable elliptical orbit.

Science and the Budget

The President's budget for the fiscal year 1959 proposes a modest increase in Federal spending for science. Planned expenditures for research and development have been raised by 8.5 per cent over 1956 to a total of $3,722 million. About four fifths of this total is scheduled for weapons research.

Basic research fares somewhat better in proportion: funds for it are set at $285 million, a rise of nearly 25 per cent. The augmented figure, however, still represents less than 8 per cent of the total research budget. Basic research will also benefit from Department of Defense plans to transfer $100 million of already appropriated funds to research. If Congress approves these plans, about half the sum is said to be earmarked for basic investigations.

The National Science Foundation, principal Federal civilian scientific agency, has had its budget tripled. The sharpest increase was in funds for developing student interest in science, improving teaching methods and teacher training, and for fellowships for ad-

vanced study; these are to increase 400 per cent over last year. NSF Director Alan T. Waterman told a House of Representatives subcommittee, however, that the budget provided only $40 million of the $50 million the Foundation had asked for basic research, and only half of an additional $25 million it had asked for the construction of research facilities.

The budget also proposes a temporary program of assistance to state and local educational authorities. This includes plans to spend $605 million over five years to improve science and mathematics teaching in primary and secondary schools. These funds, which would match state and local grants, could be used to hire consultants on educational methods, increase salaries of teachers and purchase laboratory equipment.

One Third of IGY

Far below the northeast-flowing Gulf Stream another current carries water in the opposite direction; the thin hydrogen atmosphere which forms the corona of the sun may actually fill the void between earth and sun; auroras are visible at the same time in both hemispheres; the air at the South Pole contains as much carbon dioxide as industrial regions but has more ozone than New Mexico. These are a few of the discoveries made during the first third of the International Geophysical Year. The interim report was made by Hugh Odishaw, executive director of the U. S. National Committee for the IGY, in *Science*.

It has been found that X-rays are emitted by solar flares. When the X-rays reach the earth's atmosphere, they ionize a region below the D-layer (normally the lowest layer of the ionosphere). The additional layer, which may be about 12 miles thick, evidently absorbs short-wave-radio pulses and causes the "blackouts" in radio communications often noted after a solar flare. The normal ion distribution above the D-layer seems to remain undisturbed during a blackout.

Observations from stations in the eastern Pacific confirm the existence of an electric current flowing high in the atmosphere above the Equator. This "electro-jet" may be evidence of a river of current circling the earth. It had been speculated that certain magnetic effects could be accounted for by three such rivers, one circling the earth at the Equator, the others circling the North and South magnetic poles.

The whistle-like signals originating in lightning flashes at the surface of the

SILICONE NEWS

Electronics Go Miniature

Silicones Provide the Means

SMALLER, STRONGER MIDGETS WITH SILICONES—*Smaller, always smaller. Save weight, save space. These are standard in electronic specifications. As a result today's miniatures for home, industry and defense often pack as much power as their bigger predecessors. But when heavy work loads are concentrated in small units, heat problems frequently arise. Here's how Dow Corning Silicones help subdue the heat and make possible the highest efficiency for these electronic midgets.*

RUBBER SKULL-CAP — SAC's Snarks have silicones on the brain. Delicate electronic "thinking" centers in these missiles are embedded in RTV Silastic*, the Dow Corning silicone rubber that vulcanizes at room temperature.

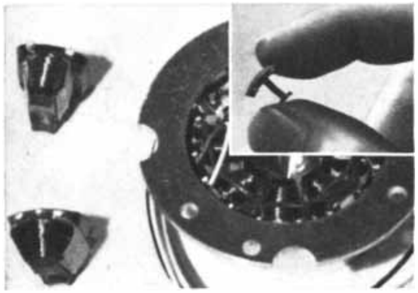
Northrop Aircraft, producer of the Snark, finds that RTV Silastic fills a multitude of needs. First, it's easy and fast to apply . . . they squeeze it from a gun as you would a caulking compound. It sets up to a rubbery solid within 24 hours. Then come the operational advantages: RTV Silastic cushions the circuits against vibration or rough handling, protects against moisture, improves electrical properties, and is easily repaired with more RTV when it's necessary to open a unit for repairs.

No other material could supply these features and withstand heat in the bargain. That's why, for the Snark's intricate electronic brains, skull sessions start under RTV Silastic.

*T.M. REG. U.S. PAT. OFF.

"MIGHTY MITE" — To provide power in certain electronic control systems, Minneapolis-Honeywell has evolved a tiny new Servo motor. No larger than a golfball, and weighing a mere two ounces, this little unit nonetheless develops a stall torque of 0.75 ounce inches and will withstand operating temperatures of 500 F and higher.

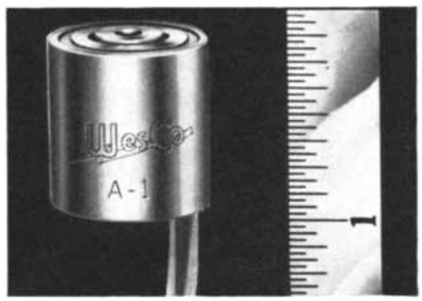
Secret of the Servo's efficiency? Silicones. Dow Corning insulating resins and molding compounds are used extensively. They make sure of the mighty mite's ability to stand up under heavy duty. Designed to drive various of Honeywell's control system assem-



blies, such as calibrators, synchros, and similar components, the Servo is a fine example of how space and weight can be saved with silicones.

IT TAKES PULL — Solenoids are magnetic coils that "suck in" a metal plunger to activate a circuit, and they're rated on their pull. Naturally, you'd expect this pulling power to diminish with size. But with silicone insulation you actually get *more* pull in a smaller package.

By using Dow Corning silicone insulating components and Sylkyd* enameled magnet wire, the West Coast Electrical Manufacturing Corporation, of Los Angeles, produces miniature solenoids of surprising strength. The WESCO A-1, for example, weighs only 2½ ounces, yet



can pull 3½ pounds. An intermittent duty unit, the A-1 saves space and weight for manufacturers of industrial computers or airborne electronics systems. Another big plus: Silicones increase the solenoid's rated service life five times!

***FOR MORE INFORMATION* on any of these silicone products or applications, write Dept. 983.**

first in silicones

Dow Corning CORPORATION
MIDLAND, MICHIGAN

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earth are being used to study the farthest reaches of the atmosphere. The "whistlers," which swing far out into space in their journey from hemisphere to hemisphere, have been found to encounter ionic and molecular particles in unexpected density even at altitudes of twice the earth's radius. This seems to indicate that the atmosphere extends much farther than had been thought.

It was known that cosmic rays which shower the earth are attracted toward the magnetic poles, but surprisingly the "cosmic ray equator" (where cosmic ray intensity is lowest) has been found to deviate from the magnetic equator. The warping may indicate the presence of heretofore-unknown magnetic fields in space which alter the path of incoming cosmic ray particles.

Study of the earth's interior has been enhanced by the discovery that earthquake waves of intermediate length travel through the mantle (the layer below the outside crust of the earth). These waves, which have periods of about 100 seconds, reveal details that cannot be detected with the longer 400-second waves which had previously been used.

IGY scientists are probing the earth with instruments which measure changes in gravity in order to map the irregularities in the earth's shape. They are digging out cores of ice from polar icecaps to trace the history of the earth's climate, shooting up rockets to probe space, hauling up living sea-creatures from record depths. Weather reports from Antarctic stations have already improved forecasting in countries throughout the Southern Hemisphere, since cold fronts begin at the poles.

Other discoveries were disclosed after Odishaw's article had appeared. Sea levels in both Northern and Southern Hemispheres fall in the spring. In the Northern Hemisphere the average sea level is eight inches lower in March than in September, but mysteriously the volume of water lost in the north apparently does not show up in the southern seas. Part of an ice shelf in Antarctica has turned out to be a huge snow-covered island about 230 miles wide and 180 miles long. The island, formerly thought to be the Filchner Ice Shelf, lies in the Weddell Sea, east of Palmer Peninsula and south of the Atlantic Ocean.

Krypton Yardstick

The precious bar of platinum and iridium at Sèvres, France, against which all the world's distance scales are

How to speed up a digital computer

New Ampex Digital Tape System quickens input and output

Ampex's new digital tape equipment is to computers as a super-super highway would be to 1958's new 300 horsepower automobiles. Computer arithmetic can move at electron speeds – but previous input/output rates have been like bumper-to-bumper traffic. Now the jam is broken.

60,000 six-bit characters per second is one of several transfer rates available on the new Ampex Digital Tape System. Depending on how you can accept the data, some Ampex rates are even faster, others are somewhat slower.

FR-300 Digital Tape Handler

To achieve a livelier pace . . .
a SYSTEM of new equipment

In a complete digital computer, the Ampex equipment provides two neatly packaged functions: input source and output receiver. By treating these as systems unto themselves, Ampex achieves optimum performance and reliability. In them, four interdependent items have been matched: tape handler, heads, amplifiers and magnetic tape. For the total result, the four are inseparable.

The Ampex FR-300 tape handler operates at 150 inches per second. With this new speed plus other format improvements contributed by the other Ampex components, transfer rates can be increased up to six fold over previous standards. Search times too can be reduced to one sixth.

The FR-300 starts or stops in 1.5 milliseconds. These times can be depended upon indefinitely. Hence they drastically reduce the buffer storage requirements of the computer system. Also, inter-

Complete Electronic Assembly

record distances are accurate and are shortened by half.

Despite its racehorse gait, the FR-300 is a workhorse machine thoroughly tested and perfected in a year-long component shakedown. Its dependability and low maintenance requirements are aimed at increasing the computer's available working hours per day.

Two other Ampex tape handlers, the FR-400 and FR-200A operate at lower speeds, serving smaller computers and auxiliary digital equipment such as converters, printers, etc.

Read/write heads and amplifiers work together to achieve higher bit-packing densities. On the Ampex system, the 200-bit-per-inch standard is conservative. Ampex's new heads can resolve pulses much closer than this. And the amplifiers easily handle the tremendous transfer rates achieved when closer bit packing and high tape speeds are combined. All-transistor design of the amplifiers achieves extreme reliability and compactness.

Ampex computer tape, a new specially formulated type, plays a key part in system reliability. To reduce *significant* dropouts and spurious noise to zero, the tape is manufactured in a completely air-conditioned plant. Employees wear lintless "surgical" clothing. And each reel is individually tested and packaged within two hermetically sealed wraps.

A tough new oxide binder on Ampex Computer Tape withstands many times the use of any previous "long wear" tapes. Virtually no oxide rubs off; heads need much less frequent cleaning. Precision reels, available as an option, protect the tape edges from damage and improve tape handling and guidance.

A newly published brochure is available describing all components of the Ampex Digital Tape System and explaining performance specifications. May we send you a copy?

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11 ONE OF A SERIES

Series FR-100

Model FR-400 Digital

Model FR-200A Digital

Series 800 Mobile and Airborne

Series FL-100 Loop Recorders

Model MR-100 Missile Recorder

theoretically checked, may soon be melted down for wedding rings. An international advisory committee for the definition of the meter has now recommended the adoption of an atomic standard of length—an orange spectral line of krypton 86. The meter is to be defined as 1,650,763.73 times this wavelength. The krypton line is the sharpest of those currently available for length measurement. In practice a line of mercury is more commonly used, and probably will continue to be for ordinary laboratory measurements.

Radioactive Waste Disposal

If atomic power is to be developed on an important scale, methods will have to be found for safely disposing of the vast quantities of radioactive "ashes" that will be produced by nuclear reactors. Last month a committee on waste disposal appointed by the National Academy of Sciences reported the results of a preliminary investigation of the problem.

At present, the committee said, the safest and most economical way to get rid of radioactive fission products is to store them in tanks. In the near future it should become feasible to bury the waste in underground salt deposits, either in worked-out salt mines or in formations especially hollowed out for the purpose. These deposits are impervious to water and can be used as natural storage tanks.

The next most promising method, economically, is to incorporate the waste into ceramic bricks which can be buried or kept in isolated sheds. A more remote possibility is to pump the material into porous subterranean limestone. Before this could be done, however, it would be necessary to find out how to prevent the waste solutions from clogging the pores of the stone.

Raw waste must be isolated for 600 years. But if the long-lived isotopes cesium-137 and strontium-90 are extracted, concentrated and disposed of separately, the remaining material will have to be contained for a period of only about 60 years.

Location of nuclear power stations and more particularly of fuel reprocessing plants should be planned with an eye to the accessibility of disposal sites, the committee warned. Many large areas of the U. S., for example the Atlantic seaboard, offer no convenient sites. Regarding the atomic power plant now under construction at Indian Point, N.Y., the report states that "almost certainly . . .

waste cannot be disposed of safely anywhere near this site." Prospects at the Savannah River installation of the Atomic Energy Commission are "equally gloomy."

The committee pointed out that the costs of storing radioactive fission products temporarily to "cool" them, of extracting long-lived isotopes and of shipping waste to distant points for ultimate disposal will have a major influence on the economics of nuclear power. The group urged that research be undertaken on the movement of liquids through porous rock, and that geologists and hydrologists be educated in the problem of radioactive-waste disposal.

Mental Retardation

That social factors play an important role in mental retardation is the conclusion of a three-year survey of research in the field. The report, by Seymour B. Sarason of Yale University and Thomas Gladwin of the National Institute of Mental Health, was released by the National Association for Retarded Children.

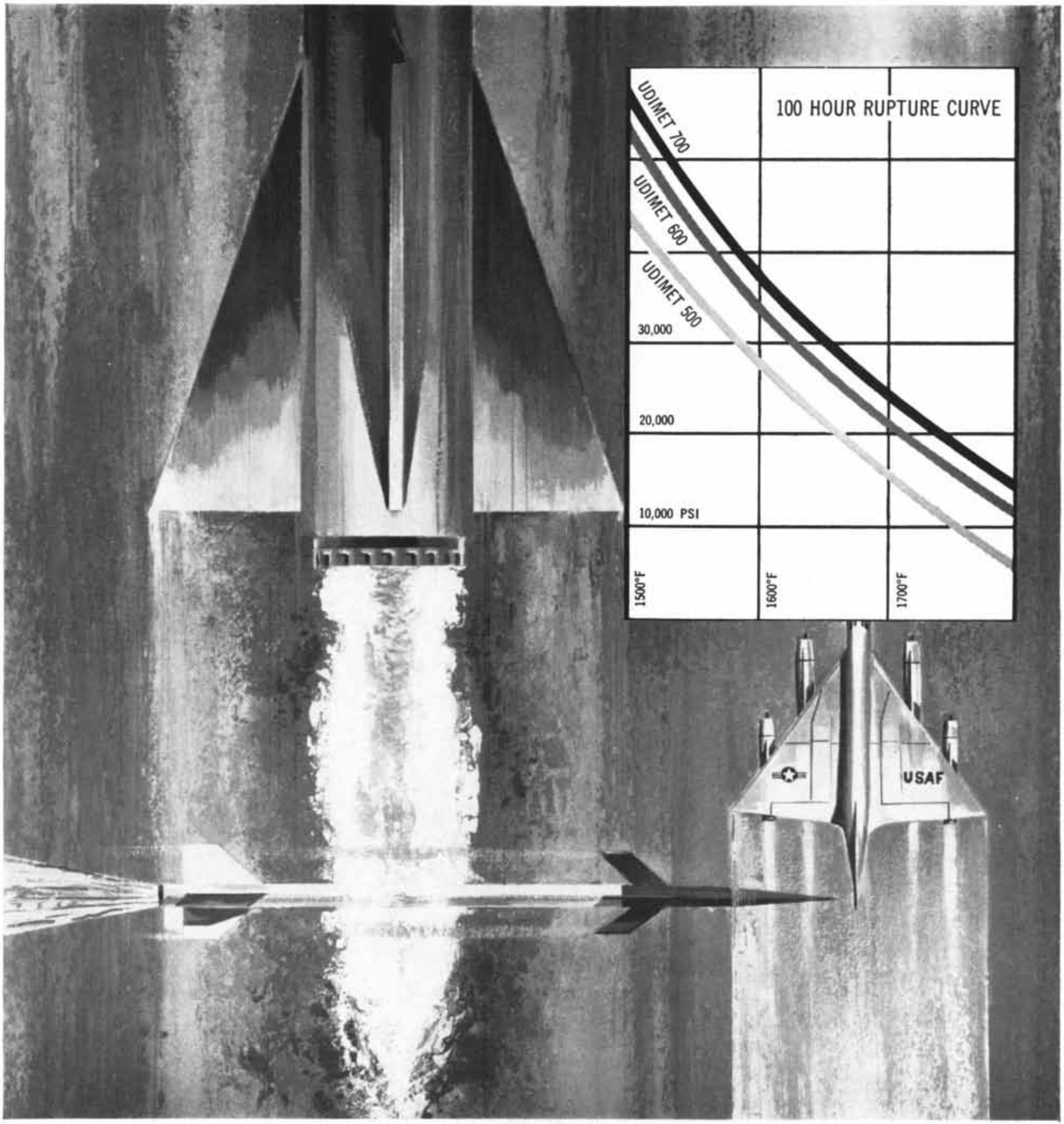
The survey stated that individuals whose retardation is not due to central-nervous-system damage come largely from the lowest economic groups, from culturally distinct minorities or from regions with poor educational facilities. Yet there has been no systematic study of how these social factors impede individual development.

Present methods of measuring mental capacity, the report said, seem to be faulty: many individuals classified as subnormal in school manage to function quite normally in later life.

Turning to the psychological problems of the retarded child, the report said that scientists have tended to assume that the deviant behavior of such a child is entirely "explained" by his low I.Q. There has been little attempt to clarify the mutual effects of intellectual and personality abnormality.

A companion study of the organic causes of mental deficiency, by Richard L. Masland of Wake Forest University, suggested that the hereditary factor in deficiency had been exaggerated. While some mental deficiency is hereditary, much of it is caused by prenatal damage, birth injury or diseases of early childhood.

Both studies stressed the need for further research in the field. More than 3 per cent of the babies born in this country each year, they stated, will never reach a 12-year level of intelligence.



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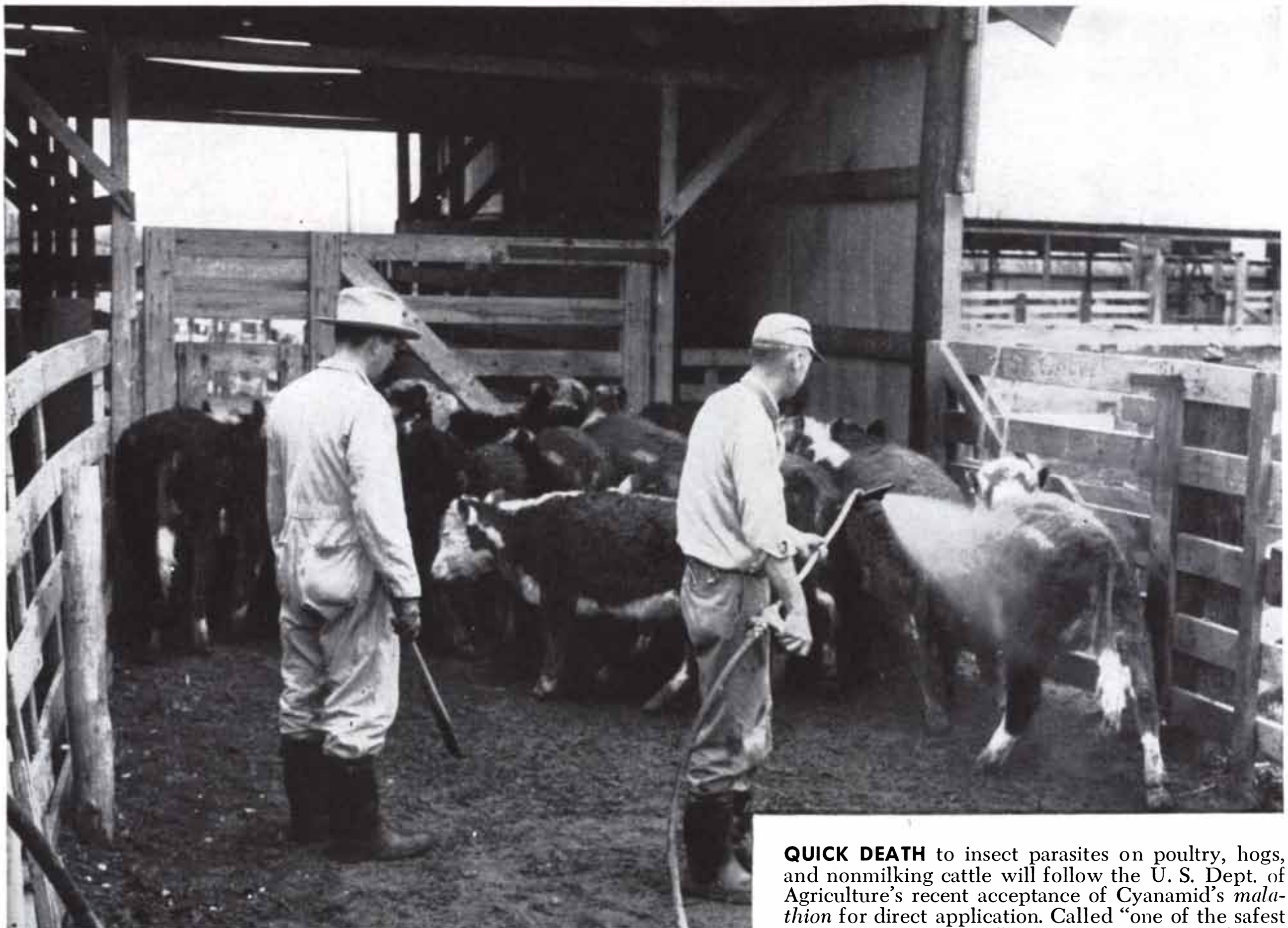
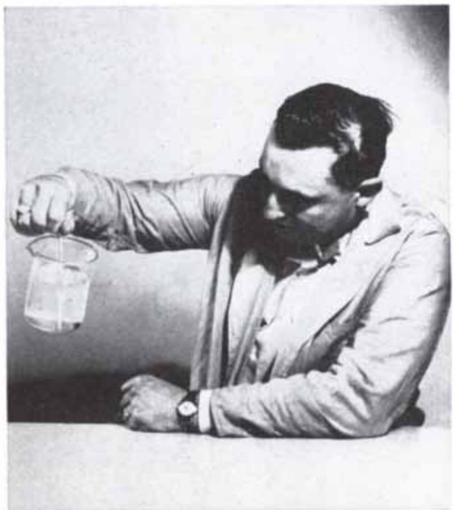
Life on the Chemical Newsfront



QUICK DEATH to insect parasites on poultry, hogs, and nonmilking cattle will follow the U. S. Dept. of Agriculture's recent acceptance of Cyanamid's *malathion* for direct application. Called "one of the safest insecticides to handle," malathion provides effective control of lice on swine, and lice and ticks on cattle. It is specially valuable in louse control, where indications are that it kills eggs as well as adults, thus extending protection. The broad-spectrum killing power of malathion is particularly useful on poultry where lice, mites and ticks are simultaneously brought under control. (Phosphates and Nitrogen Division)

NEW FREE-FLOWING PELLETS permit rubbermakers to handle the popular MBTS *Accelerator* with less dust and greater accuracy. The lumping and dusting typical of the powdered material are eliminated by these formed spherical pellets that pour freely and, shown on the right, are virtually dust-free. In the mixing operation, Cyanamid MBTS Pellets crush instantly and disperse uniformly. Pelletizing is the latest of several innovations made by Cyanamid's Rubber Chemicals Department toward producing a benzothiazyl disulfide accelerator with optimum handling and performance characteristics. (Organic Chemicals Division)

PUTTING A "BACKBONE" IN WATER is a recently developed role for N,N'-*methylenebisacrylamide.* Used in conjunction with acrylic monomers, it forms stable gels in which the water content runs as high as 95%. Added to the monomers which give normally water-soluble polymers, N,N'-methylenebisacrylamide forms stiff gels impermeable to water due to its cross-linking action. The setting time of each gel can be controlled to range from several seconds to hours. A data sheet is available from Cyanamid.
(Market Development Department)



STILL TOPS IN COLOR PERMANENCE are the Vat Dyes used for cottons, washable rayons and linens. Fixed for the life of these textile fibers, Vat Dyes withstand all the sun, wear and washing that the fabric itself can tolerate. Cyanamid *Vat Dyes* are available in an ever-widening color range, each conforming to the rigid industry standards endorsed by the Vat Dye Institute to which Cyanamid belongs. Buyers are assured of this high-quality performance when garment tags bear the statement "Guaranteed Vat Color." **(Organic Chemicals Division)**

REDUCING RAW MATERIAL AND PROCESSING COSTS are some of the benefits obtained through the use of CYQUEST 40* *sequestering agent.* Producers and purchasers of raw materials can use this remarkable sequesterant to maintain high-quality standards while avoiding costly purification steps to remove metal ions that spoil color, cause turbidity and catalyze degradation reactions. CYQUEST 40 ties up troublesome metal ion impurities in raw materials, eliminating their detrimental effect on processes and products. **(Industrial Chemicals Division)**

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HUGE PROTON SYNCHROTRON under construction at Brookhaven National Laboratory is photographed from the air. Circular tunnel housing its doughnut is 840 feet in diameter. This machine will produce particles of 25 to 30 billion electron volts (bev).

PARTICLE ACCELERATORS

The evolution of these huge machines is still proceeding at a lively pace. They are used for two purposes: to "see" fundamental particles of matter and to create new ones

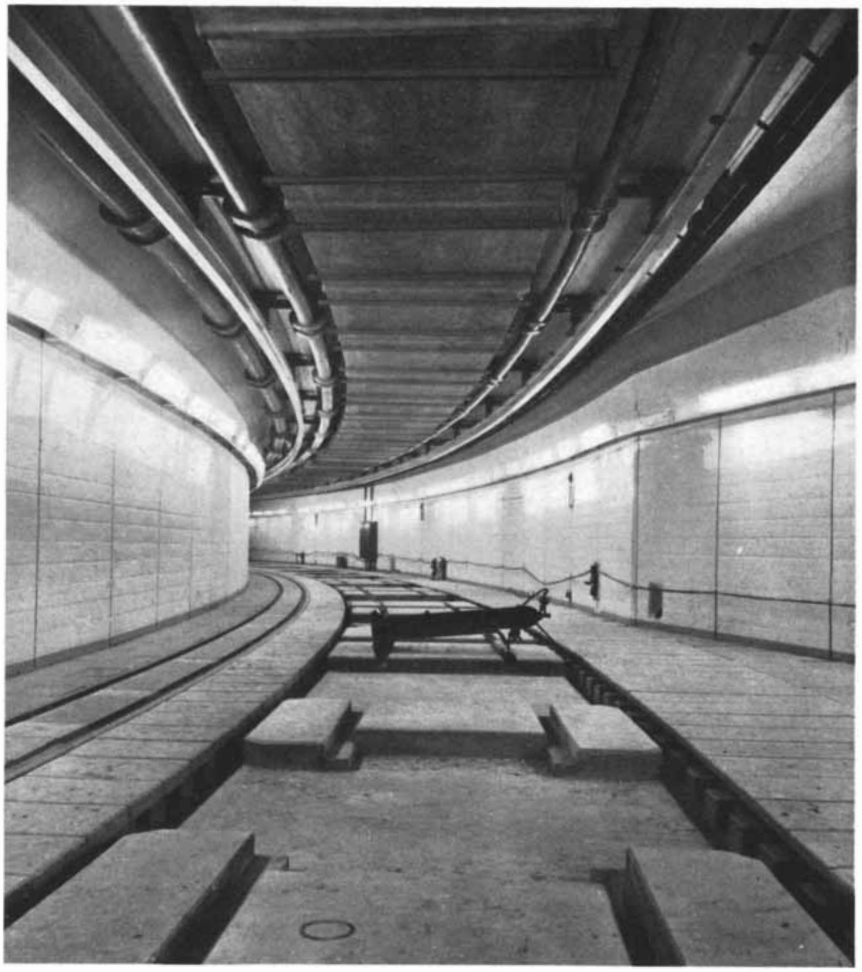
by Robert R. Wilson

From time to time in the course of history men have been swept up by intense currents of creative activity. In the pyramids of Egypt, in Greek sculpture and in Florentine painting we find monuments to such bursts of expression. My favorite example is the Gothic cathedrals that so magically sprang up in 12th- and 13th-century France, for I like to relate that magnificent preoccupation with construction to an obsession of our own time—the building of nuclear accelerators.

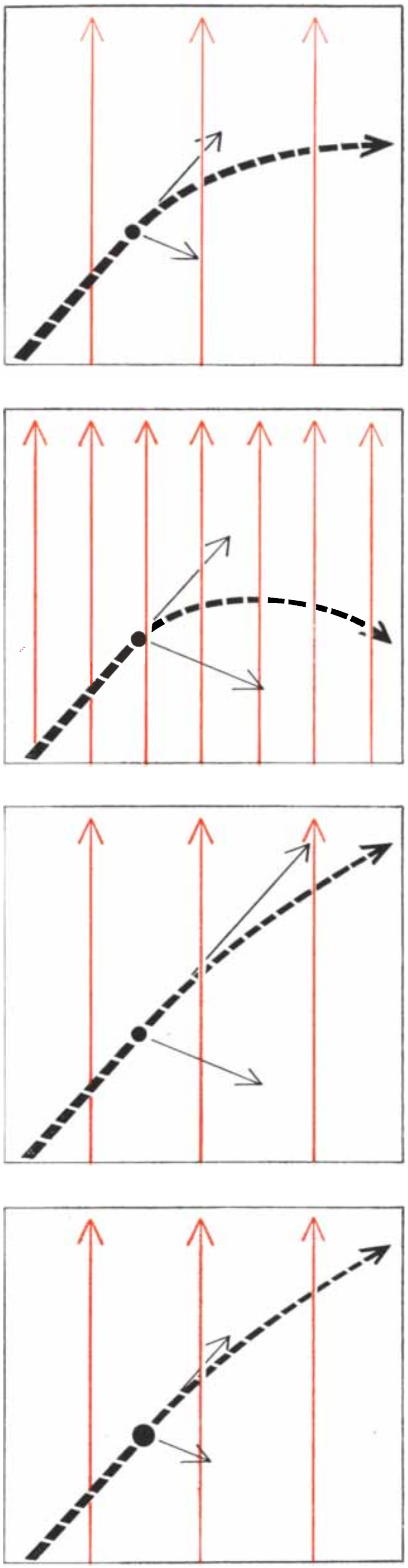
Like nuclear physics today, religion at that time was an intense intellectual activity. It seems to me that the designer of an accelerator is moved by much the same spirit which motivated the designer of a cathedral. The esthetic appeal of both structures is primarily technological. In the Gothic cathedral the appeal is primarily in the functionality of the ogival construction—the thrust and counterthrust that is so vividly evident. So, too, in the accelerator we feel a technological esthetic—the spirality of the orbits of the particles, the balance of electrical and mechanical motion, the upward surge of forces and events until an ultimate of height is reached, this time in the energy of the particles. In both cases we find the architects working at the very limit of technical knowledge. In both there is intense competition between localities, regional and national. Both structures are expensive: a really large accelerator can cost $100 million; the cost of a cathedral, in terms of medieval economics, was possibly higher.

But where a cathedral was a community enterprise, with many people in the region participating in its financing and construction, and nearly everyone in its enjoyment, an accelerator is esoteric. Its presence in a community is usually unknown and unsung. Few are the workers who help to build it, and fewer still are those who use it.

So the accelerator building boom goes on largely unnoticed, but at a quickening pace. Cyclotrons, the original "atom smashers," are now dotted almost all over the globe. They have evolved into synchro-cyclotrons, and have reached their culmination in three giant machines, one at the University of California in Berkeley, another at the European Organization for Nuclear Research (CERN) in Switzerland and another in the U.S.S.R. These machines accelerate



PROTON SYNCHROTRON IN GENEVA is designed to yield 25 bev. Shown here is a section of the interior of its ring building. This structure is approximately 660 feet in diameter.



MAGNETIC FORCE on moving charged particles (*black dots*) is indicated by arrows pointing down and to right. Upward arrows show the speed of the particles and colored arrows the direction of the field. Large dot at the bottom represents a heavier particle.

protons to energies of between 600 and 700 million electron volts (mev). Synchrotrons, another development, are even bigger and more powerful. The Cosmotron, a 2,200-ton monster at Brookhaven National Laboratory which emits 3-billion-electron-volt (bev) protons, is small compared to the 6-bev, 10,000-ton Bevatron at Berkeley. This in turn is topped by the 10-bev, 36,000-ton Phasotron in the U.S.S.R. Two even larger machines are under construction at Brookhaven and CERN; they are designed to produce protons of 25 to 30 bev. And still bigger accelerators are being planned.

Nuclear Microscopes

Why? What is the purpose behind this almost feverish effort to build more and bigger machines? Perhaps the simplest answer is that accelerators are the microscopes of nuclear physics. We usually think of an accelerator as a sort of gun, producing high-speed particles which bombard the nucleus of the atom. But since particles are known to have wave properties, it is equally appropriate to say that the accelerator shines "light" on the nuclei, enabling us to "see" them.

Now the resolving power of a microscope, *i.e.*, its ability to distinguish small objects, depends on the wavelength of the light it employs. The shortest wavelength of visible light is about four 100,000ths (4×10^{-5}) of a centimeter; with these waves one can perceive a microbe of about the same length.

To examine smaller things, biologists now use the electron microscope. The wavelength of a particle depends on its mass and its energy. At a few thousand electron volts—the energy at which electron microscopes operate—an electron has a wavelength some 10,000 times shorter than that of visible light (about 10^{-9} centimeter). With these waves one can begin to see the details of molecules.

The nucleus of an atom is about 10^{-12} centimeter in diameter. This is the wavelength of a proton with an energy of 1 mev. To "see" the nucleus we therefore need a 1-mev proton "microscope," and to make out some of its internal details we need some 10 to 20 times as much energy. Thus a laboratory interested in classical nuclear physics will invariably have a Van de Graaff accelerator or a cyclotron operating in the range of 1 to 20 mev.

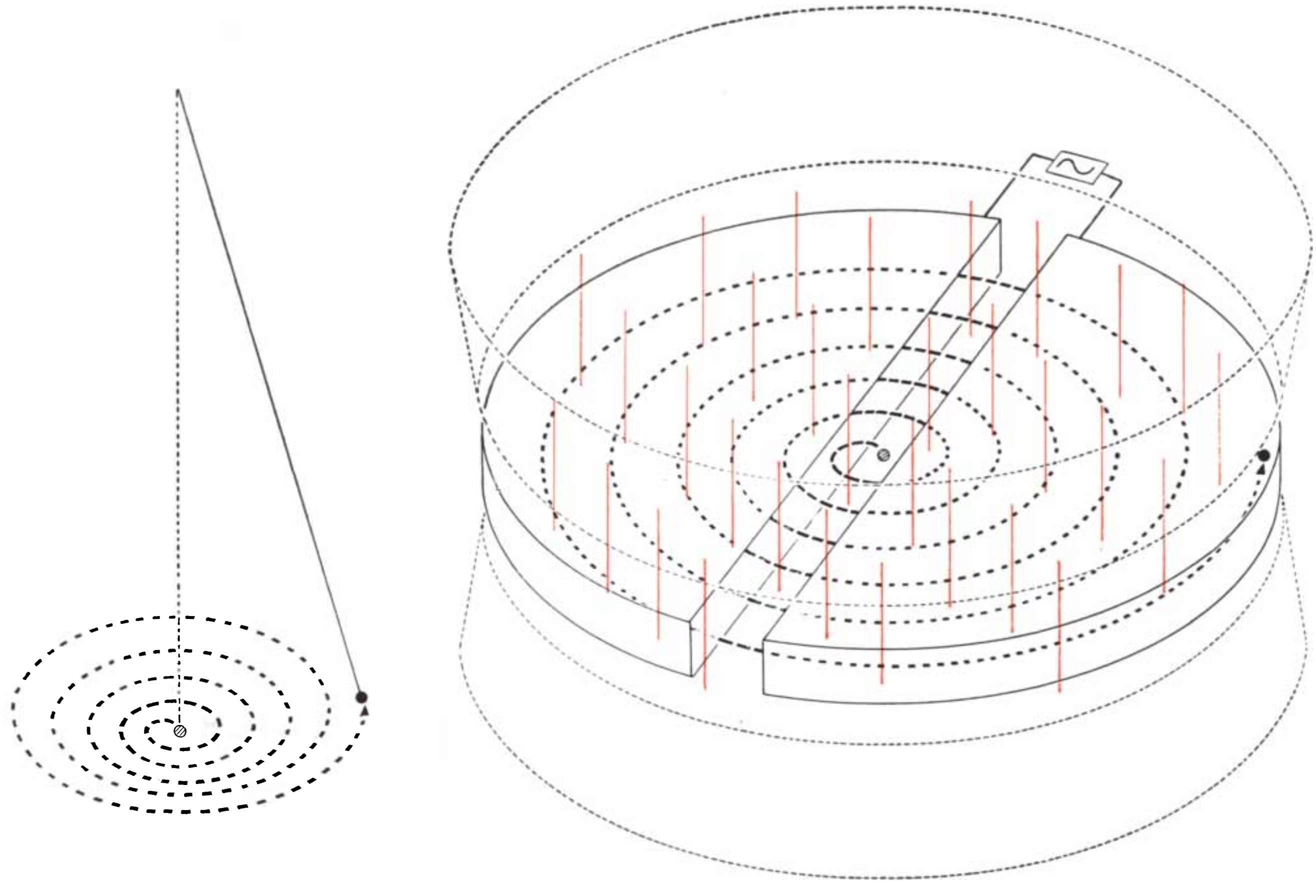
But physics has pushed beyond this point. At present many of us are interested not in the nucleus as a whole but in the structure of the protons and neutrons (nucleons) of which it is composed. It is the old problem of worlds within worlds, for the proton itself turns out to have a rich structure. It is perhaps 10^{-13} centimeter in diameter, and to resolve it requires an energy of several hundred mev. To see it in as fine detail as we can see the structure of the nucleus we must have still higher energy. It is for this reason that the 25- to 30-bev machines are under construction. If and when the structure of the proton is known, will its component parts turn out to have their own structure? Very possibly so, and if they do, machines of higher energy will be built to explore that structure.

The microscope analogy does not tell the whole story. When we get to sufficiently short wavelengths (*i.e.*, when the bombarding particles in our accelerators reach sufficiently high energy), we not only see particles, but we also make new ones. These new particles are created out of energy. At 1 mev an electron has enough energy to create a pair of particles—an electron and a positron. At 150 mev it makes pi mesons (pions) when it collides with a nucleon. Our 1-bev electron accelerator at Cornell University produces more massive particles: K and lambda mesons. The Bevatron, which produces 6-bev protons, is able to create antiprotons, antineutrons and still heavier particles such as xi and sigma mesons.

Thus as the energy of the machines has increased it has become possible to create more and heavier new particles. Obviously the exciting next step is to attain even higher energies, and then to see what sort of monster particles are created. One has the very strong feeling that new particles will indeed show up. It may well turn out that they will prove to be only complexes of particles which we already understand; however, it is exactly to answer such questions that we are building the machines.

Originally we constructed our accelerators in order to search for the ultimate in elementary particles. We expected these particles to be fragments and hence to be successively smaller; it was to improve our definition of them that we went to higher energies. Ironically the fragments now seem to get larger. One has the uneasy feeling that new machines make new particles which lead to the construction of new machines, and so on *ad infinitum*. In fact, there may be lurking here a new kind of indeterminacy principle which will inherently limit our knowledge of the very small.

So much for the reasons why accelera-

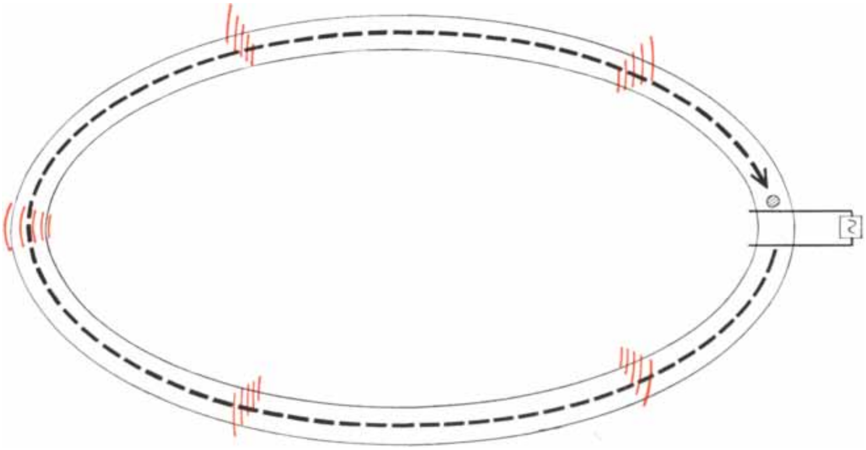


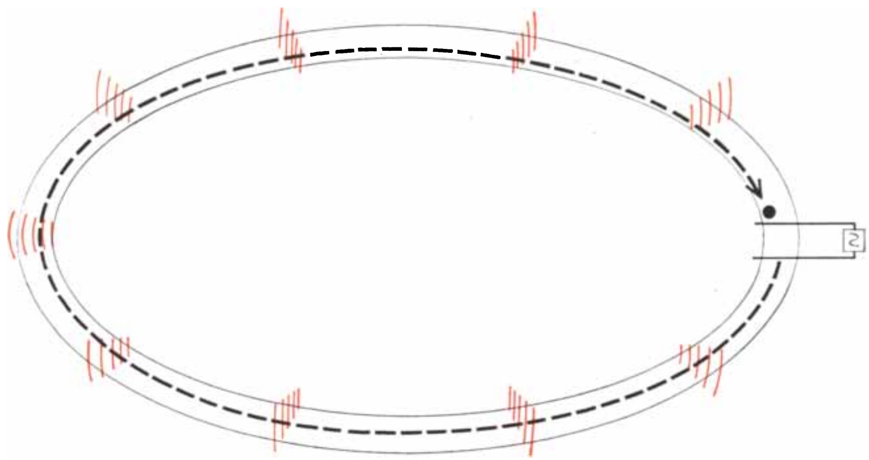
CYCLOTRON'S OPERATION is like that of a circular pendulum (*left*) in which the weight is pushed repeatedly to give an ever-widening swing. The schematic diagram at the right shows a particle (*dot*) spiraling within two D-shaped electrodes. The magnetic pole pieces which provide the guiding field (*colored lines*) are outlined in light broken lines. The particles are accelerated by an oscillating electric field between the dees. The generator which produces the field is shown as a wavy line within a rectangle (*top*).

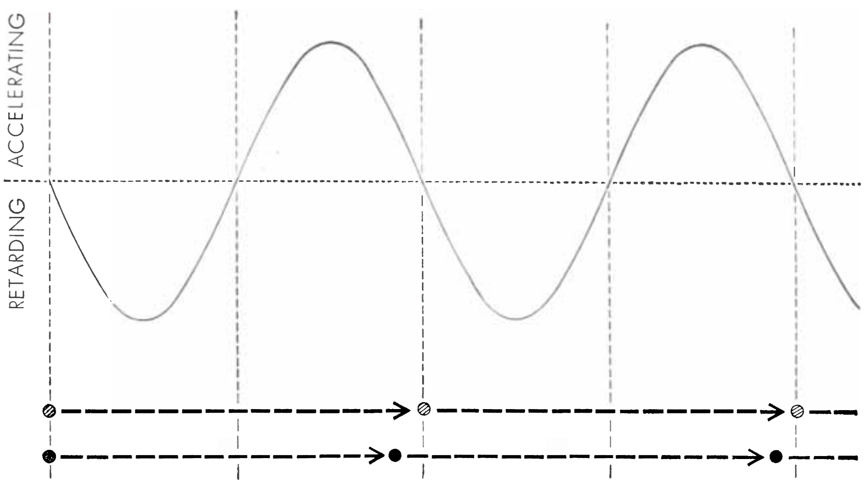
tors are built. Let us turn to the machines themselves. All of them operate on the same fundamental principle: charged particles (electrons or positive ions, usually protons) are put into an electric field which exerts a force on them, pushing them to high speeds and energies. (The electron volt, in which the energy is usually measured, is the energy acquired by a particle with one electronic unit of charge accelerated by a potential difference of one volt.) The simplest form of accelerator is a pipe along which a steady electric field accelerates the particles. This is the well-known Van de Graaff machine. To obtain higher energies a long pipe may be used with several accelerating electrodes which kick the particles to higher and higher speeds as they travel down the tube [see "The Linear Accelerator," by Wolfgang Panofsky; SCIENTIFIC AMERICAN, October, 1954]. But to attain a really high energy by this method would require an extremely long pipe. To get around this difficulty the particles can be made to travel in a circular or spiral path which brings them back through the same electrodes where the accelerating voltage is applied again and again.

It is with such circular machines that we are chiefly concerned in this article. In these machines the circular motion is brought about by magnetic fields. A magnetic field exerts a force on all electric charges that move through it; the force is always at right angles to the direction of the charges' travel. It is the same kind of force that acts on a stone whirled at the end of a string. The magnetic field, like the string, forces the particles to move in a circular path. The stronger the field, the sharper the curvature of the path; on the other hand, the faster or heavier the particle, the less it is curved by a given field [*see diagrams on opposite page*].

The simplest and oldest type of accelerator to make use of magnetic bending is the cyclotron. The operation of this machine can be most easily visualized by imagining a weight suspended by a string and pushed so as to describe a circular motion. As with any pendulum the time required to complete a full circular swing is the same whether the circle is small or large. Thus if the weight is pushed rhythmically it will move outward in an ever-widening circle, returning to the pushing point in the same time on each revolution [*see diagram above*]. So it is in the cyclotron: each ion whirls inside of two semicircular electrodes or "dees," getting an electrical push when it passes from one to the other. A vertical magnetic field provides a constant inward push and, like the string, holds the ion in a circular path and guides it back to the gap between the dees, where it is given another electrical push. The velocity of the ion then becomes greater and, as a result of its inertia, the curvature of the circular path caused by the magnetic field becomes larger. The time taken to traverse a full circle is the same no matter how big the radius, because the increase in speed just compensates for the increase in path-length per turn. Now if the voltage across the dees is made to oscillate rapidly, and if its period is adjusted so that it exactly matches



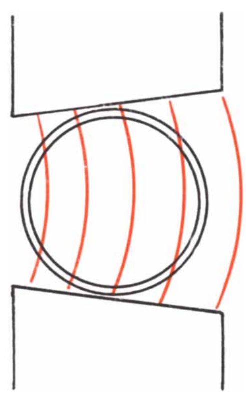




the period of revolution of the ions, then the ions will be pushed in the right direction at the right time at each crossing of the gap between dees; the energy of the ions will build up until their path takes them to the edge of the magnetic field, where they can be used or extracted in the form of a beam.

If the cathedrals had great designers such as Suger of St. Denis and Sully of Notre Dame, the accelerators have their Cockcroft of Cambridge and Lawrence of Berkeley. In 1928 J. D. Cockcroft and E. T. S. Walton built a device in which a voltage generated between two electrodes accelerated ions to a high enough speed to cause the disintegration of a bombarded nucleus. They were still working in the magnificently simple tradition of Ernest Rutherford's laboratory at the University of Cambridge. A quite different tradition was established with the building of the first cyclotron by Ernest O. Lawrence in 1930. It has spread from his laboratory at the University of California and has come to dominate experimental nuclear physics in this country. Indeed, one can begin now to trace this spirit abroad, particularly to the U.S.S.R., where it may flourish even more vigorously than it does in the U. S.

This tradition, called "berkelitis" by its detractors, is a true departure in experimental physics. Previously experimental equipment had been constructed to test a particular surmise or idea. But building a large accelerator is more analogous to outfitting a ship for an expedition of exploration, or to the construction of a huge telescope to study a variety of astronomical objects. After several cyclotrons had been built at Berkeley, the



SYNCHROTRON restricts particles to a nearly circular path by means of a magnetic field (*colored lines*) which grows stronger as the particle energy increases. At top an electron (*hatched circle*) is in an orbit that brings it to the accelerating gap (*right*) just as the voltage changes from accelerating to retarding (*curve at bottom*). In the center drawing the field is made stronger and the electron (*black circle*) is bent more strongly, following a shorter path and arriving at the gap in time to get a push. After a number of pushes it spirals out to the original path. The cross section at bottom right shows magnetic pole pieces around the doughnut.

students and associates of Lawrence traveled far and wide to spread the gospel. By World War II they had helped to build cyclotrons not only at universities in the U. S., but also in several other countries. The biggest of these machines produced protons of about 10 mev. As we have seen, this is an appropriate energy for exploring the nucleus as a whole, but not for examining its parts. Just before the war Lawrence had begun to build a giant cyclotron, to enter the energy region above 100 mev, with which he could start to probe nucleons.

The Synchrotron

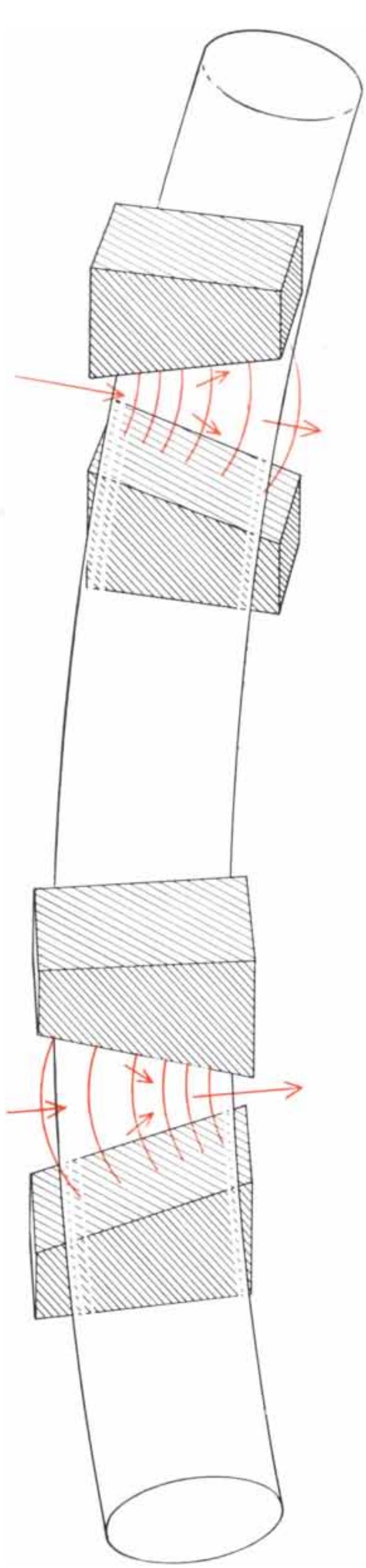
It was characteristic of Lawrence that he went ahead despite a prevalent conviction that the energy limit of the cyclotron was about 20 mev. This conviction was based on an effect predicted by Albert Einstein's theory of relativity: particles traveling at nearly the speed of light will increase in mass. At 20 mev a proton has entered this "relativistic" region, and further increases in energy will result not so much in greater speed as in greater mass. When this happens, the particle in a cyclotron begins to fall behind schedule as it spirals farther outward, and it no longer arrives between the dees at the right time to get a push from the oscillating voltage.

The war interrupted work on Lawrence's big machine. Its huge magnet was used to separate isotopes of uranium for the atomic-bomb program. At the end of the war V. I. Veksler of the U.S.S.R. and E. M. McMillan of the University of California independently and almost simultaneously enunciated the so-called synchrotron principle. This principle showed the way to accelerating particles into the completely relativistic region. It was exactly the sort of *deus ex machina* that Lawrence had envisioned when he gambled some $1 million in starting his big cyclotron. The principle was immediately adopted. A successful synchro-cyclotron was built which produced protons in the region of 100 mev (eventually 730 mev). In the next few months a number of important features of the proton were discovered.

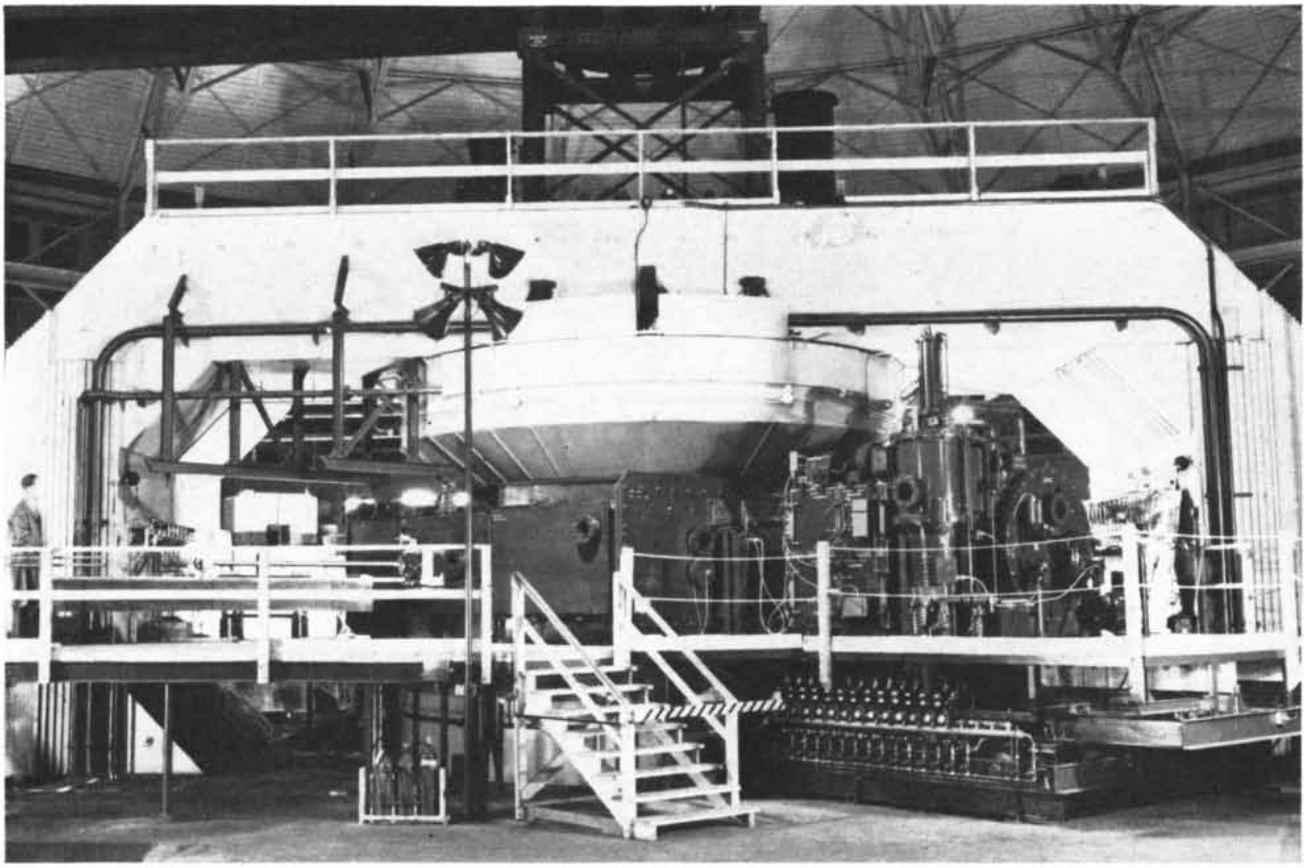
To understand the synchrotron principle, it is easier to consider its application in the electron synchrotron rather than in the more complicated synchro-cyclotron. Some half-dozen of these electron accelerators, with maximum energies of about 300 mev, were also built just after the war.

In a synchrotron electrons travel on a circular orbit inside a narrow doughnut-shaped vacuum vessel. At one point in the doughnut is a pair of accelerating electrodes across which there is an oscillating voltage like that in the cyclotron. A ring-shaped magnet surrounding the doughnut produces a field which forces the particle to travel on orbits close to the center of the tube [*see diagram on opposite page*]. The electrons are injected into the doughnut from a small linear accelerator at an energy of about 2 mev. At this energy their speed is some 98 per cent of the speed of light; hence they cannot travel much faster. To make matters simpler let us assume that the speed is exactly the speed of light and that the whole increase in energy goes into mass. Now imagine an electron in a circular orbit at the center of the doughnut. The electron is held there by a constant magnetic field. Also imagine that our oscillating voltage is applied, but that the electron crosses the accelerating gap just at the time when the voltage falls through its zero value. The frequency of the voltage is made the same as that of the electron traveling around its orbit at the constant speed of light. The electron now passes the gap on all subsequent turns just as the voltage becomes zero. Thus nothing happens; the electron remains on its orbit and keeps the same energy. Now we increase the magnetic field slightly. Since the energy (mass) is still the same, the particle is forced into a sharper curve, *i.e.*, its orbit gets smaller. But because the orbit is smaller and the speed is constant, the time it takes the electron to return to the accelerating gap is shorter. Hence the electron arrives slightly before the voltage has fallen to zero; it is accelerated slightly. On the next turn, if the energy is still not large enough, the orbit will still be too small: the electron will arrive still earlier and be accelerated even more. Eventually the energy will increase enough (that is, the electron will get heavy enough) so that it is bent less sharply and edges out to its original orbit. If the energy should become too great, the orbit will be too big and the time it takes the electron to make each turn will be too long. This will cause the electron to drop behind the accelerating voltage and be pushed backward so that it will lose energy. Thus we have a beautiful automatic device for keeping the electron on the right orbit, or at least oscillating around the right orbit. That is all there is to the synchrotron principle or, as it is sometimes called, phase focusing.

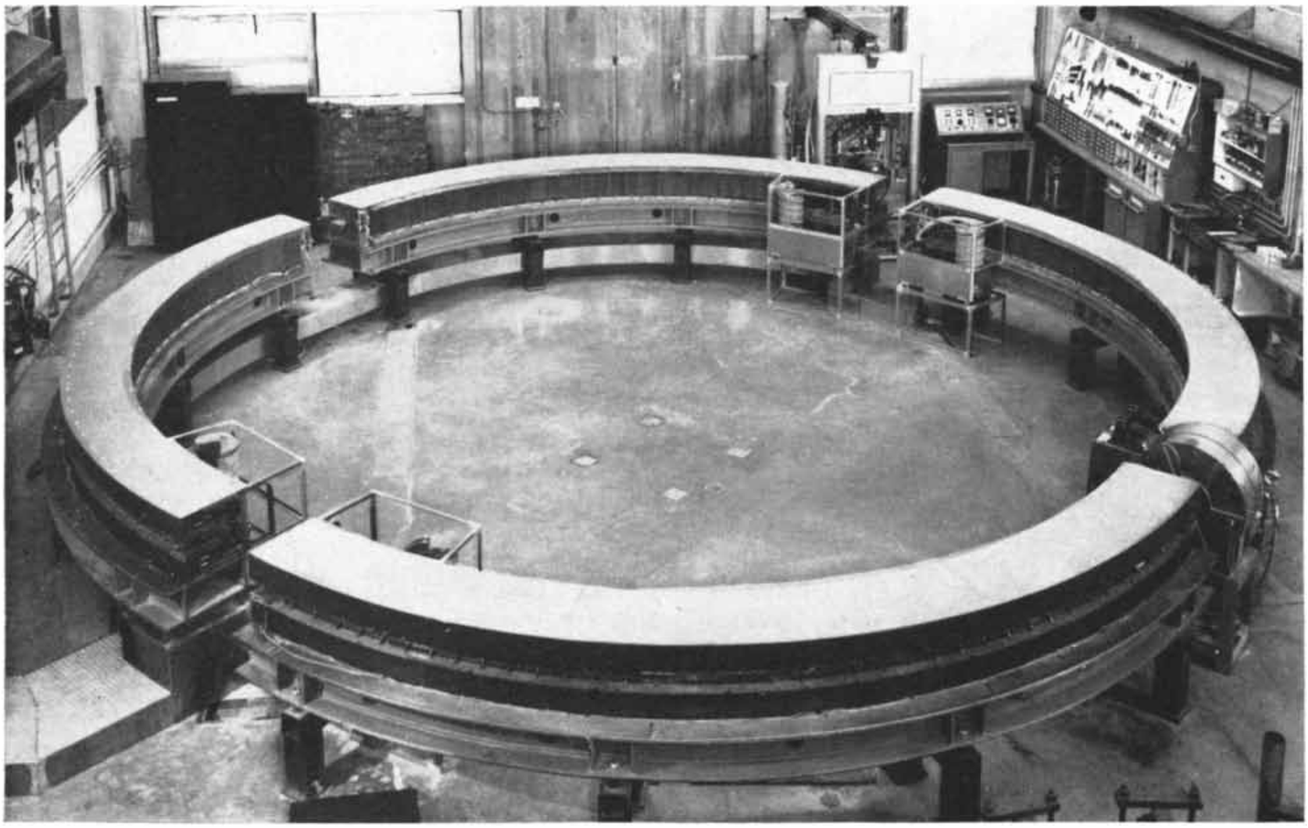
Now we can see that, if the magnetic field of the synchrotron is increased continuously, the energy of the electrons



STRONG FOCUSING is produced by magnetic fields which are alternately bowed out and in. Horizontal arrows show radial forces on the particles at inner and outer edges of the field. Slanted arrows represent forces which focus or defocus particles vertically.



SYNCHRO-CYCLOTRON at the Berkeley Radiation Laboratory of the University of California is now the most powerful machine of its kind. A modification of its design last year increased the energy of its proton beam to 730 million electron volts (mev).



ELECTRON SYNCHROTRON was photographed in the author's laboratory at Cornell University while its guiding magnet was under construction. Machine, which produces an energy of 1 bev, is the first to use strong focusing. Accelerating electrodes are at right.

will also increase continuously; the electrons will receive energy at just the right rate to keep them on the central, or synchronous, orbit. In practice electrons can be injected into the doughnut when the magnetic field is rather weak (about 10 gauss) and ejected when the field is quite strong (more than 10,000 gauss). A synchrotron with a large enough radius can accelerate electrons up to energies of about 10 bev. There are now about six machines, built or being built, which are designed to yield electron energies between 1 and 1.5 bev. At Cambridge, Mass., a 6-bev electron synchrotron is being constructed by a joint Harvard University–Massachusetts Institute of Technology group.

Let us return to the synchro-cyclotron. It works in essentially the same way as a synchrotron but it is shaped like a cyclotron. Instead of a varying magnetic field it has a constant field, but the frequency of the accelerating voltage applied to the dees is varied. This means that the synchronous orbit of the protons is not a fixed circle but a growing spiral.

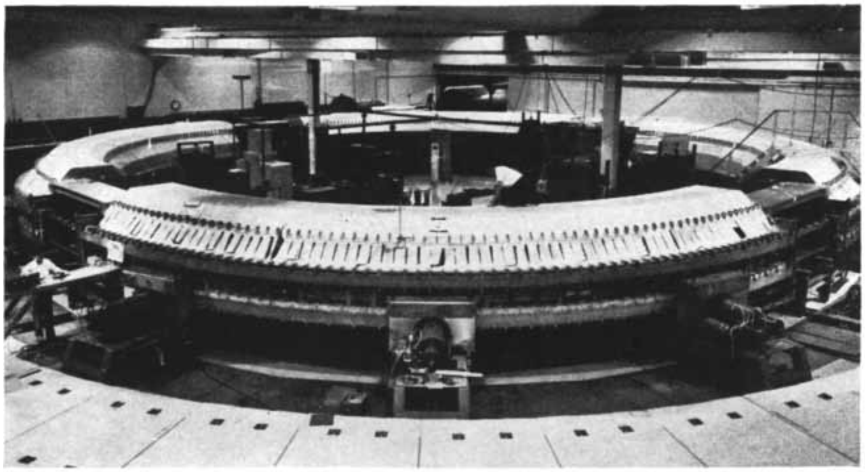
In another class of accelerators, the proton synchrotrons, both the magnetic field and the frequency of the accelerating voltage are varied. The increasing field counteracts the protons' tendency to spiral outward as they get up to relativistic energies, and the orbit is again a fixed circle. Above about 5 bev the protons are traveling practically at the speed of light, and from here on the proton synchrotron works just like an electron synchrotron.

If I may extend the figure of speech with which I began this article, each kind of accelerator has its own architectural style. To me synchro-cyclotrons are baroque. Proton synchrotrons are definitely Romanesque, although their rounded arches are horizontal. Electron synchrotrons have a lightness and grace that could only be Gothic.

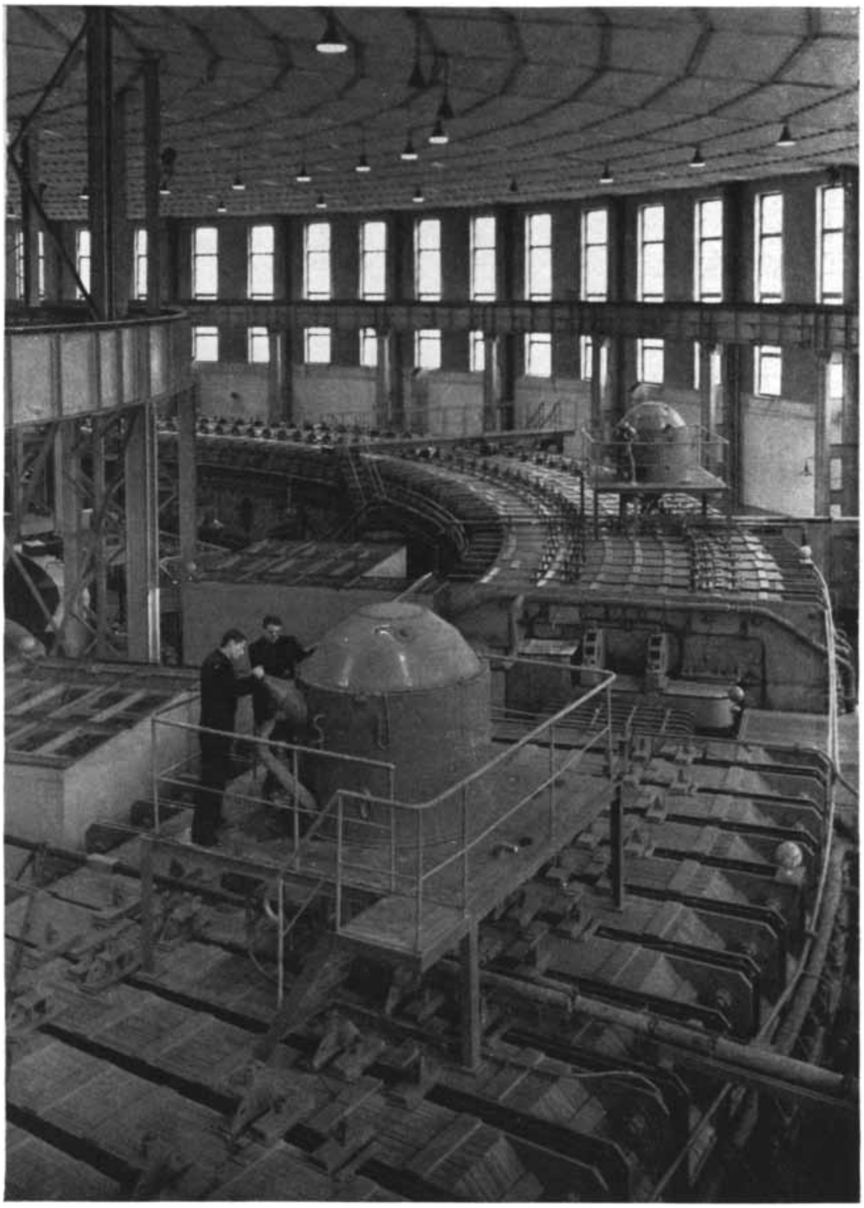
The Newer Machines

This brings us more or less up to date in the evolution of accelerators. We may now ask whether we are near the end of this movement in physics or still at its beginning. The field still has tremendous vigor, and it is my guess that we are at about the same stage as the cathedral builders were after they had completed Notre Dame of Paris. The significant innovations were behind them, but most of their masterpieces were yet to come.

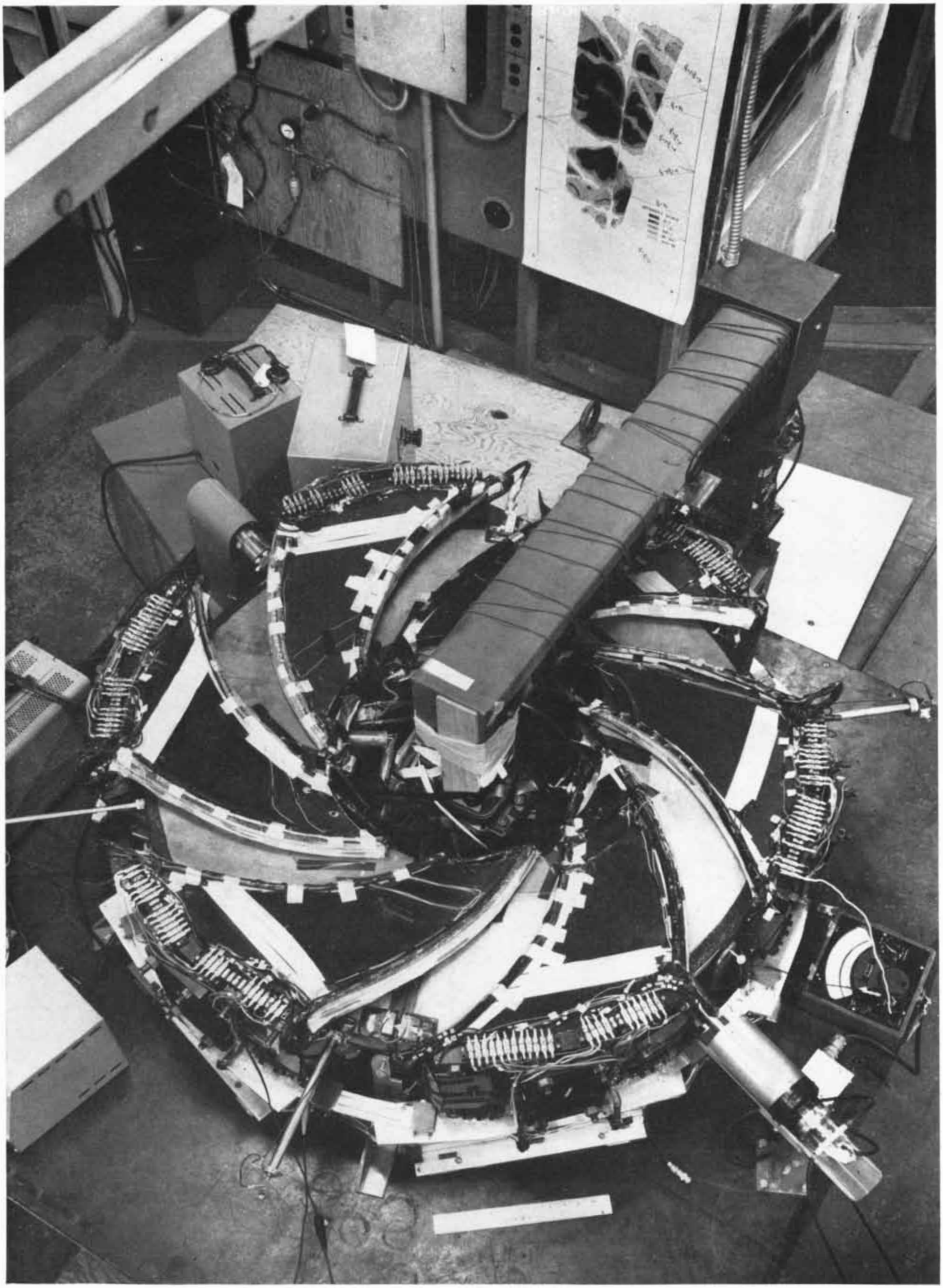
Early in this article I mentioned that two machines now under construction, one at Brookhaven National Laboratory



COSMOTRON, the 3-bev proton synchrotron at Brookhaven National Laboratory, was the first one of the multi-bev accelerators. Its 2,200-ton magnet has an inside diameter of 60 feet.



PHASOTRON is a 10-bev proton synchrotron in the U.S.S.R. Its magnet, of which a portion appears in this photograph, weighs 36,000 tons and is approximately 200 feet in diameter.



FFAG (fixed-field alternating-gradient) design is embodied in an electron accelerator built as a model for a larger proton machine at the laboratory of the Midwestern Universities Research Association in Madison, Wis. The dark spiral sectors are the magnets.

and the other at CERN in Geneva, will produce protons of 25 to 30 bev. Both of these machines are proton synchrotrons; each will cost between $20 million and $30 million. The diameter of the orbit traveled by their protons will be nearly 1,000 feet!

These machines were made possible by the discovery at Brookhaven of a new principle called strong focusing [see "A 100-Billion-Volt Accelerator," by Ernest D. Courant; SCIENTIFIC AMERICAN, May, 1953]. This principle involves a reshaping of the guiding magnetic field so that the particles are held much closer to their ideal orbit. It means that the doughnut can be thinner, and the surrounding magnet smaller and lighter.

Until now we have considered only the radius of the orbit, *i.e.*, the size of the circle on which the particles travel. However, the particles can not only drift in and out but also up and down; thus they must be focused vertically as well as horizontally. In old-style synchrotrons the lines of force in the magnetic field are bowed slightly outward [*see diagram on page 68*]. This has the effect of forcing particles back toward the center line when they move above or below it. But the bowed field gets somewhat weaker with the distance from the center line. Hence a particle that wanders too far from the center line is not strongly pushed back toward it.

In strong focusing the field is broken into sectors which are alternately bowed outward and inward [*see diagram on page 69*]. The sectors bowed outward provide sharp vertical focusing, but are even worse than the old field-shape at bringing a particle in from an orbit that is too large. In other words, they do not focus radially. On the other hand, the sectors bowed inward increase in strength as the radius gets bigger, and provide strong radial focusing. Vertically, however, they have the wrong effect on the particles, tending to spread rather than to focus them. It turns out that each of the defocusing influences is overbalanced by the focusing effect of the other sector; the net result is a much more tightly restricted beam. This method of focusing was successfully used in the Cornell 1-bev electron synchrotron, and it will be applied in the 6-bev Harvard-M.I.T. electron synchrotron.

Not to be outdone by CERN and Brookhaven, the U.S.S.R. has announced that it will build a 50-bev strong-focusing proton synchrotron. The magnet will weigh about 22,000 tons and will have a diameter of 1,500 feet. It would seem that whatever we do, our Soviet friends can do too—and with a factor of two in their favor.

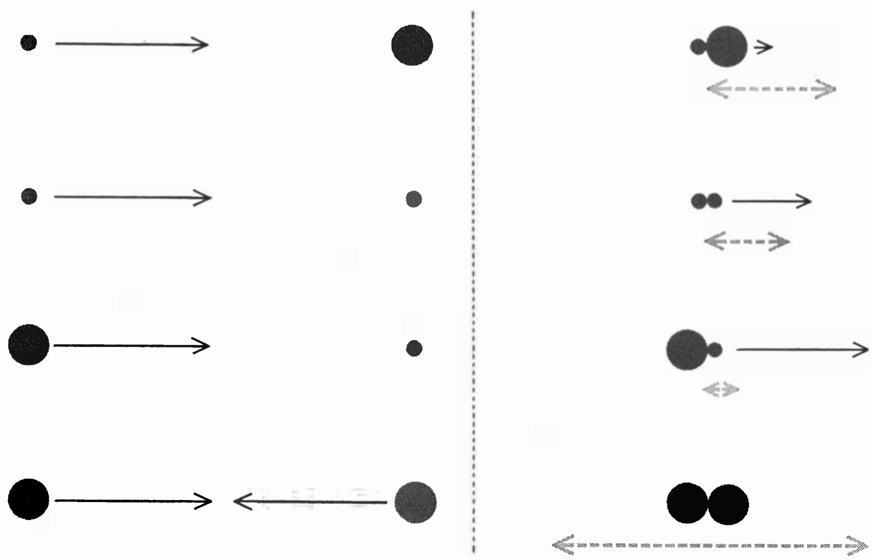
"FFAG"

The most exciting recent development in this country has been the "fixed-field alternating-gradient" accelerator proposed by Keith R. Symon of the Midwestern Universities Research Association (MURA). The so-called FFAG machine is really a rococo cyclotron in which the magnetic field is shaped in such a way as to allow the cyclotron to work into the high-energy relativistic region. We have already seen how the ordinary cyclotron is limited to accelerating protons to about 20 mev. When this limitation was first pointed out in 1938, L. H. Thomas of the Ohio State University suggested a way to get around it. He proposed to scallop the pole tips of the cyclotron magnet so that the surfaces would consist of a series of ridges running out from the center, with valleys in between. Thomas showed that the strength of the resulting field would increase toward the outside, compensating for the protons' relativistic increase in mass, and would also focus the protons so that they would stay in the vacuum chamber. Thomas's scheme was far too complicated for the techniques of the time, and it was ignored. Now we realize that he had anticipated the strong-focusing principle. Two Thomas-type cyclotrons are now under construction, one at Oak Ridge National Laboratory, the other at Berkeley. Both of them will produce protons and deuterons in the range of several hundred mev.

We can now understand an FFAG type of accelerator if we imagine that the radial scallops of the Thomas magnet are twisted into spiral ribs. (Is this the flamboyant style that presaged the end of the Gothic period?) The twisting introduces an additional kind of strong focusing. In fact, the idea grew out of strong focusing; only later was its similarity to the Thomas cyclotron recognized. The idea of FFAG has been exploited to the full by the workers of the MURA laboratory at Madison, Wis. They have imagined and computed (using two high-speed computing machines) all sorts of variations of the FFAG geometry, and have built several models that have successfully demonstrated the practicality of the scheme.

The advantage of the fixed-field design is twofold. First, it is easier to control a constant field than a varying one. Second, the fixed-field machines can be operated continuously, whereas the synchrotrons and synchro-cyclotrons must operate cyclically, or in pulses, a new cycle starting each time the field reaches its maximum value. Continuous operation means that more accelerated ions are produced per unit time; in other words, the beam has a higher intensity.

According to the MURA workers, the increased intensity that can be obtained with FFAG machines will make it possible to circumvent a serious limitation



USEFUL ENERGY in a collision depends on the motion of the particles after impact. Solid arrows at left represent energy of motion of bombarding particles. Solid arrows at right show energy of motion of the system after impact. Broken arrows indicate fraction of total energy available for desired reactions. Small dots are light particles; large dots, heavy ones. When like particles are made to collide head-on (*bottom*), all of their energy is available.

on accelerators which I have not mentioned as yet. This limitation concerns the amount of energy that is actually available to produce the reactions we are looking for.

When a high-energy ion from an accelerator strikes a stationary target particle, part of the energy goes into moving the target, and is wasted. It is as if we were trying to break a stone by hitting it with a hammer. To the extent that the hammer blow simply moves the stone, the energy is not available for breaking it. Now if the hammer is very light and the stone very heavy, we can see that the target will not move very far; almost all the energy of the hammer will go into breaking or chipping the stone. If we use a heavy sledge on a light pebble, most of the energy goes into moving the stone, and very little of it is available for breaking the stone. If the hammer and stone weigh the same, they will tend to move off together with half the speed of the incoming hammer; exactly half the energy will be available for breaking the stone.

It is the same with atom-smashing. But here relativity plays a particularly dirty trick, robbing us of most of the advantage to be gained by increasing the energy of the bombarding particles. We have seen that really high energies mean an increase in mass. Thus as we go up in energy we increase the weight of our "hammer" and lose a larger and larger fraction of its energy. At 1 bev a proton is already noticeably heavier than when it is at rest; when it hits a stationary proton, 57 per cent of the energy is wasted and only .43 bev is available for useful purposes. At 3 bev (the energy of the Brookhaven Cosmotron), the available portion is 1.15 bev; at 6 bev (the Berkeley Bevatron) the available portion is 2 bev; at 10 bev, 2.9 bev are available; at 50 bev, 7.5; at 100 bev, 10.5. We see that increasing the energy 100 times from one to 100 bev results in only a 20-fold actual gain.

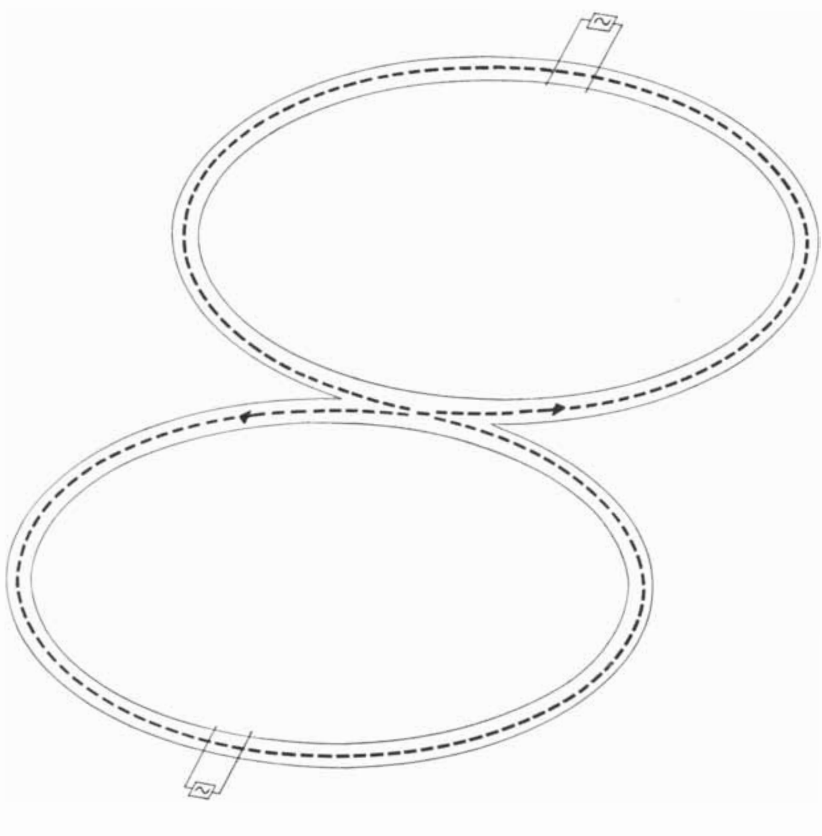
Suppose, however, that instead of firing a moving particle at a stationary one, we arrange a head-on collision between two high-energy particles. Then the mass increase is neutralized, and there is no tendency for the colliding particles to move one way or the other. All the energy of both of them is now available for the desired reactions. This is what the MURA designers propose.

They have envisaged a bold design, called "synchroclash," in which two 15-bev accelerators are placed so that their proton beams intersect and the particles collide with each other. This will yield an available energy of 30 bev, whereas in the case of a 30-bev proton colliding with a proton at rest only 6 bev would be available. In fact, to attain a useful energy of 30 bev in the ordinary way would mean using at least 500 bev. The success of the synchroclash idea turns on the intensity of the accelerator beams: there must be enough protons to make collisions reasonably frequent. The MURA proposal languished for several years, but interest in it seems to have revived. Perhaps the complicated orbits of the artificial satellites have had something to do with the new willingness to consider attempting the complicated orbits of FFAG.

Soviet Ideas

The Soviet designers have gone off in different directions. Veksler has been thinking of a scheme in which one approaches the ideal accelerator, namely one in which the accelerating field appears exactly in the vicinity of the ions but nowhere else. He envisages a small bunch of ions in a plasma (a gas of ions) exciting oscillations or waves in an electron beam. These waves are to act together coherently to give an enormous push to the ions being accelerated. If this is not clear to the reader, it is because it is not clear to me. The details have managed to escape most of us because of a linguistic ferrous curtain, but Veksler speaks of the theoretical possibility of attaining energies up to 1,000 bev. The proof of the idea must wait until it is put into practice. It should be remarked, however, that other wild schemes of Veksler, for example the synchrotron principle, are incorporated into most of our conventional accelerators today.

G. I. Budker of the U.S.S.R. has also presented some speculative ideas which have obviously been inspired by efforts to produce controlled thermonuclear reactions. Budker proposes an intense circular electron beam maintained by a weak magnetic guide field. The high current of the beam will cause it to "pinch" to a very small diameter because of its own magnetic field. The idea then is to use the very strong local magnetic field around the pinched beam as the guide field of a conventional accelerator [*see diagram on page 76*]. With an electron beam six meters in diameter one could expect to hold protons with an energy as high as 100 bev. Budker and his colleagues have constructed a special accelerator in which they have achieved a 10-ampere current of 3-mev



SYNCHROCLASH design would set two accelerators side by side so that their beams overlapped. Head-on collisions between particles would provide the maximum of useful energy.

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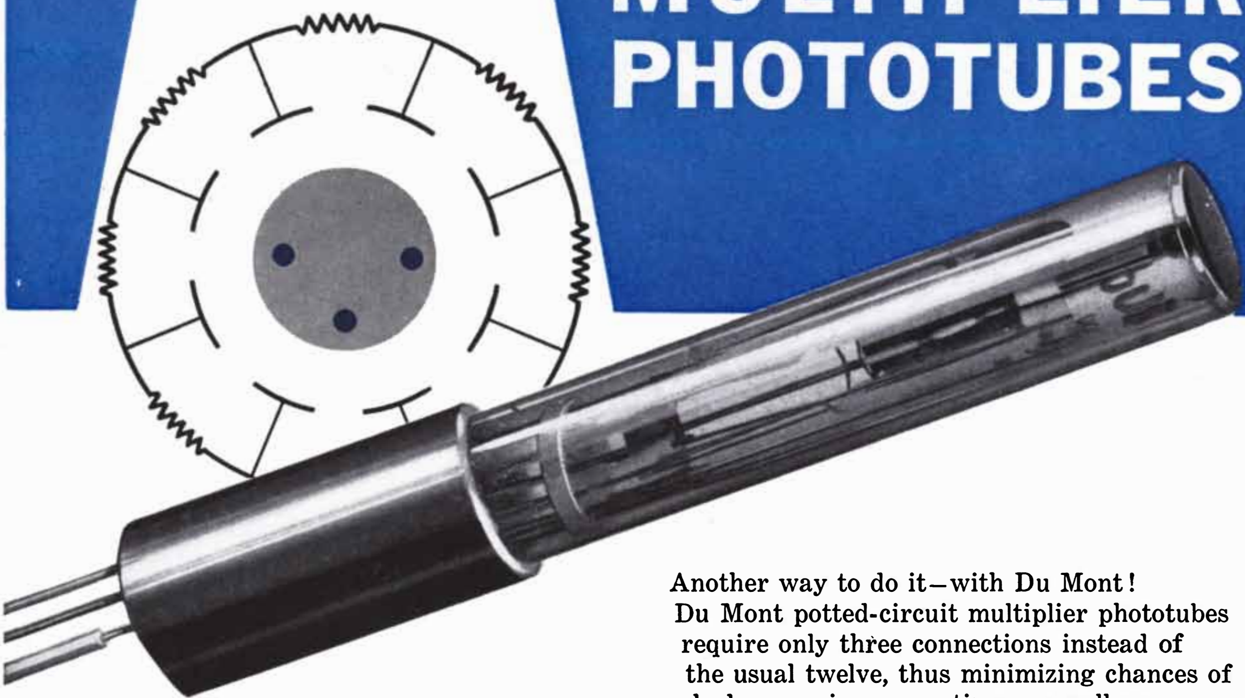

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electrons, and they expect to attain much higher currents and energies before long. It could well be that something really revolutionary will come out of this energetic work.

Our own thermonuclear program has inspired research on very strong magnetic fields [see "Strong Magnetic Fields," by Harold P. Furth et al.; Scientific American, February]. It seems likely that this development will find an application to the guidance of particles in multi-bev accelerators.

Electron Accelerators

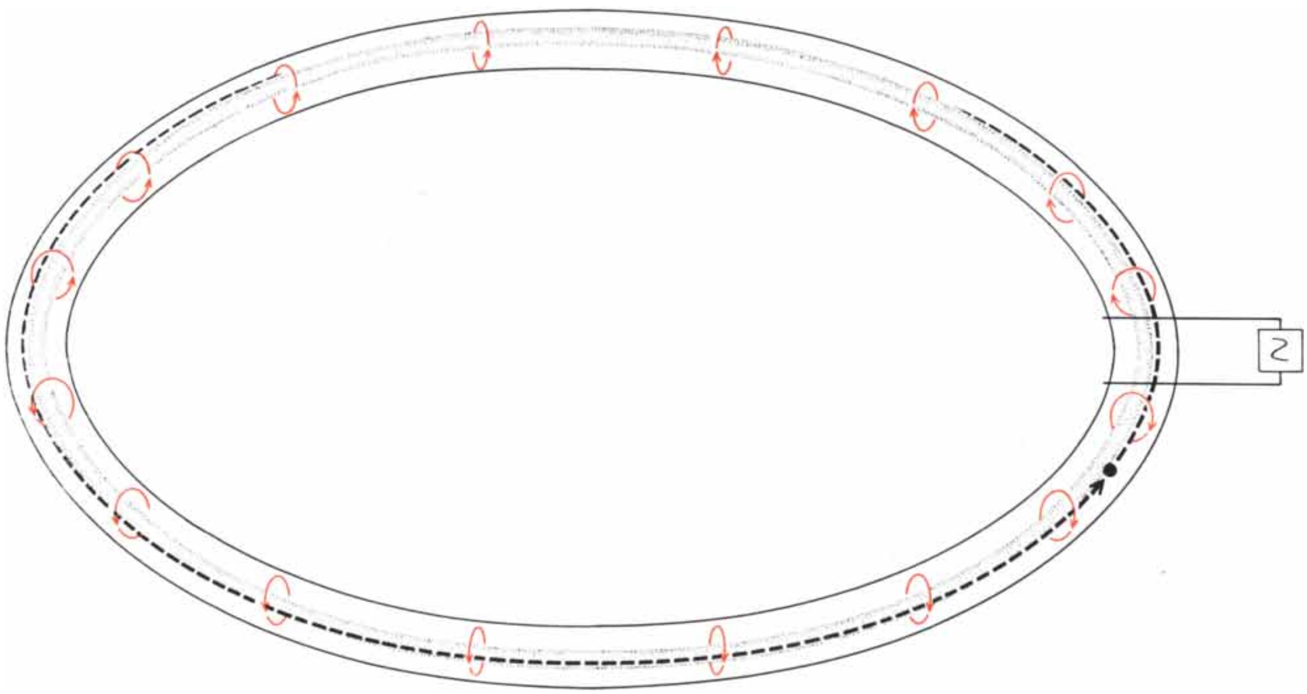
These new machines we have been discussing are proton accelerators, but there is vigorous activity in electron machines as well. We have already mentioned the Harvard-M.I.T. synchrotron which will attain 6 to 7.5 bev, and the half-dozen other smaller machines in the billion-volt range. The 220-foot linear electron accelerator at Stanford University has been on the scene for some time. Its energy has steadily increased so that it may now be used in experiments at 600 mev. We expect to welcome it to the 1-bev club before long.

The linear machine is significant because there is a special difficulty in reaching high energy with electron synchrotrons. When electrons are made to travel on a curved path at high speeds they give off strong electromagnetic radiation. The effect is easily visible to the naked eye; the luminous horizontal beam on the cover of this issue of Scientific American is synchrotron radiation. The difficulty is that this radiation can represent a substantial loss of energy, and it increases rapidly as the energy of the machine goes up. In the Harvard-M.I.T. synchrotron the amount of energy radiated is almost prohibitive (about 10 mev per turn at 7.5 bev). To reach higher energies, say 20 bev, the Stanford group has been thinking in terms of a linear accelerator, which does not have this radiation difficulty because its particles do not move in a circle. Such a machine might be as much as three miles long.

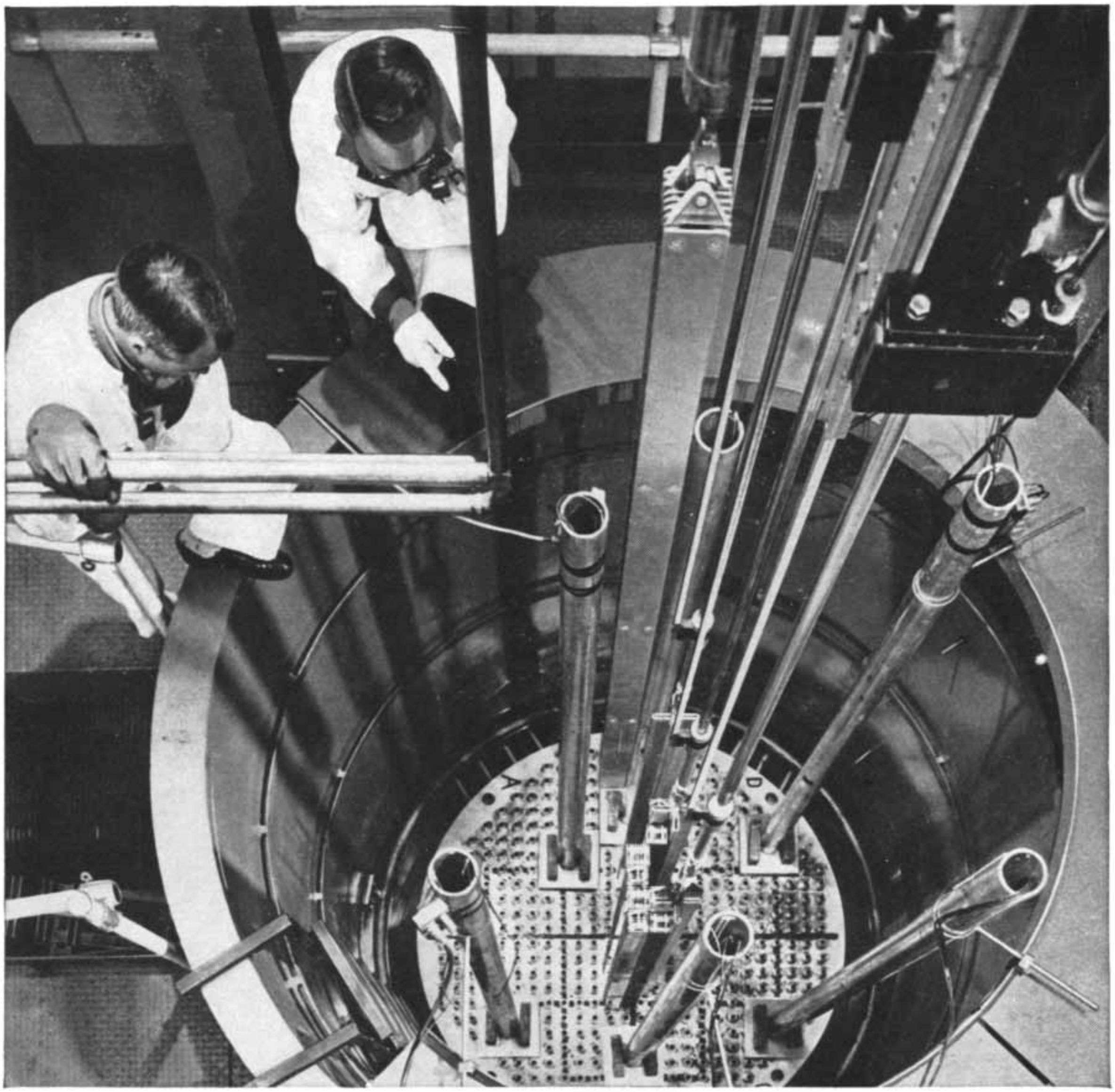
I am not convinced that the limit of electron synchrotrons has been reached. Indeed, it is not difficult to imagine a 50-bev electron synchrotron. The radiation problem would be solved by reducing the curvature of the electron beam, that is, by increasing its radius to, say, half a mile. I believe that the upper limit of the electron synchrotron may be as high as 100 mev.

While we are "thinking big" we should not forget Enrico Fermi's proposal to ring the earth with a vacuum tube and, using the earth's magnetic field, obtain 100,000 bev. For that matter, now that artificial satellites are commonplace, we might put up a ring of satellites—each containing focusing magnets, accelerators, injectors and so on—around the earth. Something like a million bev could be expected from this accelerator, which we might as well call the lunatron. At the very least such a device will eliminate the need for vacuum pumps, since it will be outside the atmosphere.

Villard de Honnecourt and later Viollet-le-Duc have left us detailed accounts of the builders of cathedrals and of their methods. It seems to be pretty much the same story then and now. The designer of the cathedral was not exactly an architect, nor is the designer of an accelerator exactly a physicist. Both jobs require a fusion of science, technology and art. The designers of cathedrals were well acquainted with each other; the homogeneity of their work in different countries is evidence of a considerable interchange of information. The homogeneity of accelerator design demonstrates the same interchange today. Our medieval predecessors were only human; one gets the definite impression that they were subject to petty jealousies, that occasionally there was thievery of ideas, that sometimes their motivation was simply to impress their colleagues or to humiliate their competitors. All these human traits are occasionally displayed by their modern counterparts. But one also gets a strong impression of the excitement of those mighty medieval creators as they exulted in their achievements. This sense of excitement is no less intense among modern nuclear physicists.



PINCH EFFECT might be used to provide a magnetic guiding field for an accelerator, thus eliminating the heavy magnet. The dotted ring is a pinched plasma. Its magnetic field, which is shown by colored lines, would act to hold particles near its outer edge.



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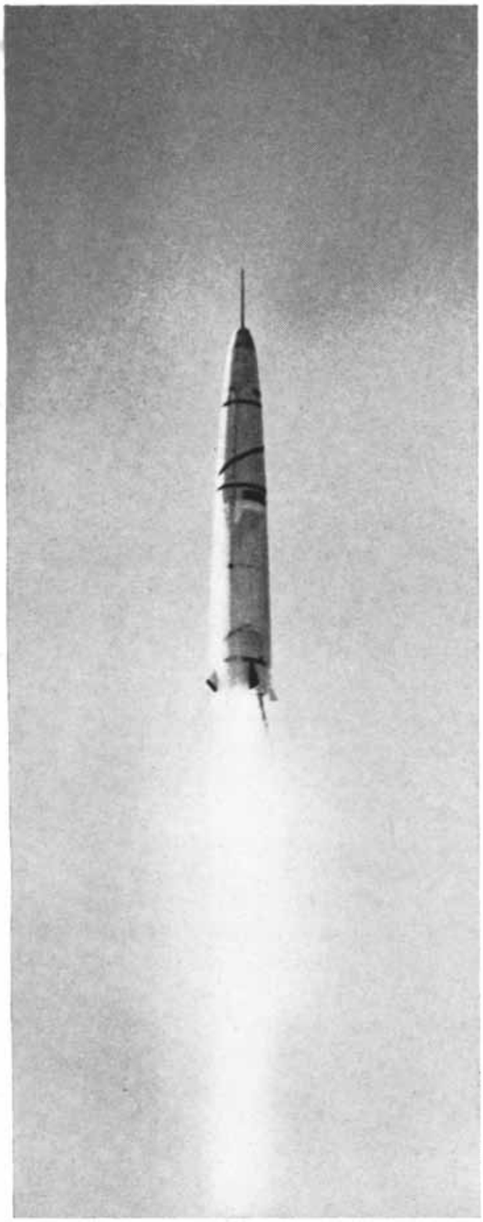

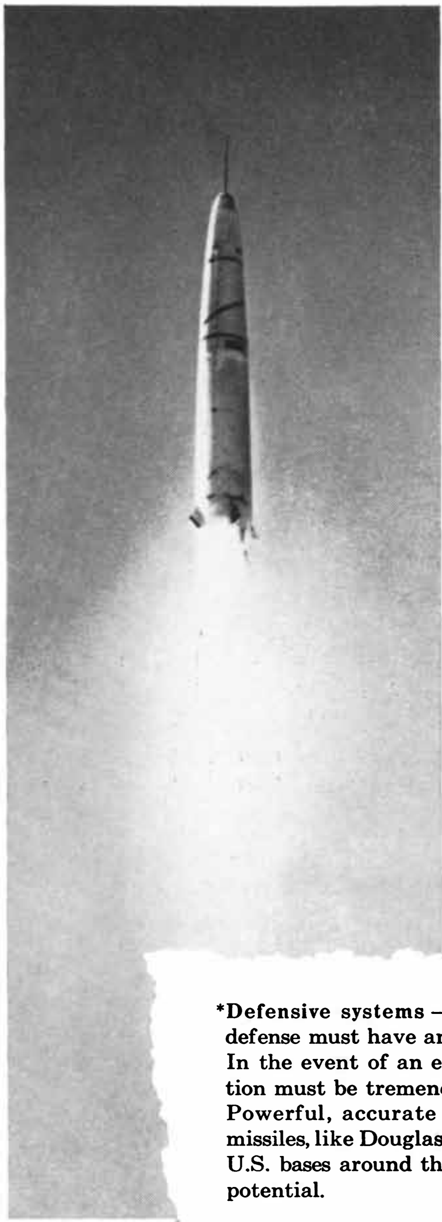

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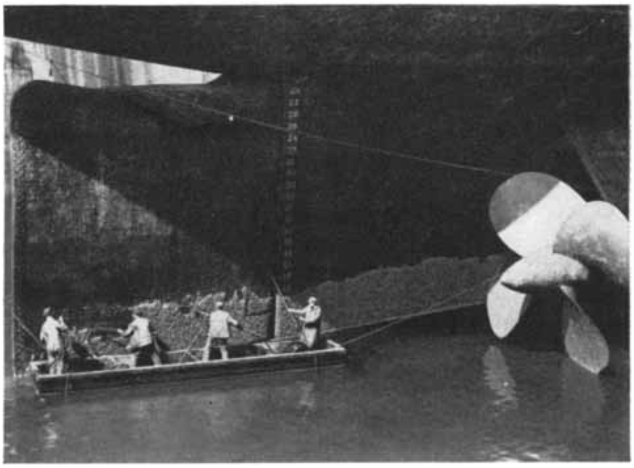

"Barnacle Bills" can be cut ... with MUTUAL sodium copper chromate

This useful combination of properties also has led us to test MUTUAL sodium copper chromate in preservative combinations for wood, cordage, fabrics and paper, and in agricultural fungicides.

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Did it ever occur to you that your product might be epoxidizable? Or even hydroxylatable?

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With H_2O_2, you can upgrade such olefins as soya bean oil, cottonseed oil, tall oil, turpentine, linseed oil or unsaturated petroleum derivatives.

By upgrading, you find yourself making resin plasticizers, glycols, stabilizers, insecticides, monomers, lubricants, waxes, surfactants or brake fluids.

In the epoxidation and hydroxylation processes, hydrogen peroxide reacts with unsaturated olefins to form a completely different class of chemical compounds. Of course, hydrogen peroxide has been around for some time, but recent developments now permit broad commercial use of these processes.

Research people working in chemicals, plastics and pharmaceuticals will be interested in a new Solvay Process Division up-to-date review and bibliography on the subject.

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Paper coaters know that if they want to keep a coating from coming off in water, they must insolubilize the binder after application. Starch, casein, protein and latex are the most widely used paper coating and sizing adhesives. The major advantage of starch is its ease of use, but this is offset by its lack of water resistance. On the other hand, although casein, protein and latex give good water resistance, they are more expensive.

May we suggest a starch coating modified with U.F. CONCENTRATE-85, for low-cost, water-resistant paper coatings. A product of our Nitrogen Division, U.F. CONCENTRATE-85 is a low-cost, non-resinous, high-concentration urea-formaldehyde product.

You can obtain different degrees of insolubility by adding 2 to 50% to the starch, though 20% generally makes an excellent coating. Other assets: a simple mixing operation, a useable pH range of 4 to 8.

We have available a new technical paper on the subject, "A new product for the insolubilization of starch films."

NEW URETHANE BOOKLET

In these columns, we've talked about what the industry calls "the next great synthetic." Allied's interest in urethane materials lies with our National Aniline and Barrett Divisions, which produce the key chemicals—diisocyanates and polyester resins respectively—used in making these versatile plastics. Now we have a new booklet available on urethane materials, detailing their applications and their future.

FOR MORE INFORMATION about any of these developments, just write, on your company letterhead, to Allied Chemical, Dept. 38, 61 Broadway, New York 6, N. Y.

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Allied Chemical

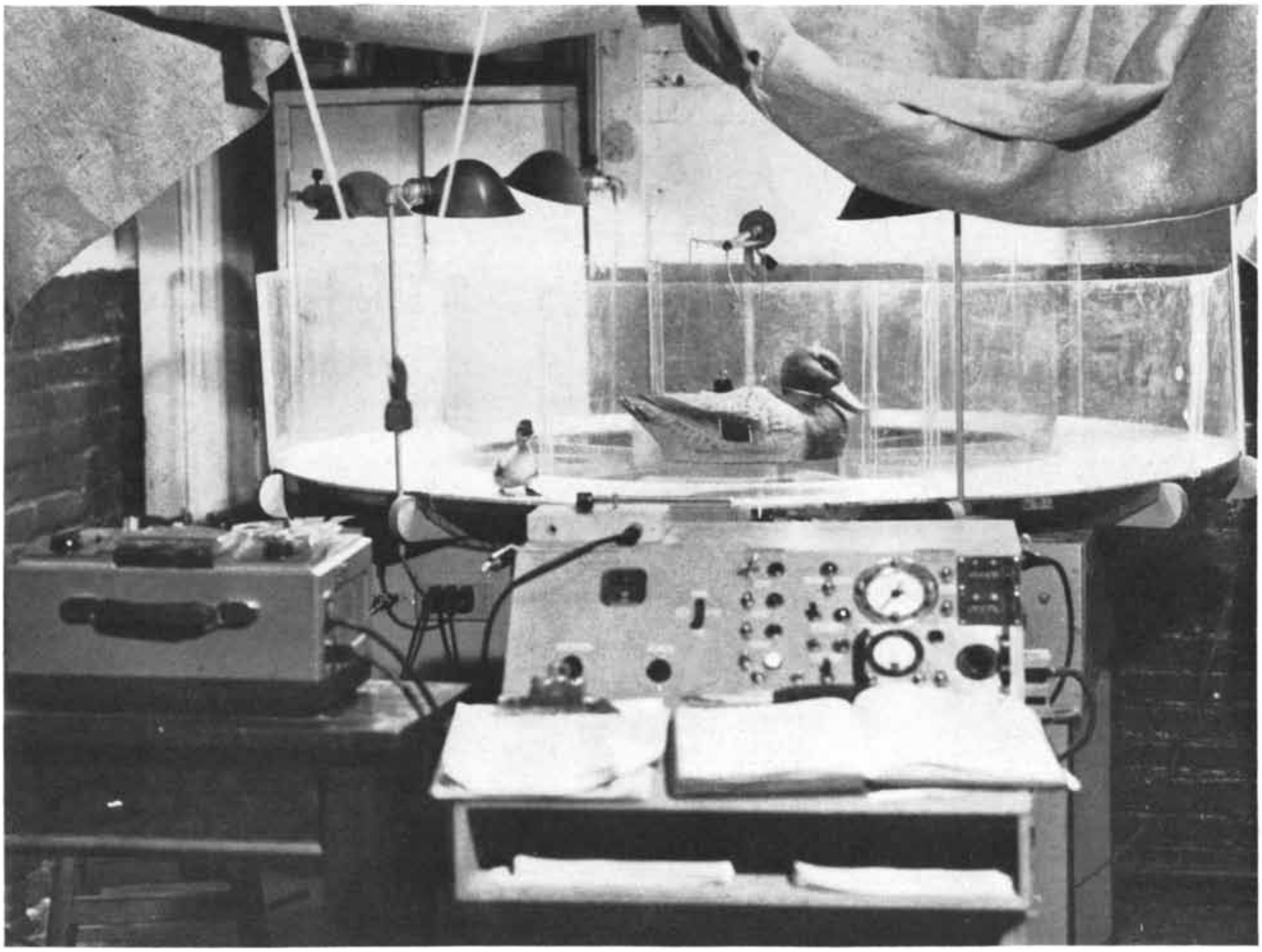
"Imprinting" in Animals

When ducklings are hatched, the first moving object they see is usually their mother. They proceed to follow her. If they see another moving object, however, they follow it instead

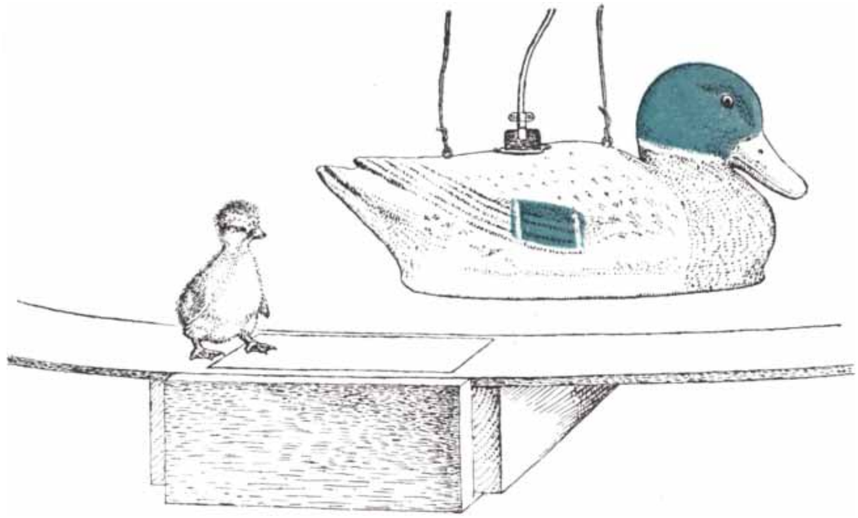
by Eckhard H. Hess

What is meant by "imprinting" in animals? The best answer is to describe an experiment performed on geese by the Austrian zoologist Konrad Lorenz. On an estate near Vienna Lorenz divided a clutch of eggs laid by a graylag goose into two groups. One group was hatched by the goose; the other group was hatched in an incubator. The goslings hatched by the goose immediately followed their mother around the estate. The goslings hatched in the incubator, however, did not see their mother; the first living thing they saw was Lorenz. They then followed Lorenz about the estate!

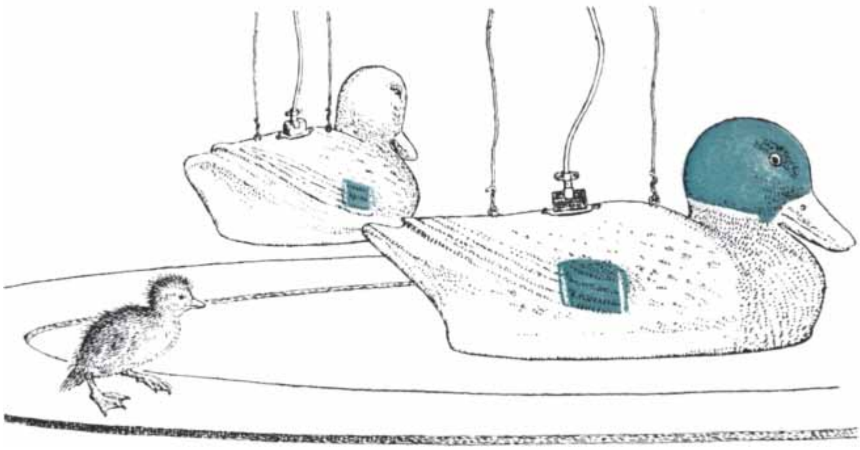
Lorenz now marked the two groups of goslings to distinguish them. He placed all the goslings under a large box, while the mother watched anxiously. When the box was lifted, the two groups of



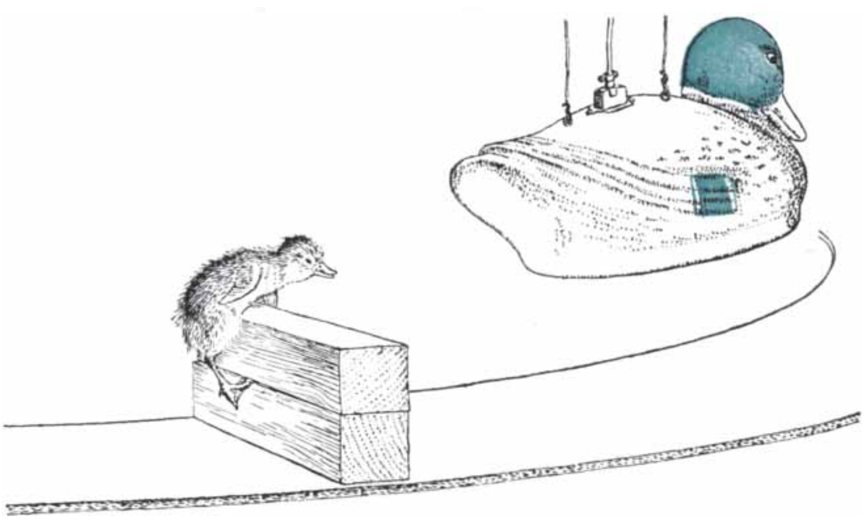
APPARATUS used by Hess and A. O. Ramsay in the study of imprinting consists primarily of a circular runway around which a decoy duck can be moved. In this photograph a duckling follows the decoy. In the foreground are the controls of the apparatus. At the top of the photograph is a cloth which is normally dropped so that movements of the experimenter will not distract the duckling.



DUCKLING IS IMPRINTED by placing it in the runway behind a model of a male duck which is wired for sound. Below the duckling is a trap door through which it is removed.



DUCKLING IS TESTED for imprinting by placing it between the male model and a female model which emits a different sound. If it follows the male, response is scored as positive.



DUCKLING SCALES AN OBSTACLE in the runway in an experiment to determine whether the effort it expends during imprinting is related to its score when it is tested.

goslings streamed to their respective "parents." Lorenz called this phenomenon, in which an early experience of the goslings determined their social behavior, "imprinting." Although earlier investigators had observed the effect, he was the first to name it and to point out that it appeared to occur at a critical period early in the life of an animal. He also postulated that the first object to elicit a social response later released not only that response but also related responses such as sexual behavior.

Students of behavior generally agree that the early experiences of animals (including man) have a profound effect on their adult behavior. D. O. Hebb of the University of Montreal goes so far as to state that the effect of early experience upon adult behavior is inversely correlated with age. This may be an oversimplification, but in general it appears to hold true. Thus the problem of the investigator is not so much to find out *whether* early experience determines adult behavior, but rather to discover *how* it determines adult behavior.

Three statements are usually made about the effects of early experience. The first is that early habits are very persistent and may prevent the formation of new ones. This, of course, refers not only to the study of experimental animals but also to the rearing of children. The second statement is that early perceptions deeply affect all future learning. This concept leads to the difficult question whether basic perceptions—the way we have of seeing the world around us—are inherited or acquired. The third statement is simply that early social contacts determine adult social behavior. This, of course, is imprinting.

Although imprinting has been studied mainly in birds, it also occurs in other animals. It has been observed in insects, in fishes and in some mammals. So far as mammals are concerned the phenomenon appears to be limited to those animals whose young are able to move about almost immediately after birth. For example, imprinting has been described in sheep, goats, deer and buffalo. For better or worse these observations have not been made under controlled laboratory conditions. One exception is a study begun in our laboratories at the University of Chicago. One of our students has observed that imprinting appears to occur in guinea pigs. Our work has dealt mainly, however, with imprinting in birds.

Lorenz and other European workers

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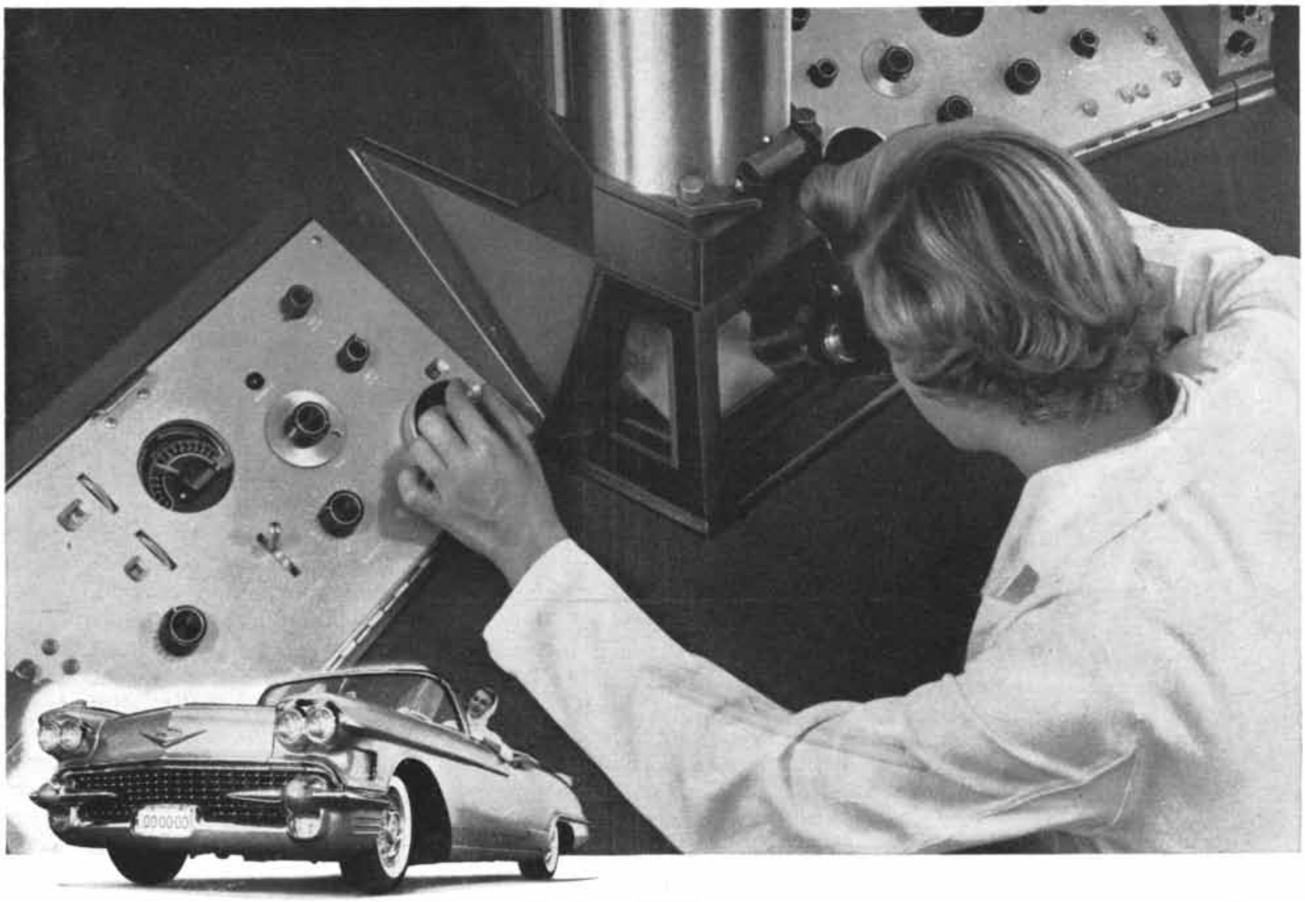
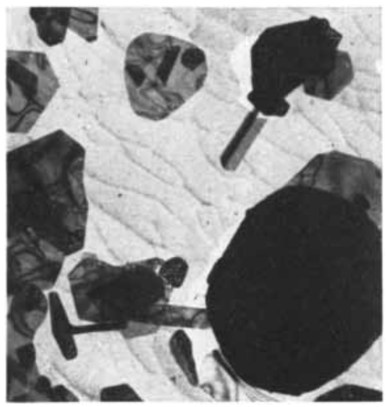


RCA Electron Microscope helps build better cars at General Motors

Automotive masterpieces have virtues that are more than "skin deep," thanks to basic research with the RCA Electron Microscope. At General Motors Technical Center in Detroit, studies using the instrument range in scope from determining deformation in crystalline solids to quality control problems in connection with heat-treated metals. Recently, GM researchers correlated the score resistance properties of an alloy used in bearings with the precipitation of silicon.

Micrographs, such as shown, indicated that optimum performance resulted when the aluminum-silicon-cadmium-bearing material was heat treated to precipitate the thin crystallites of silicon throughout the matrix. Particle size and distribution were studied by means of electron microscopy and positively identified by electron diffraction.

RCA Electron Microscopes are providing valuable information regarding size, shape and structure of particles smaller than 20 angstrom units. With the ability to produce direct electron image magnifications up to 200,000X, the RCA Electron Microscope is advancing man's knowledge in many fields, as diversified as automobiles and cell structures . . . chemicals and viruses. Installation supervision and contract service are available through the RCA Service Company.



Undissolved silicon (large opaque particles) and thin silicon plates in an aluminum matrix, magnification 12,000 diameters. (Micrograph courtesy General Motors Research Staff.)

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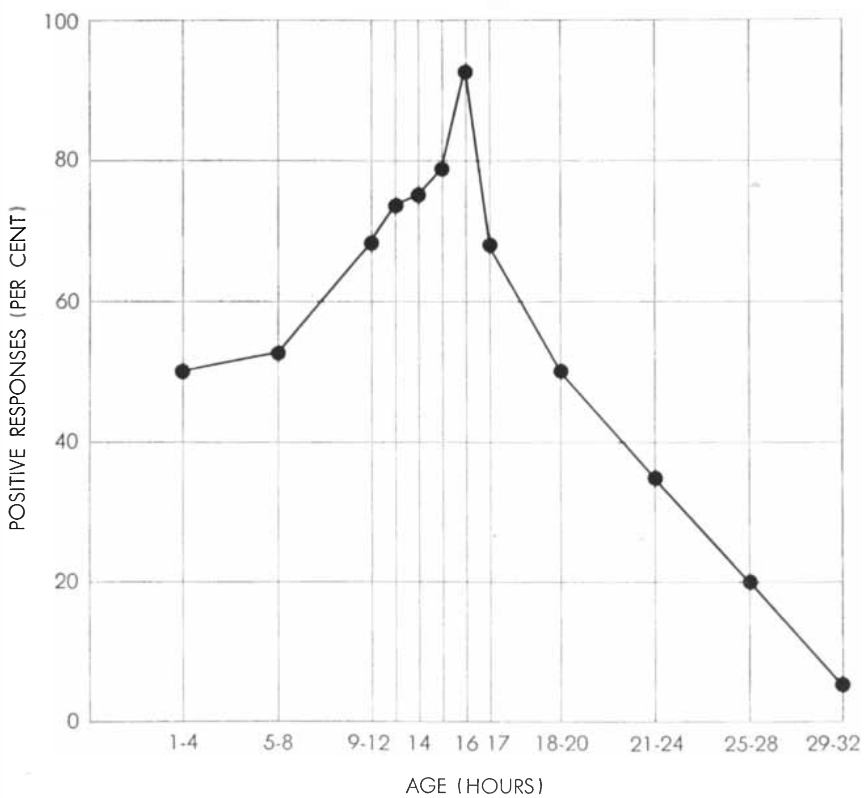
have shown that a variety of birds are most easily imprinted during the first day after they are hatched, and that the birds will follow not only other animals but also inanimate objects. In this country A. O. Ramsay of the McDonogh School in McDonogh, Md., succeeded in making young Canada geese and mallard ducklings follow a small green box containing an alarm clock. Some ducklings and goslings responded to a football. In the early 1950s I met Ramsay and we decided to begin a cooperative study of imprinting under laboratory conditions. Among our goals were the following. What is the critical age at which imprinting occurs? How long must young birds be exposed to the imprinting object in order for them to discriminate between it and similar objects?

The subjects used in the experiments described here were mallard ducklings. We were fortunate in that our laboratory in Maryland had access to a small duck pond in which we could keep relatively wild mallards. The birds laid their eggs in nesting boxes, so the eggs could be regularly collected and hatched in laboratory incubators. Our experimental apparatus consisted of a circular runway about five feet in diameter and 12 inches wide, the walls of which were made of transparent plastic. Our imprinting object was a model of a male mallard duck, of the sort used by duck hunters as a decoy. The model was suspended from a motor-driven arm pivoted at the center of the apparatus; thus it could be moved around the runway at various speeds. Inside the model was a loudspeaker through which tape-recorded sounds could be played.

After the mallard eggs were collected, they were placed in a dark incubator. When the young birds were hatched, they were kept in individual cardboard boxes so that they would have no visual experience until they were put into the imprinting apparatus. The boxes were then kept in a brooder until we were ready to work with the birds. After each duckling was exposed to the imprinting object (the decoy duck) in the apparatus, it was automatically returned to its box by means of a trap door in the floor of the runway. The bird was then lodged in another brooder until it was to be tested for the imprinting effect.

The imprinting itself was accomplished first by placing the young mallard in the runway of the apparatus about a foot away from the decoy. As the bird was released, the loudspeaker inside the decoy was made to emit a human rendition of the sound "GOCK



CRITICAL AGE at which ducklings are most strongly imprinted is reflected by this curve. Each black dot on the curve is the average test score of ducklings imprinted at that age.

Mass Produced Aspherics Revolutionize Optical Design

The science of optics dates back to the days of Galileo. In this modern age of electronics and atomic energy, optics is often passed over as a science in which there is really nothing new to be learned. Yet, in the past few years, a development has been quietly taking place which bids fair to revolutionize the optical industry and obsolete many standard optical designs. This development is the invention of production techniques by which lenses using aspheric surfaces can be quantity produced economically.

An aspheric lens, i.e., a lens whose surfaces conform to some curve other than a sphere, such as a hyperbola or a parabola, is often able to replace several conventional lenses and frequently permits performance unobtainable with spherical surfaces alone. Until recently aspherics could be generated only by laborious hand methods.

Perkin-Elmer has pioneered in both aspheric production techniques and the equally important development of computation methods for designing aspheric optical systems. Many Perkin-Elmer products for industry and the military are already utilizing aspheric optical elements. These new optics may soon appear in many common products, such as cameras, microscopes, and telescopes.

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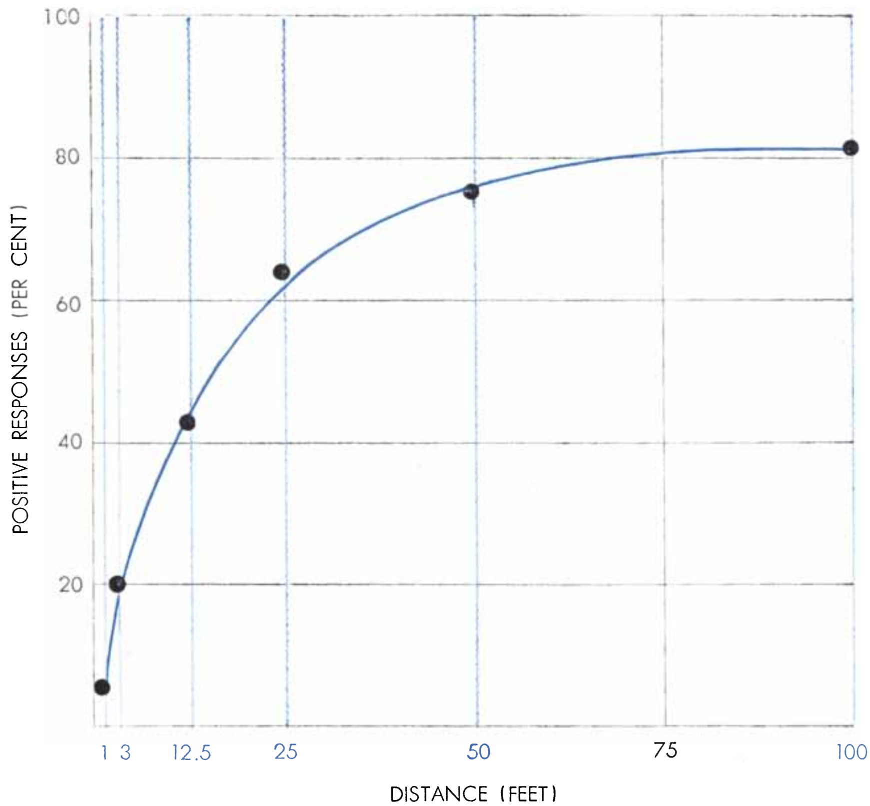
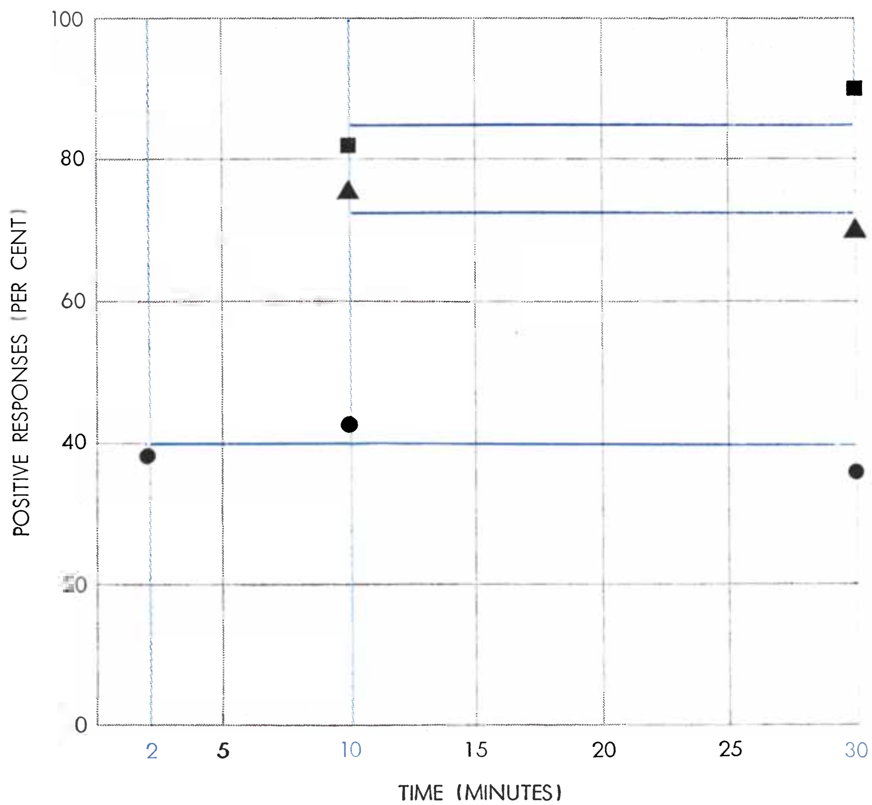


DISTANCE TRAVELED during imprinting affected the scores of ducklings as indicated by this curve. The farther the ducklings had traveled, the more strongly they were imprinted.



TIME ELAPSED during imprinting had little effect on the scores. The squares represent ducklings which had traveled 100 feet during imprinting; triangles, 50 feet; dots, 12.5 feet.

gock gock gock gock," and after a short interval the decoy was moved around the runway. The imprinting period, during which the duckling followed the decoy, usually lasted 10 minutes. We can also imprint ducklings with a silent object, or even with sound alone. In one experiment we tried to imprint ducklings with the "gock" sound while they were still in the egg. This effort was unsuccessful.

The bird was tested for imprinting by releasing it between two decoys four feet apart. One decoy was the male model with which the duckling had been imprinted; the other was a female model which differed from the male only in its coloration. One minute was allowed for the duckling to make a decisive response to the silent models. At the end of this time, regardless of the duckling's response, sound was turned on in both models. The male model made the "gock" call; the female emitted the sound of a mallard duck calling her young. This latter sound was a recording of a real female. Four test situations were run off in sequence: (1) both models stationary and silent; (2) both models stationary and calling; (3) male stationary and female moving, both calling; (4) male stationary and silent, female moving and calling. Each bird was scored according to the percentage of its positive responses, *i.e.*, the number of times it moved toward the male model as opposed to doing something else.

To determine the age at which an imprinting experience was most effective we imprinted our ducklings at various ages after hatching. In this series of experiments the imprinting experience was standard: it consisted of having the duckling follow the model 150 to 200 feet around the runway during a period of 10 minutes. It appears that some imprinting occurs immediately after hatching; however, only those ducklings imprinted between 13 and 16 hours after hatching consistently made a maximum score [*see chart on page 84*].

To answer the question how long the imprinting experience must last in order to be most effective we varied not only the time during which the duckling was exposed to the model but also the distance traveled by the duckling as it followed the model around the runway of our apparatus. We exposed groups of ducklings to the model for the same length of time (10 minutes), but during that time moved the model at different speeds so that the ducklings in each group moved a different distance (1,

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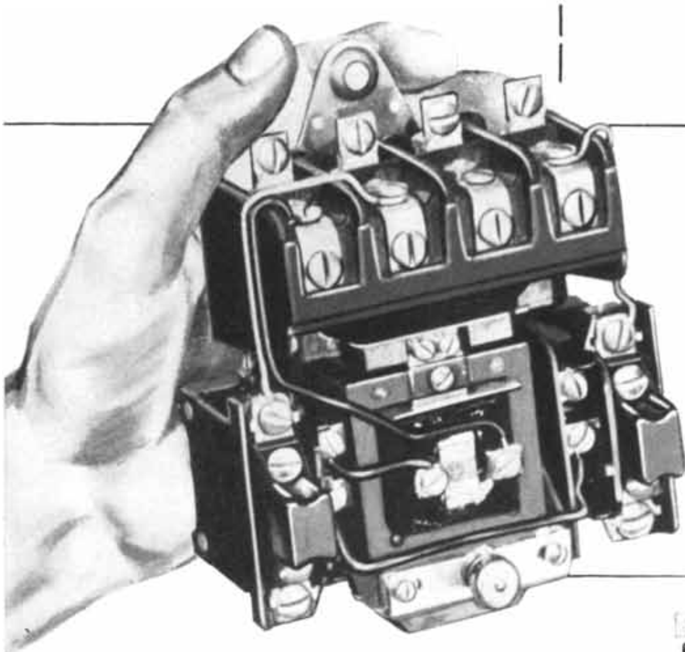

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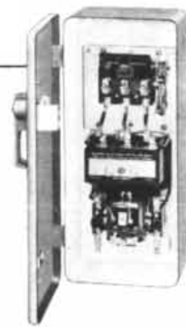

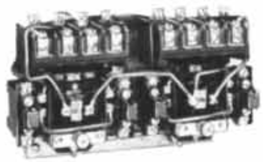

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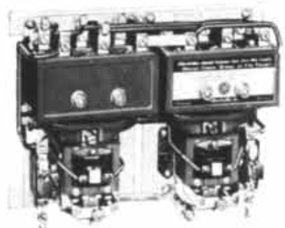

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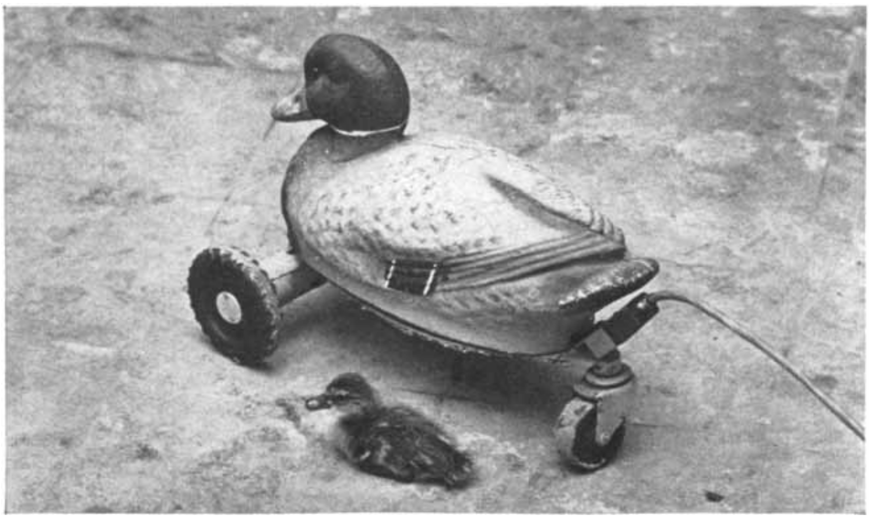
12½, 25, 50 and 100 feet). All the ducklings were imprinted between 12 and 17 hours after hatching. The results showed that at distances up to 50 feet the strength of imprinting increased with the distance traveled [*see chart at top of page 86*].

We now allowed other groups of ducklings to travel the same distance, but over different periods of time. One turn around our runway is 12½ feet; a duckling can walk this distance in something less than two minutes. We moved the decoy so that groups of ducklings made one turn around the runway in 2, 10 and 30 minutes. The scores of these animals were essentially identical [*see chart at bottom of page 86*]. Moreover, there was no significant difference between the scores of ducklings which followed the decoy 100 feet in 10 minutes and those which traveled the same distance in 30 minutes.

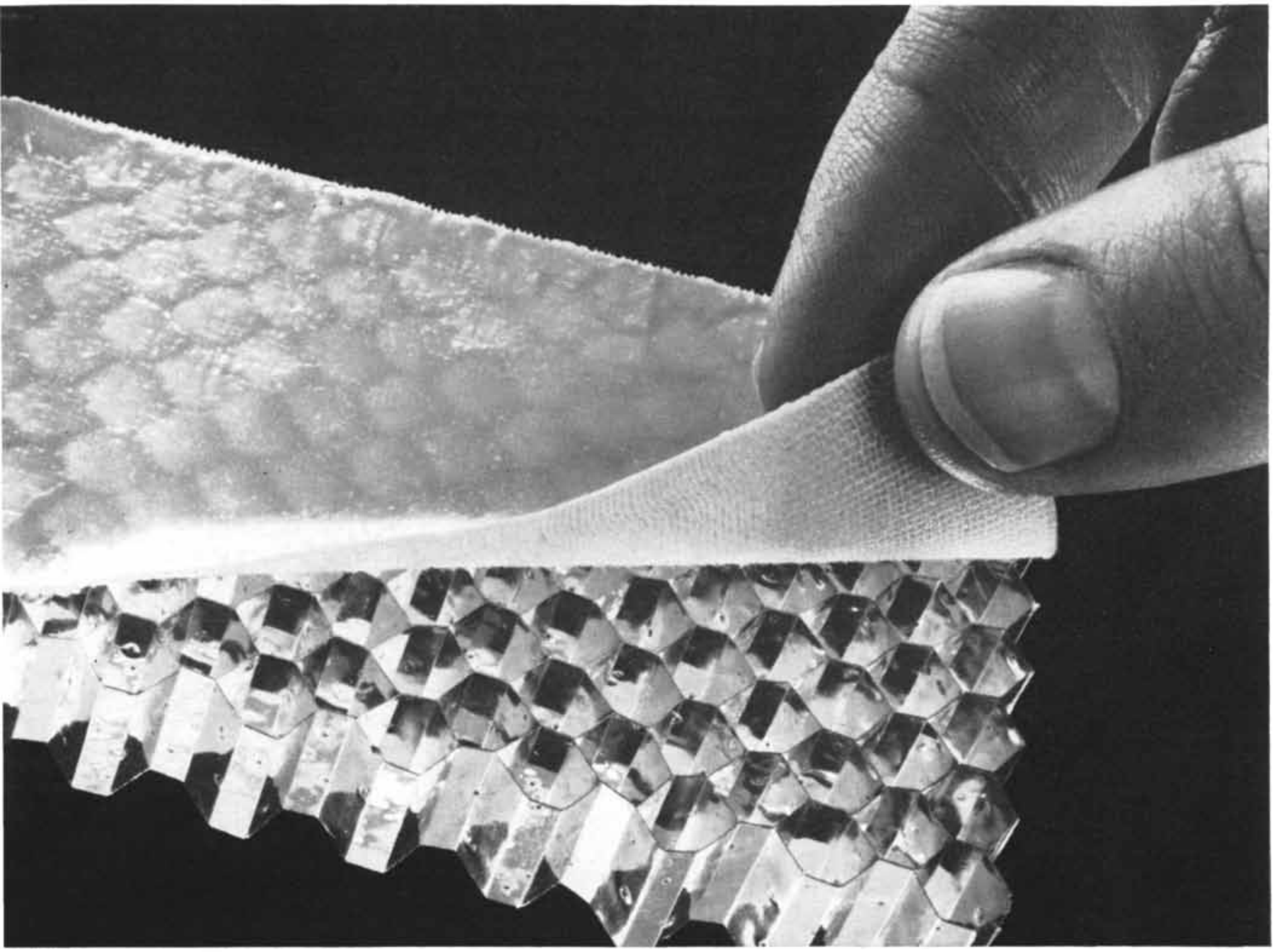
In other words, the strength of imprinting appeared to be dependent not on the duration of the imprinting period but on the effort exerted by the duckling in following the imprinting object. To confirm this notion we tried two supplementary experiments. In the first we placed four-inch hurdles in the runway so that the ducklings not only had to follow the model but also had to clear the obstacles. As we suspected, the birds which had to climb the hurdles, and thus expend more effort, made higher imprinting scores than those which traveled the same distance without obstacles. In the second experiment we allowed the duckling to follow the decoy up an inclined plane, with similar results. After further experiments we came to the conclusion that we could write a formula for imprinting: the strength of imprinting equals the logarithm of the effort expended by the animal during the imprinting period.

Now that we had this basic information, we began to explore other aspects of imprinting. We had been puzzled by the fact that the imprintability of ducklings rapidly declines soon after they are 16 hours old. We had noticed, as had other workers, that ducklings develop their first emotional response when they are 16 to 20 hours old. This response is an avoidance or fear of moving objects. Twenty-four hours after hatching almost 80 per cent of the ducklings exhibit this fear; the proportion increases to 100 per cent at about 32 hours. Does this fear response knock out imprinting?

At the time we were reflecting on this question the tranquilizing drugs had just been introduced, and it occurred to us that these drugs which reduce fear and anxiety might solve our problem. We administered meprobamate (Miltown) to 24-hour-old ducklings; their fear response was indeed reduced. We then imprinted the drugged birds 26 hours after hatching. Ducklings 26 hours old are of course imprinted very weakly, but we were surprised that the imprinting scores of these animals were even lower than normal. In other words, eliminating fear did not improve imprintability. Later we found that the tranquilizer also interfered with the imprinting of young mallards at an age when they were normally most imprintable. So far our best conclusion is that meprobamate, being a muscle relaxant, nullifies the effectiveness of the imprinting experience by re-



REMOTE-CONTROLLED DECOY was used by Hess and his colleagues in other imprinting experiments. Here both decoy and duckling move about freely rather than on a runway.



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laxing muscular tension. It is also possible that in the imprinting process some degree of anxiety is necessary. This anxiety, from an admittedly human viewpoint, may merely be the fear of being left alone; the duckling might thus tend to follow the imprinting object as it moved away. We are continuing our study of these drugs because we feel that it may not only shed some light on the mechanism of imprinting but also may give us valuable information about the action of the drugs themselves.

We have also considered the genetic side of imprinting. We have kept ducklings which were highly imprintable and bred them separately from ducklings which showed very little imprinting response. Significant differences appeared even in the first generation: the offspring of imprintable parents were easily imprinted; those of less imprintable parents were difficult to imprint. We are also following up those animals which have had experimental imprinting experiences to determine what influence, if any, these experiences have on their adult behavior. So far the results are inconclusive, but they do suggest that experimental imprinting of mallards affects their adult behavior, particularly with respect to courtship patterns.

We have performed imprinting experiments not only with mallards and, as indicated earlier, guinea pigs, but also with other kinds of ducks, several varieties of geese, with sheep, turkeys, pheasants, quail and chickens. We have had some success in imprinting certain breeds of chicks (mainly Cochin bantams and Seabright bantams), but in general domestic fowl cannot be as clearly imprinted as wild birds.

What does all this have to do with human behavior? Of course it is not really necessary to relate our work to such behavior; it is interesting and important in its own right because it tells us something about the way an organism adapts itself to the world. We do feel, however, that the work has some implications which are relevant to humans. It has long been known, for example, that in order for a child to develop normally it must have a certain amount of attention and handling during a critical period of its infancy. This period is doubtless not as sharply defined as the imprinting period in birds, but it may lie within the first six months of life. Jere Wilson of our group is studying the smiling response of infants in an effort to get at some aspects of human behavior which may involve imprinting.

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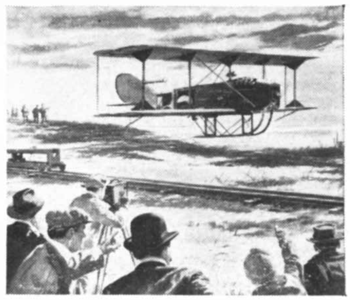

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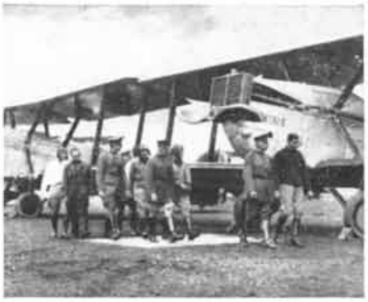
1919 Gyroscopic Turn Indicator and Drift Set guided Navy's NC-4 Flying Boat on first transatlantic flight.



1924 Precise navigation for the first round-the-world flight by Army's Douglas planes was provided by Sperry Master Compasses.

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1946 Sperry began design of Sparrow I missile which later became first U. S. operational air-to-air missile.

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1956 Advanced Sperry gyroscopes form core of electronic flight control and bombing system for B-52 bombers.

1957 B-58 Hustler, first supersonic jet bomber, has extremely accurate Sperry navigation and guidance system.

1957 Albacore, the sub that "flies" under water, has complete Sperry gyroscopic control system similar to an airplane's.

1958 Douglas DC-8 jetliner will have new Sperry automatic flight control system to relieve pilot fatigue and increase passenger comfort.

19?? Sperry gyroscopic devices are destined to guide space-piercing missiles and vehicles of the future.

Helmholtz

This 19th-century German was a deep and versatile investigator. Although he had been trained as a physician, he made important contributions to physics, physiology and the theory of knowledge

by A. C. Crombie

"My mind absorbed avidly, like a revelation, the first law I knew to possess absolute, universal validity, independently from all human agency: the principle of the conservation of energy."

These words are from the *Scientific Autobiography* of the great German physicist Max Planck. The law to which they refer—which says essentially that energy, like matter, cannot be created or destroyed but only transformed—was indeed a revelation to scientists of the mid-19th century. Its implications and the problems it posed dominated physics in the period between the electromagnetic researches of Faraday and Maxwell and the introduction of the quantum theory by Planck in 1900. It is certainly one of the most important ideas in the history of physical science.

Like many great scientific discoveries, the law of the conservation of energy was arrived at independently by several men. Its broadest and most definitive formulation was given by the German physicist, physiologist and philosopher Hermann von Helmholtz. Yet at the time he published his account of energy conservation he was not a professional scientist but a young doctor practicing in the Prussian army.

Helmholtz's scientific accomplishments were extraordinarily wide in range. To physics he contributed not only his work on the conservation of energy but some of the most important germinal ideas on the electrical theory of matter and of light and radio waves. In physiology he carried out the first systematic experimental investigation of the sense organs, especially the eye and ear. These investigations in physiology led him to epistemology and the philosophy of science. Here his genius played a major part in turning German philosophy from its resolute preoccupation with philology and history toward a concern with science.

The remarkable breadth of his achievements is a testimonial to the advantages of forcing a man of genius to consider problems outside his usual field of interest. By natural bent Helmholtz was a theoretical physicist and mathematician. His father, however, could not afford to give him a university education; to obtain a government scholarship Helmholtz had to take up the study of medicine. As a medical student and army surgeon he was forced to look at scientific problems from an unusual point of view and to enrich and discipline his unifying mathematical and physical intuitions by contact with concrete and particular facts.

Hermann Helmholtz (the "von" was added when he was ennobled many years later) was born at Potsdam in 1821. His father was a master at the Potsdam Gymnasium; his mother was the daughter of an army officer and a direct descendant of William Penn. As a young child Helmholtz was delicate and seems to have learned slowly; a relative, writing to reassure his ambitious parents, reminded them that the great Alexander von Humboldt had learned nothing before he was eight. Nonetheless when Helmholtz entered school at seven he is said to have astonished his teachers with his intuitive grasp of geometry, learned from playing with toy blocks.

Geometry appealed to the young Helmholtz because of its orderliness. He had a bad memory for disconnected facts and was hopeless at history. But geometry failed to satisfy him for long. As he said many years later: "It dealt exclusively with abstract forms of space, and I delighted in complete reality." The first fragments of physics which he learned at the Gymnasium revealed to him "the mighty fullness of Nature, to be brought under the dominion of a mentally apprehended law." The prospect of winning "intellectual mastery over Nature" was to fascinate him for the rest of his life.

Helmholtz's first attempts to generalize reality had been cast in geometrical terms. The study of physics soon shifted his thinking to "a kind of mechanical mode of view." He discovered with delight that he had an intuitive grasp of the distribution of strains and stresses in any mechanical arrangement. Experienced mechanics and machine-builders also have this sort of intuitive understanding, but, as Helmholtz later put it, "I had the advantage over them in being able to make complicated and specially important relations clear by means of theoretical analysis."

In 1838, when he was 17, Helmholtz entered the Friedrich-Wilhelm Institute of Medicine and Surgery in Berlin. Its professor of physiology—the first man to hold that title in any country—was Johannes Müller. Through Müller's influence Helmholtz soon became interested in seeking out physicochemical explanations for biological processes. His first original contribution to science, published soon after his graduation, was in the field of anatomy; it showed that the nerve fibers of invertebrates originate in ganglion cells. For relaxation from his medical and physiological studies he read mathematical works by Euler, Bernoulli and d'Alembert, along with the poetry of Goethe and the philosophy of Kant.

As a scholarship student at the Institute Helmholtz had had to agree to serve 10 years as an army surgeon. Fortunately he was able to continue his physiological researches in a laboratory fitted up in the Potsdam barracks where he was stationed. These researches, which were to lead him to the law of the conservation of energy, were inspired by the controversy over "vitalism" that stirred all workers in the life sciences in the first half of the 19th century.

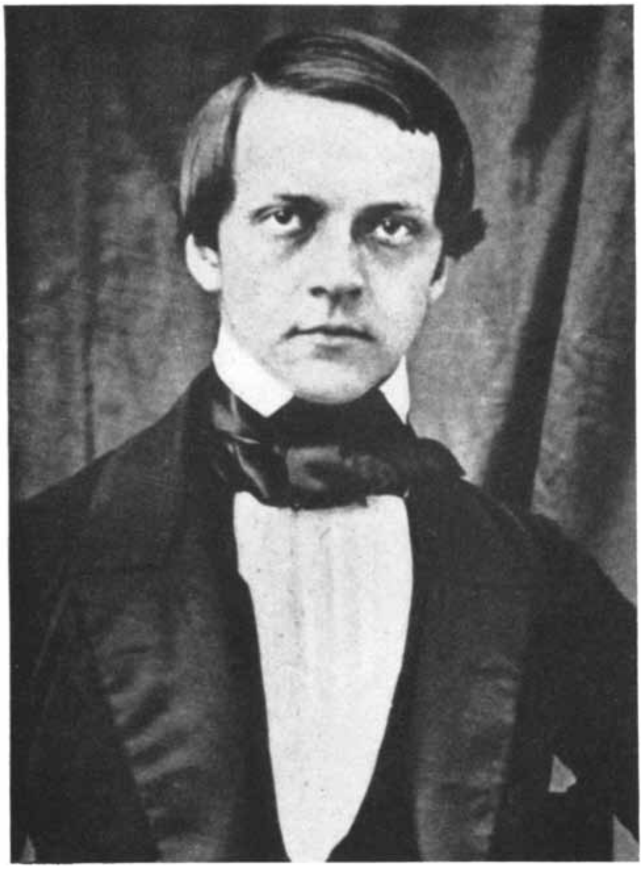
As Helmholtz himself put it: "Most physiologists had at that time adopted G. E. Stahl's way out of the difficulty, that while it is the physical and chemical forces of organs and substances of the living body which act on it, there is an indwelling vital soul or force which could bind or loose the activity of these forces; that after death the free action of these forces produces decomposition, while during life their action is continually being controlled by the soul of life." He went on to say: "I had a misgiving that there was something against nature in this explanation; but it took me a good deal of trouble to state my misgiving in the form of a definite question."

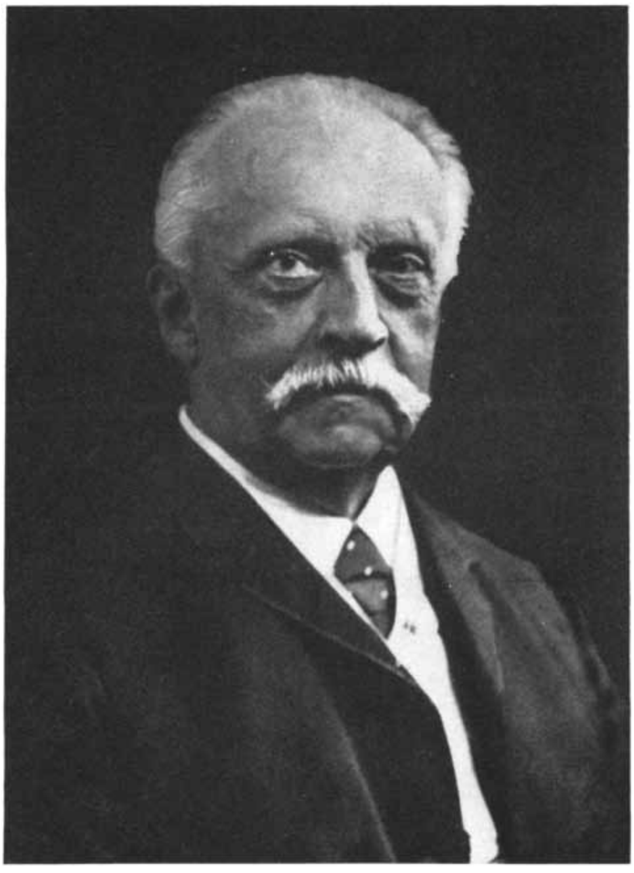
It was the great German chemist Justus von Liebig who succeeded in formulating the question. Are the mechanical energy and heat produced by an organism, he asked, entirely the product of its own metabolism? Helmholtz, in his barracks laboratory, set out to discover the answer. His first investigations into the metabolism of muscle showed that the heat of the body comes entirely from the foodstuff and oxygen supplied to it. The heat given off by an animal, he found, was equal to that produced by burning the animal's food in a calorimeter. There was none left over to indicate the operation of a vital force.

Now Bernoulli, d'Alembert and other 18th-century mathematicians had already developed Newton's law of the conservation of momentum to show that machines cannot originate energy, but can only convert the energy they receive from without into various forms of motion. Thus a man may give potential energy to a weight-powered clock by winding up the weight; as the weight falls this potential energy will be converted into the kinetic energy of the clock-mechanism. But when the weight reaches the bottom, the clock will stop. A perpetual-motion machine, which works without input of energy, is impossible. "Stahl's theory," Helmholtz later wrote, "ascribed to every living body the nature of a *perpetuum mobile.*" The concept of a vital force that could engender and direct physical forces without consuming energy struck Helmholtz as a paradox.

The resolution of this paradox stimulated Helmholtz, already able to move with ease in many different branches of science, to apply his powerful mathematical vision to a general solution of the whole problem of energy transformation. In 1847 he was able to present his theoretical solution to the Physical Society in Berlin, in his famous paper "On the Conservation of Energy."

Assuming that perpetual motion is impossible, he asked what the relations between the various known forces of nature must then be. His answer was that these forces cannot arise out of nothing. Mechanical energy cannot be generated in any natural process without a corresponding expenditure of energy. But neither can energy disappear. A quantity of energy may be lost to a particular machine (as in the clock when the weight reaches the bottom) but not to the universe as a whole (the kinetic energy of the clock's mechanism is converted into an equivalent quantity





HELMHOLTZ is shown as a young man and at the age of 60. The daguerreotype at left was made about 1842, the year he graduated from medical school. The photograph at right was made in 1881, when he was professor of physics at the University of Berlin.

of heat). "Nature as a whole," Helmholtz wrote, "possesses a store of energy which cannot in any wise be added to or subtracted from. . . ." The quantity of energy is as eternal as the quantity of matter, the indestructibility of which had been established by Lavoisier.

Helmholtz went on to examine the implications of his thesis. The atomic and molecular theories, already well-secured as scientific principles, held that matter consists of elementary particles with unalterable properties, and that chemical changes involve merely the redistribution of these particles in space. To this conception Helmholtz added the postulate that all forces can be analyzed into mechanical forces acting between these elementary particles; even heat is due to atomic or molecular motion. All forms of energy are ultimately kinetic; the final aim of natural science must be to reduce itself to mechanics, with mass and energy as the fundamental, indestructible quantities.

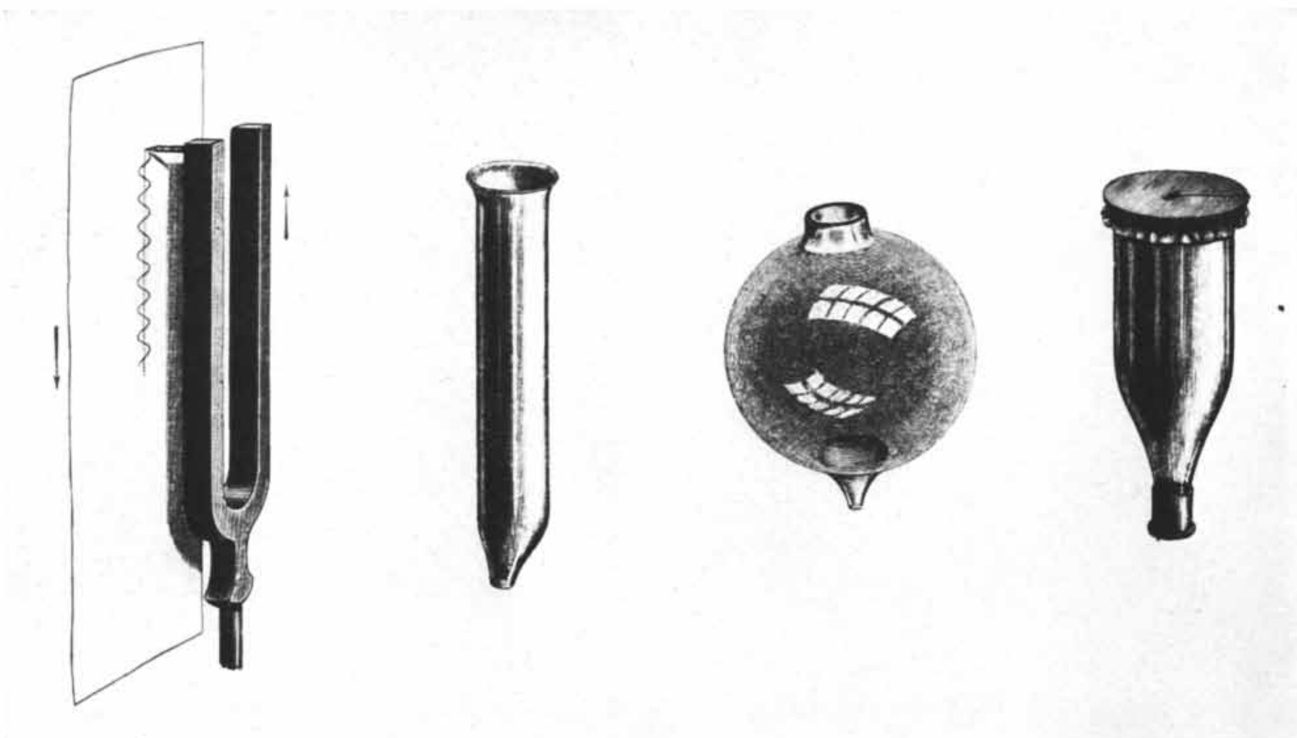
Applying his principle in detail, Helmholtz showed how to compare the kinetic energy of a moving body, the electrical energy produced by a thermocouple, the energy of a magnet moved by electricity, and simple heat energy. This could be done by reducing each form of energy to the amount of mechanical work it could do. Chemical reactions, he pointed out, also conserved energy: the German chemist G. H. Hess had proved only a few years before that the heat liberated when two or more elements united to form a given compound was the same no matter what intermediate stages preceded the final result. Whatever the mode of transformation of one into another, all forms of energy were an exactly measurable equivalent of the kinetic energy of matter in motion.

"I think that in the foregoing," he concluded, "I have proved that the above-mentioned law does not contradict any hitherto known facts of natural science, but is supported by them in a striking manner." Complete experimental confirmation of the law, he added prophetically, "must be regarded as one of the principal problems of the natural philosophy of the future."

Helmholtz was not the first to formulate the law of the conservation of energy; he soon found that Julius Robert von Mayer, another German physician, and the English physicist James Joule had both anticipated him. But it was undoubtedly Helmholtz who saw and presented mathematically the law's profound general implications.

The law of the conservation of energy revolutionized many branches of science. In physiology it helped to eliminate vitalism and opened up new areas of research by regarding the body as a machine which converts food and oxygen into heat and work. It provided the main program for physics during the rest of the 19th century. From then on, as Helmholtz's most brilliant pupil Heinrich Hertz later wrote, the physicist's object was "to refer all phenomena . . . to the laws which govern the transformation of energy." From Helmholtz's original conception Clausius, Boltzmann, Kelvin and other physicists were able during the next 50 years to construct the imposing structure of modern thermodynamics. Helmholtz himself helped to clarify the concept of entropy, the basis of all subsequent cosmological systems. He even delivered a lecture on the ethical consequences of the assertion that the universe is tending toward a "heat death" of uniform temperature and eternal rest.

Helmholtz's paper, despite the incredulity which at first greeted it (the leading German journal of physics refused to print it), soon launched him on the academic career for which he had long hoped. Two years after its publication (as a pamphlet) Müller was able to extract him from the army and get him appointed lecturer in anatomy at the Berlin Academy of Arts. The following year he was appointed professor of physiology at Königsberg. Immediately on receiving this appointment he married

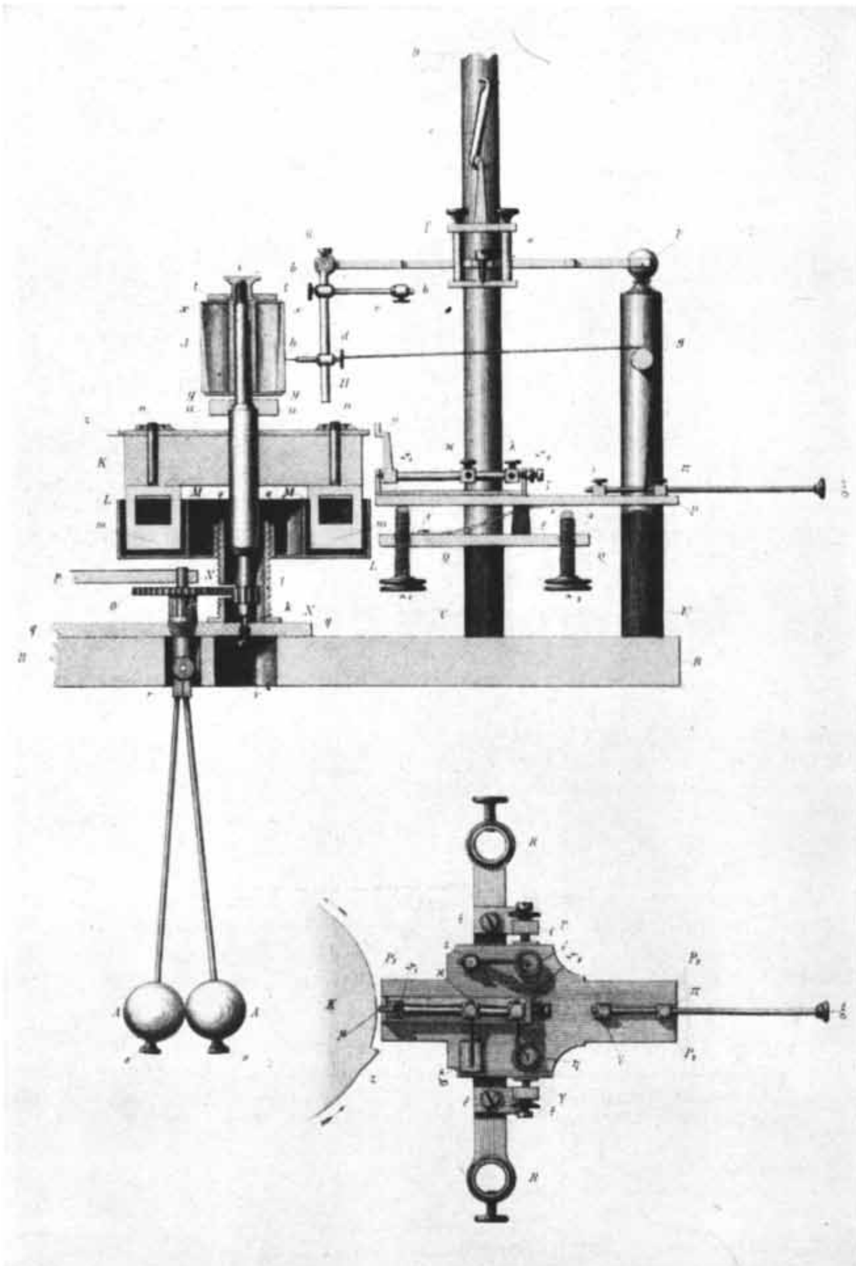


PHYSICS OF SOUND was studied by Helmholtz with the aid of a tuning fork (*left*), which traced its vibrations on a moving sheet of paper. He devised glass resonators of various shapes as a means of analyzing complex musical tones into their constituent parts.

Olga von Velten, whose father, an army surgeon, had been one of Helmholtz's superiors at Potsdam. In 1855 Helmholtz moved to Bonn as professor of anatomy; the young couple's home there, with its terrace overlooking the Rhine, became the center of a distinguished group of friends. In 1858 the Helmholtzes moved to Heidelberg, where Hermann was to spend 13 years as professor of physiology. In 1859 Olga died after a long illness; two years later Helmholtz married Anna von Mohl, whom he described with affectionate irony as having had the benefit of a "fashionable" education.

It was at Königsberg that Helmholtz began the investigations which were to lead him toward the other great question that guided his life's work: the origin of human knowledge. Again he began with the experimental study of a highly specific question and ended with broad, general conclusions. As his studies of vitalism had given birth to the law of the conservation of energy, so his theory of knowledge emerged from a lengthy and exact investigation of the nervous system and sense organs.

In 1850 little was known about what actually happens in the nervous system. Nervous activity was thought to be somehow related to electricity; Helmholtz's friend Emil Du Bois-Reymond had already described the electrical changes which accompany a nerve impulse. Helmholtz carried this work an important step further. By hitching a pointer to a frog's leg he was able to record on a smoked-glass plate its twitchings under electrical stimulation. By timing the interval between stimulus and twitch, he was able to make the first measurement of the speed of a nerve impulse. He made similar experiments on his own arms and those of his assistants. He was able to show that whatever passed along the nerves to deliver messages to the brain was a material change, moving with a definite speed; nerve fibers thus resembled the wires of an electric telegraph.



MUSCLE CONTRACTIONS under electrical stimulation were timed by Helmholtz with this apparatus. By means of it he was able to measure the speed of impulses in the nerves.

Turning to the special sense organs which receive impulses from the outside world, he made a thorough study of the eye, investigating the path of light in that organ, the resulting impulses in the optic nerve and their interpretation in the brain. While preparing an anatomical demonstration for one of his classes, he invented the ophthalmoscope. This instrument, which makes possible the examination of the living retina, quickly became essential equipment for every eye doctor.

He measured variations in the curvature of the lens in close and distant vision and explained the muscular mechanisms by which the eye focuses itself on near and far objects, as well as the way in which the two eyes secure a single image from two different stimuli. He reestablished the theory of color vision advanced half a century earlier by Thomas Young, according to whom all colors are perceived by three primary sensations—red, green and violet—received by three different systems of optic nerves. Helmholtz used this theory to explain the different kinds of color blindness.

The result of these investigations, *Physiological Optics*, was published in three parts between 1856 and 1867. It is one of the great landmarks of 19th-century science.

Helmholtz next turned to the ear. Beginning with an investigation of the physics of sound, to which he made important original contributions, he looked into the way in which different sounds excite the cochlea. He studied differences in tone qualities (such as distinguish one musical instrument from another) and explained them in terms of the relative strength of overtones. His discussion of this point, involving de-

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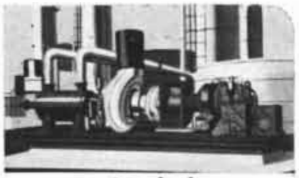

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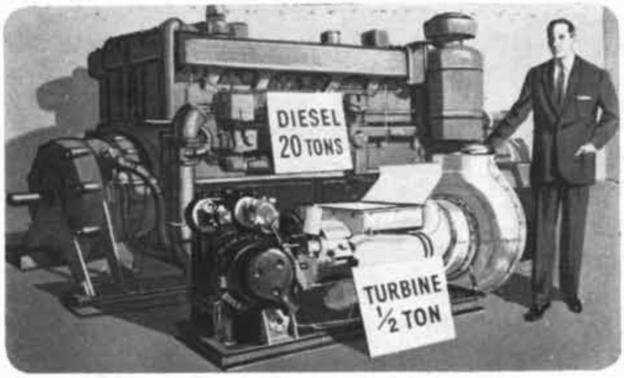

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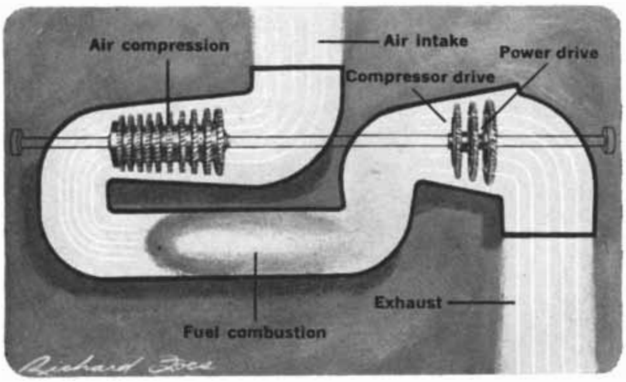

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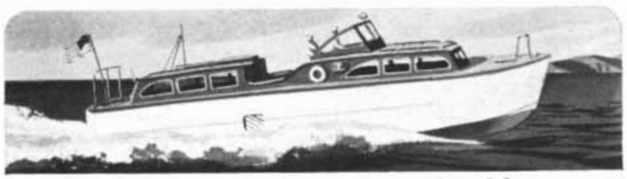

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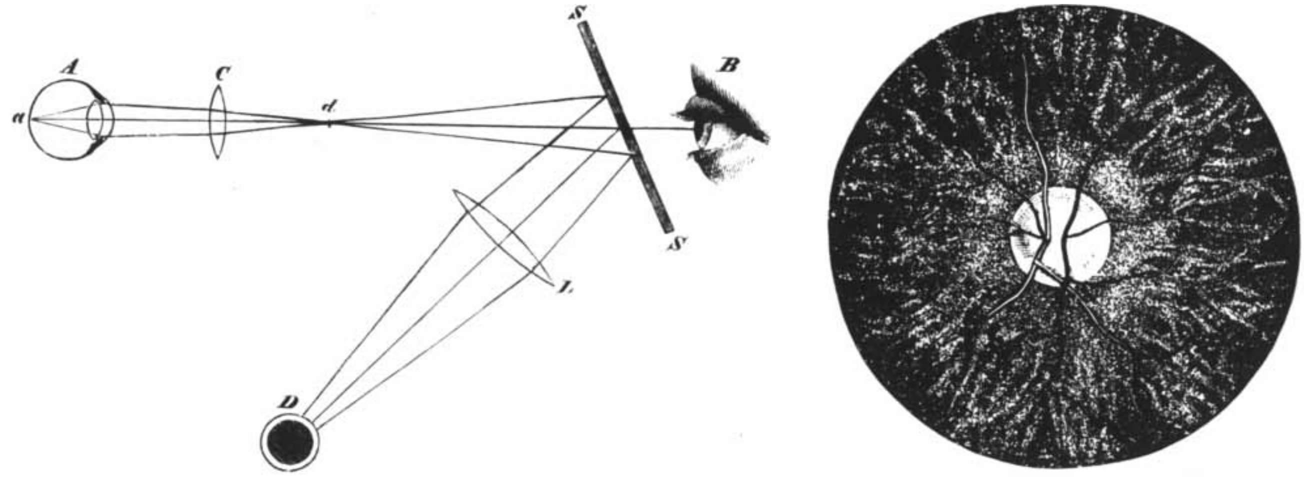


THE OPHTHALMOSCOPE, invented by Helmholtz, uses lenses (*C and L*) and a mirror (*S*) to focus a beam of light and reflect it into the eye (*A*). The observer (*B*) can then examine retina (*shown at right in drawing by Helmholtz*) through hole in mirror.

tailed studies of scales in Eastern and Western music and a theory of vowel tones, is evidence of his own love of music; it is one of the most charming marriages of science and esthetics. Later he made an equally interesting study of the relation of optics to painting.

From these detailed physiological researches Helmholtz now began to evolve his theory of knowledge. Sense perception—the process by which we know external things—he had already analyzed into two stages. The first stage he held to encompass the physical processes through which stimuli are received by the sense organs and transmitted to the brain; the second concerned the interpretation of the messages of "knowledge" by the mind.

Müller, Helmholtz's teacher, had already noted that there is no one-to-one correspondence between a sensory stimulus and the sensation it produces. A given nerve tends to produce the same type of sensation no matter how it is stimulated (for example, pressure on the eyeball in a dark room will stimulate the optic nerve to produce the sensation of light). Müller explained this fact by postulating physiological differences between the various sensory nerves.

Helmholtz further developed this principle in his studies of what is now called "color constancy." He noted that the same subjective sensation of color can be produced by light of quite different physical composition (for example, this page would look green if it was illuminated either by pure green light or by a mixture of blue and yellow light). From this and similar facts Helmholtz concluded that "our sensations are, as regards their quality, only *signs* of external objects, and in no sense *images* of any degree of resemblance." The only connection between the sensation and the external object which produces it is the fact that both appear simultaneously.

Our sensations, then, do not resemble the objects they symbolize, any more than the letters on this page resemble the sounds they represent. Sensations are "signs that we have *learned to decipher*, . . . a language given us with our organization by which external objects discourse to us." Our ability to understand this language, Helmholtz believed, is not inborn. Like any other language it is learned "by practice and experience."

Thus Helmholtz's theory of knowledge derived from his factual approach through empirical physiology. This approach, born of the fusion of medicine and mathematics that had formed his mind, is well illustrated by his analysis of the origin and significance of geometrical axioms.

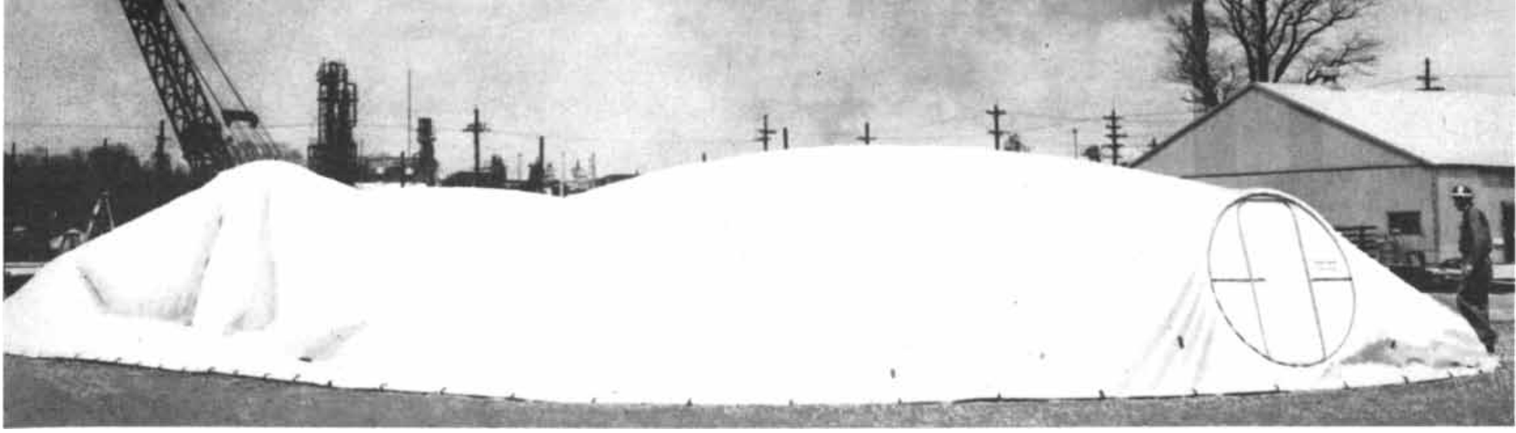
Kant had supposed that these axioms were innate *a priori* determinants of all our conceptions of space. Helmholtz, approaching the problem quite differently, asked under what conditions we arrive at our knowledge of these axioms. He concluded that they were not innate but rather the result of our perceptions of space as mediated by the spatial extension of the retina. Since they were not intuitive but the fruit of observation, they could be tested by observation and replaced if they proved incorrect.

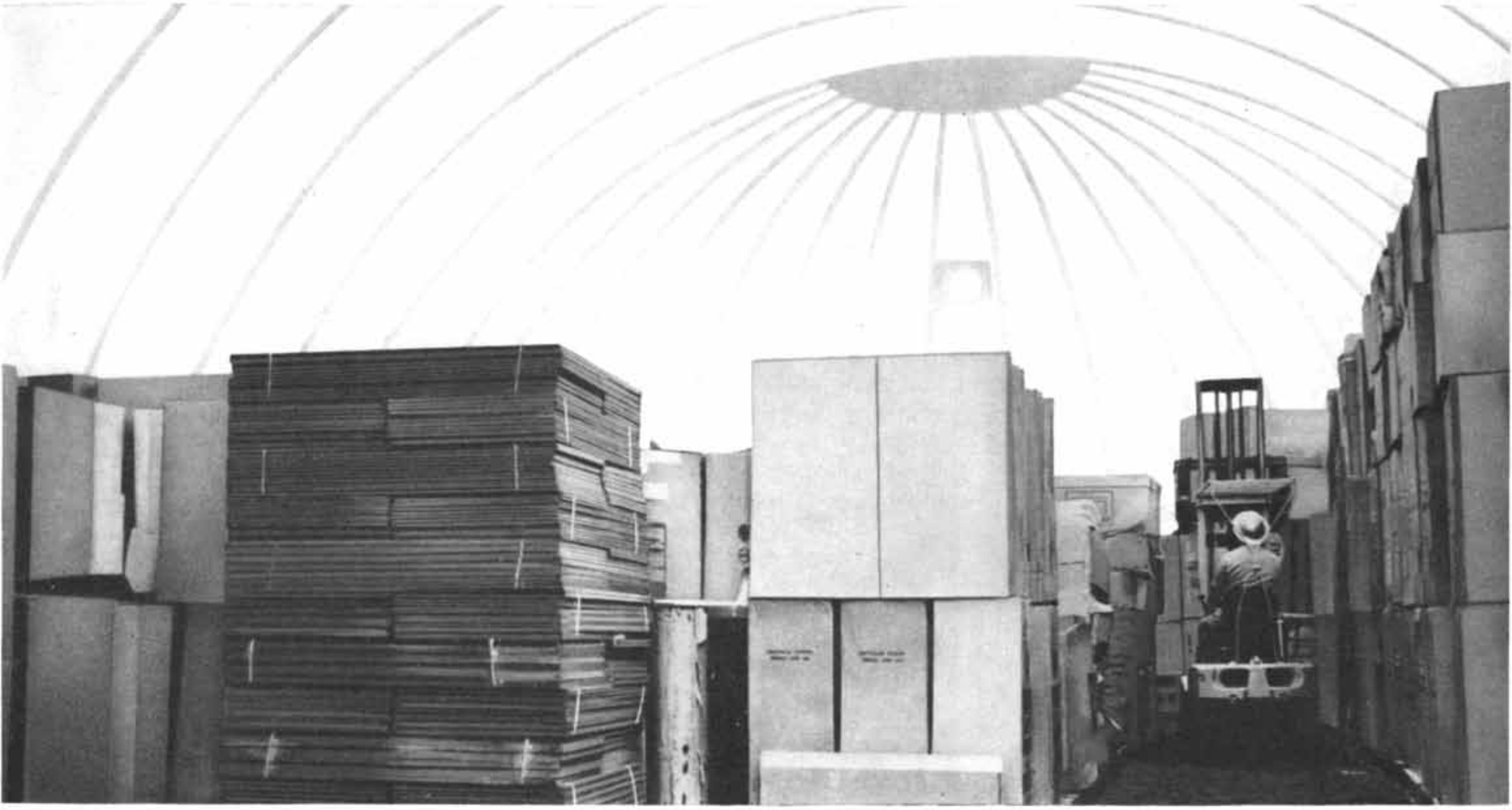
With this view of geometrical axioms, it is not surprising that Helmholtz—albeit with some initial hesitation—came to applaud the non-Euclidean geometries of Lobachevsky, Gauss and Riemann. His own work in geometry, dating from 1870, became, along with that of Riemann, the basis of the important developments in the field which took place toward the end of the century.

Helmholtz's empirical investigations into philosophy made him increasingly dissatisfied with the school of metaphysical idealism which then dominated German philosophy. This school had been founded at the beginning of the 19th century by Hegel, who held that a purely speculative philosophy could replace all the other sciences. To Helmholtz, the experimentalist, this notion seemed absurd. As early as 1859 he wrote his father, from whom he had acquired his interest in philosophy, that Hegel "diverted philosophy from its proper scope and gave it problems it can never accomplish." The task of philosophy, he held, was not to try to replace science but to supplement it by investigating the source and functions of knowledge, after the example of Kant and his disciple Johann Fichte.

"I believe," Helmholtz declared, "that philosophy will only be reinstated when it turns with zeal and energy to the investigation of epistemological processes and of scientific methods. There it has a real and legitimate task. The construction of metaphysical hypotheses is vanity. Most essential of all in this critical investigation is the exact knowledge of the processes of sense perception." He added: "I believe that any German university which had the courage to appoint a scientific man with an inclination to philosophy to its chair of philosophy would confer a lasting benefit on German science."

Helmholtz's crusade to reform philosophy along empirical lines entitles him





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to be numbered among the fathers of the modern philosophy of science. Though he himself was apt to declare that too much philosophy made one vague, his own writings on the philosophy of science have all the confident feel of reality that only a scientist can give.

Though Helmholtz during his later years became increasingly preoccupied with physiology and philosophy, his contributions to physics did not end. Indeed, the culmination of his academic career came with his appointment as professor of physics at Berlin in 1871, and his appointment as president of the State Institute of Physics and Technology in 1888.

During these years he pursued experimentally and theoretically ever more remote applications of the conception of matter in motion. He made a mathematical study of the analogy between the motion of fluids and the electromagnetic action of electrical currents in wires. The equations he produced inspired Kelvin to conceive of an atom as a vortex in the ether, in which different chemical properties were associated with different combinations of vortex rings.

Later he developed Faraday's conception that the bonds between chemical elements are electrical in character. From experiments on the electrolysis of substances in solution he was able to calculate the equivalence of electrical, chemical and mechanical forces. His work on this subject was a fundamental contribution to the theory that matter consists of electrically charged atoms and to the whole conception of valency on which modern chemistry is based.

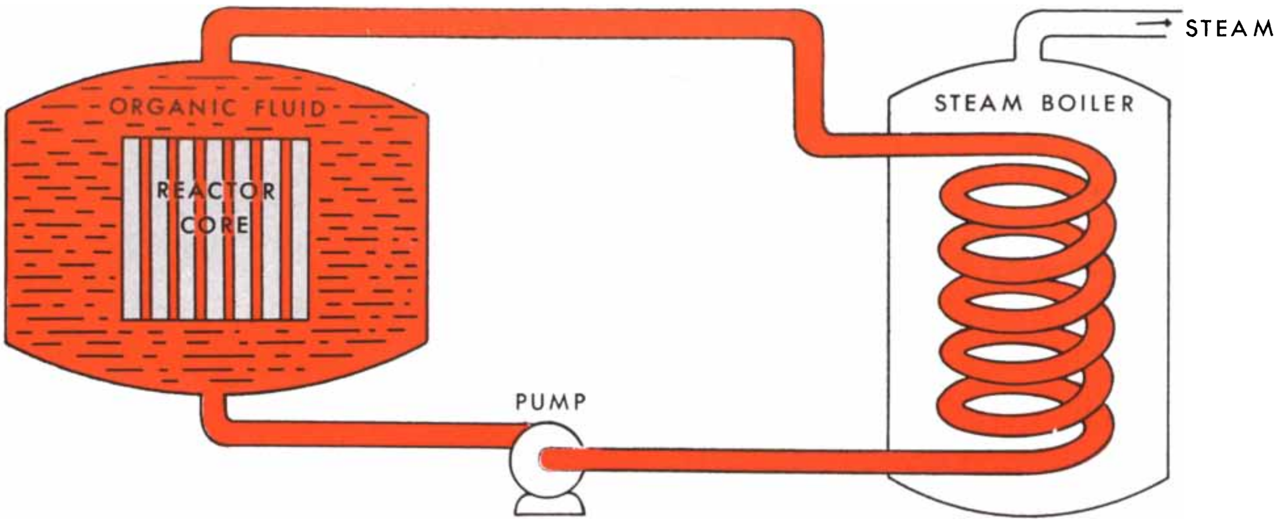
The most far-reaching later manifestations of Helmholtz's mathematical insight were concerned with the nature of electrical and magnetic forces. Here we have the vision of the mathematician, strained to its utmost, combined with the practical logic of the experimenter to penetrate the structure of the physical world. Faced with three rival theories of electromagnetic forces, Helmholtz showed that all three were special cases of a more general mathematical theory, and devised theoretical and experimental tests to determine which special theory was to be adopted. Two of the three were eliminated, and Helmholtz was left with the theory of Faraday and Maxwell, according to which electrical and magnetic forces are propagated through an all-pervading ether. Helmholtz's mathematical interpretation of Maxwell's theory that light is another form of electromagnetic wave in the ether stimulated Hertz to make his famous experiments in electromagnetic radiation. These not only established Maxwell's theory of light, but made possible the development of radio communication.

Helmholtz's genius was remarkably original, versatile and productive. In this article I have tried to indicate the main lines of his thought and to relate them to the chief qualities of mind from which his discoveries seem to spring. He himself became deeply interested in the processes of scientific discovery; his essays on the subject, drawing heavily on his own experiences, are among the most interesting of his philosophical writings. Here is an example from a lecture, "On Thought in Medicine," which he delivered in 1877. If it leads some readers back to Helmholtz's own writings, the main purpose of this article will have been fulfilled:

"In speaking against the empty manufacture of hypotheses, do not by any means suppose that I wish to diminish the real value of original thoughts. The first discovery of a new law is the discovery of a similarity which has hitherto been concealed in the course of natural processes. It is a manifestation of that which our forefathers in a serious sense described as 'wit'; it is the same quality as the highest performances of artistic perception in the discovery of new types of expression. It is something which cannot be forced, and which cannot be acquired by any known method. . . .

"When we fancy that we have arrived at a law, the business of deduction commences. It is then our duty to develop the consequences of our laws as completely as may be, but in the first place only to apply to them the test of experience, so far as they can be tested, and then to decide by this test whether the law holds and to what extent. This is a test which never really ceases. The true natural philosopher reflects at each new phenomenon whether the best-established laws of the best-known forces may not experience a change; it can of course only be a question of a change which does not contradict the whole store of our previously collected experiences. It never thus attains unconditional truth, but such a high degree of probability that it is practically equal to certainty."

It is not as common as one could hope for creative minds, whether in science or in art, to be so conscious of their mental processes and so well equipped to criticize logically the results of these processes. The combination of these gifts makes Helmholtz all the more worthy of our study.



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Artificial lowering of body temperature is becoming a useful medical technique. Already it has made possible unusual heart operations and has proved valuable in the treatment of shock

by Raymond J. Hock and Benjamin G. Covino

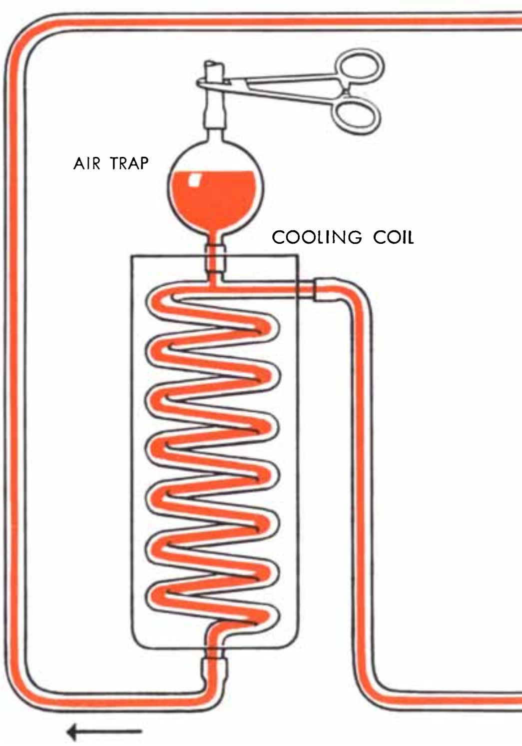
Every winter we read stories in the newspapers about people who have died from exposure to cold. In man, as in most warm-blooded animals, the reduction of body temperature much below normal causes death. Since cold-blooded animals and even warm-blooded hibernators can survive a far greater reduction of their body temperature for prolonged periods, we do not fully understand why human life should be so sensitive to cold. We do know, however, that life processes in general slow down as temperature falls. This knowledge, incomplete though it is, has recently proved a boon to surgery. In "freeze surgery," as it has been called, the patient's body is chilled 10 or 15 degrees below normal, usually by immersing it in ice water. With the body's demand on its circulatory system thereby sharply reduced, surgeons are able to perform heart operations that were unthinkable a few years ago. The technique is rapidly finding application in other branches of surgery, in the prevention of shock and in other medical problems. With practice advancing faster than understanding, lowered body temperature, or "hypothermia," is now of interest to many research groups.

Hypothermia has been likened to hibernation. The analogy is attractive, but it is helpful only if it provides an occasion for considering the significant differences between the two states. In the true hibernator, body temperature falls spontaneously to about the temperature of the environment; heart and respiratory rate and other bodily processes throttle down accordingly. With metabolism reduced to 2 per cent of normal and even less, the animal is enabled to survive the winter without eating. This adaptation is somehow built into the animal's physiological make-up, and it is a major feature of its existence. For example, the Arctic ground squirrel, studied by one of us (Hock), spends more than half the year in hibernation. In its winter lair this little creature's heart continues to beat with the temperature of its body reduced to three or four degrees above freezing. Upon awakening, the animal spends the rest of the year recovering and preparing for the next hibernation by increasing its body weight 20 to 40 per cent.

In a nonhibernator such as man there are no physiological mechanisms to reduce metabolism and body temperature in response to lower environmental temperature. In fact, the body is geared to the opposite response of stepping up its metabolism to maintain its normal temperature. A lowering of the body temperature, whether by accident or in preparation for surgery, is an event for which no provision is made in our physiological make-up.

The first observations of hypothermia in humans were recorded in Germany in the 1870s, in connection with the treatment of drunken persons suffering from exposure. These indicated that people could rarely survive reductions of body temperature to 75 degrees Fahrenheit, obviously a temperature well above freezing. Several cases recently reported in this country, however, show that some human constitutions can stand even severer trials. In 1951 a young woman was hospitalized in Chicago after an overnight exposure out-of-doors to below-zero weather. An hour and a half after her arrival in the hospital her temperature was still only 64.4 degrees F. She recovered, but was so badly frostbitten that both of her feet and most of her fingers had to be amputated. In 1956 a two-year-old child and its 50-year-old grandmother were found "frozen rigid," according to press accounts, in a slum apartment in Marshalltown, Ia. Both were revived, the grandmother from a temperature of 70 degrees and the child from a temperature of 60.8 degrees, the lowest recorded temperature from which a person has recovered. Except for the effects of frostbite, it seems, recovery in these cases was complete.

From the observation of patients under controlled hypothermia and from animal experiments, we are beginning to get a picture of what goes on inside the



HYPOTHERMIA can be produced by several methods. This drawing shows "extracorporeal cooling," in which blood is with-

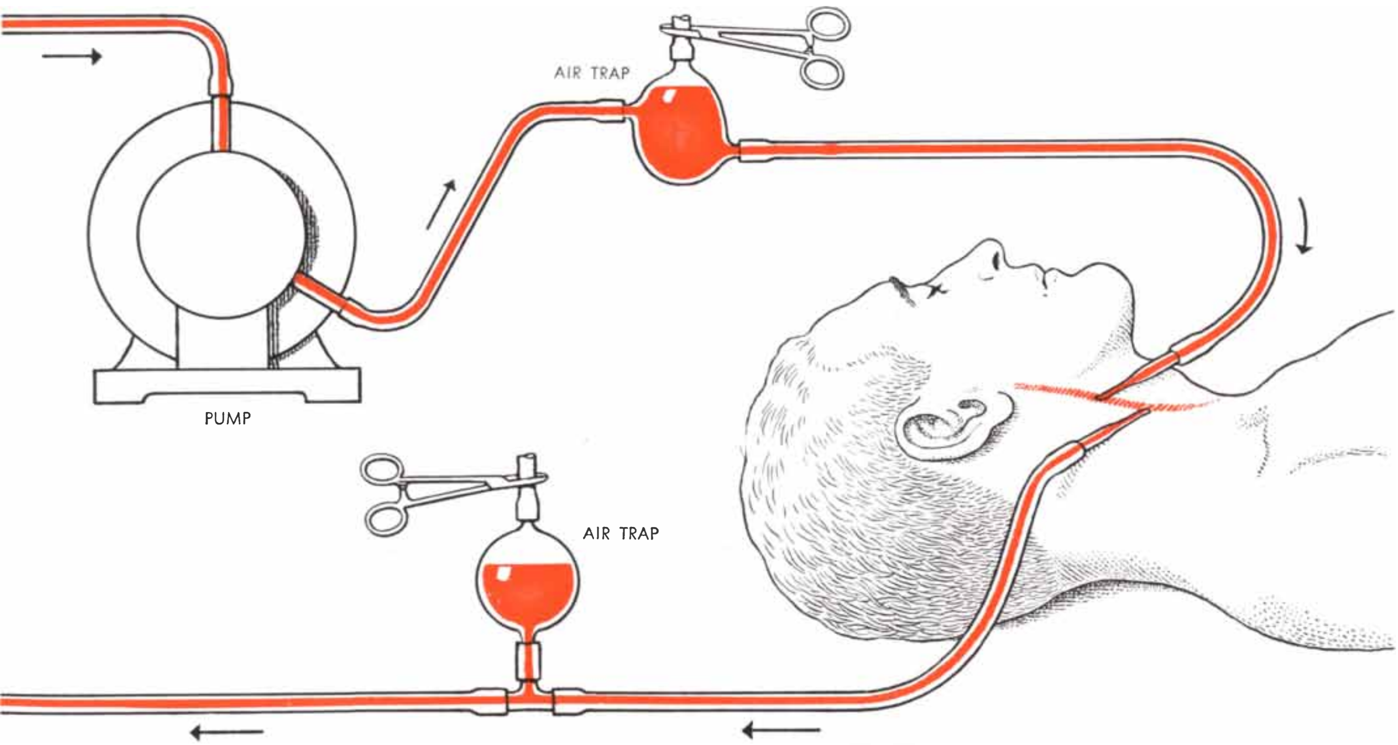
body as its temperature is reduced. The most impressive finding is the close dependence of metabolism on temperature. Metabolism falls with temperature in linear fashion; at 68 degrees it is only 25 per cent of normal. This slowdown in the processes of life is accompanied by a corresponding decline in the performance of the circulatory system. The pulse rate drops off, apparently as a direct consequence of the effect of cold on the pacemaker, the system of neuromuscular tissue in the heart that times and coordinates its contractions. Concurrently the volume of blood in circulation falls, as the plasma is sequestered in the peripheral capillary beds. At 68 degrees, if this low temperature is reached without other untoward developments, the output of the heart is down to 15 per cent of normal.

This depression of the circulatory system can greatly facilitate the work of the heart surgeon. With the body at normal temperature, the surgeon is in the position of a mechanic attempting to repair a motor while it is running. As late as 1940 few operations inside the heart were even attempted; despite brilliant progress in technique since then, surgeons have rarely opened the heart to operate on its interior, and then have worked blindly through a narrow slit in the heart wall. Now, with the patient in hypothermia, it is possible to shut off entirely the already reduced flow of blood through the heart. For a few minutes the surgeon can operate within a bloodless heart, with the site of operation under his direct vision.

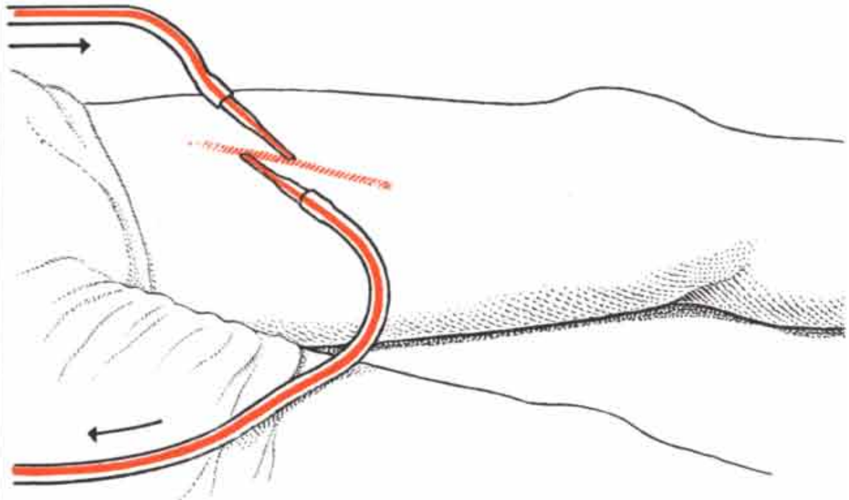
Just how many minutes can be made available to the surgeon by this shutdown of circulation is determined by the hazard to the brain rather than to the heart. The brain is extremely vulnerable to oxygen deprivation. At the normal rate of metabolism it may suffer irreversible damage from an extremely short interruption of its blood supply. Hypothermia, however, depresses the brain's metabolism just as it does that of other organs. The effects of cold show up first in the centers located high in the cerebral tree, with impairment of the ability to coordinate mental processes and to perform intricate physical routines. At a body temperature of 86 degrees the cold narcosis familiar to readers of Jack London commences, and consciousness may be lost, though there are reports of individuals who maintain consciousness and even the faculty of speech at a temperature of 77 degrees. The lower cerebral centers which control such functions as respiration are the last to be inactivated; these centers continue to function, with the depth and rate of respiration drastically reduced, at temperatures as low as 68 degrees.

From such deep depression of its activity the brain appears to recover completely. No mental impairment or abnormality is observed following an episode of properly controlled hypothermia. Even with its metabolism reduced by hypothermia, however, the brain is exposed to the hazard of oxygen deprivation during the period when its blood supply is shut off to permit heart surgery. At a body temperature of 86 degrees—the present limit of hypothermia in practice—the safe period is six to eight minutes. If hypothermia could be safely managed at a lower temperature and the brain's metabolism thereby reduced further, the time available to the surgeon could be prolonged. The limiting factor here is the effect of hypothermia on the heart.

Evidence from animal experiments indicates that the principal cause of death in hypothermia is an irreversible breakdown in the coordination of the heart action, a condition known as ventricular fibrillation. The rhythm of the heart first falters when the temperature goes below 80 degrees. In man it is the auricles, the entrance chambers of the



drawn from the body (*right*), passed through a chilled coil (*left*) and returned. Blood can be taken from the femoral artery (*see next page*) or from the carotid artery as shown here. By using the carotid the brain can be made some 20 degrees cooler than the rest of the body. Circulation can then be stopped for up to 14 minutes, during which surgeon can open heart and operate on its interior.



EXTRA-CORPOREAL COOLING of blood from the femoral artery produces a general lowering of body temperature rather than local brain cooling shown on preceding two pages.

heart, that are initially affected. Thereafter the ventricles begin to develop extra beats, then bursts of rapid contractions and finally the uncoordinated contractions of ventricular fibrillation that engage the entire musculature of the heart and terminate in heart failure. This pattern of activity is usually not spontaneously reversible and has been observed in 70 per cent of the experimental animals. Probably most people who are found "frozen to death" have died in this manner.

Experimental animals which do not succumb to ventricular fibrillation continue to exhibit a progressive slowing down in their heartbeat as their body temperature is brought lower. The heart finally stops beating between 60 and 50 degrees. From this condition, however, animals have been revived after varying periods of cardiac standstill. At the Arctic Aeromedical Laboratory in Fairbanks, Alaska, we have successfully rewarmed two dogs after keeping them an hour and 15 minutes with no heartbeat at a temperature below 60 degrees.

Why so many animals develop ventricular fibrillation is a question that has attracted the interest of many investigators. The susceptibility of the heart to fibrillation can be demonstrated by applying electrical stimuli of various strengths to the ventricle before and during hypothermia. Such tests have shown that there is one threshold for the stimulus that induces a normal heart contraction and another for the stimulus that brings on fibrillation. During hypothermia the normal threshold remains constant. The fibrillary threshold, however, is markedly reduced by hypothermia. At 86 degrees an electrical stimulus of 15 milliamperes is insufficient to start fibrillation; at 75 degrees, fibrillation may be triggered by a stimulus of only 3.4 milliamperes.

Several factors seem to be implicated in the production of this lethal abnormality. The blood of experimental animals subjected to hypothermia exhibits increased acidity. This can be offset, and the chances of fibrillation reduced, by increasing the rate of breathing. Other evidence suggests that cold affects the activity of nerves which are external to the heart, but which are involved in its action. The level of calcium and potassium in the blood also seems to be affected in ways which tend to produce fibrillation. But we do not yet know how all these factors interact.

In surgery the risk of ventricular fibrillation is increased by the shock of the operation itself. Deep hypothermia cannot truly take its place in the armamentarium of surgery until additional information is gained by the various research groups working on the problem. Meanwhile the risk can be minimized by reducing body temperatures to no lower than 86 degrees. At this temperature the heart rhythm remains undisturbed, yet metabolism is slowed sufficiently to allow blood circulation to be halted for several minutes.

Hypothermia was first reported as a medical procedure in 1941 by Temple Fay and L. W. Smith, then at Temple University in Philadelphia. They had noticed that cancers rarely spread to the extremities of the body, where temperatures are six to 20 degrees lower than in the trunk. In contrast, the breast, a common site of cancer, has a high temperature. It occurred to Fay and Smith that

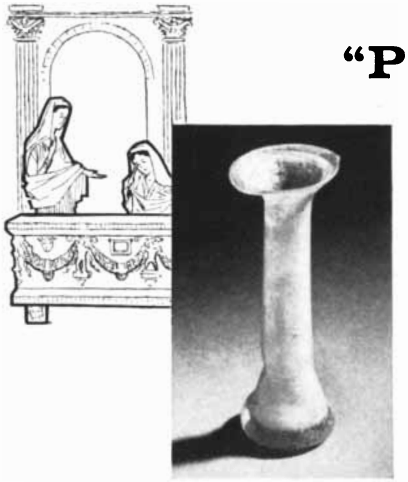
reduction of body temperatures might slow or halt the growth of cancer tissue. In a number of hopeless terminal cases the patients' temperatures were reduced to 80 degrees and held there up to eight days. Though the treatment did not affect the cancer, it achieved relief from pain for as long as five months and lessened or eliminated the need for opiates. Further work along these lines was soon undertaken at Lenox Hill Hospital in New York, and similar results were reported in a number of cases of cancer, leukemia and even drug addiction.

In France after World War II Henri Laborit was looking for a method of treating shock, the principal immediate cause of death in severely wounded war casualties. Since the autonomic nervous system appears to play a central role in the onset of shock, Laborit reasoned that blocking of the autonomic nervous system might diminish shock and allow patients to survive its crisis. None of the standard nerve-blocking drugs, however, achieved the general depression he was seeking. The concurrent discovery of chlorpromazine, a powerful depressant now widely used as a tranquilizer, solved the problem. Combined with several of the nerve-blocking drugs in a "lytic cocktail," it induced the desired autonomic block, evidenced in a slower heart and pulse rate and a lower body temperature. The mild hypothermic effect of the drugs suggested that the auto-

EFFECTS OF HYPOTHERMIA on men and experimental animals are contrasted with those of hibernation. Hibernators can survive temperatures which would be fatal to other animals. Hummingbirds and bats show a sharp temperature drop during sleeping hours.

THIS IS GLASS

a report to men who make decisions



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Legend has it that in grieving their departed, ancient Romans collected their tears in vases and buried the vases with the deceased. Such vases go back to the Rome of about 300 A.D. Yet, today a tourist can buy one of these "priceless" bits of antiquity for an outlay of two dollars. How come? Because untold numbers of these vases are still intact. Time, weather, heat, cold, dust, dampness—*nothing* has bothered these tiny vessels made of *glass*. Glass *lasts*. And glass has a compelling beauty matched by no material known to ancient or modern man. Glass wipes clean with a damp cloth. Glass doesn't rust, tarnish, or fade. It stays new looking almost forever. Some of the ways in which the myriad forms of today's glass are being used are spelled out in a well-illustrated booklet called "This Is Glass." The short time it will take you to become acquainted with its contents will be repaid many times over. Send for a copy.

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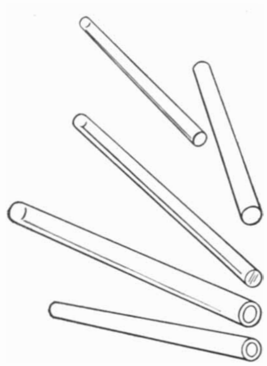

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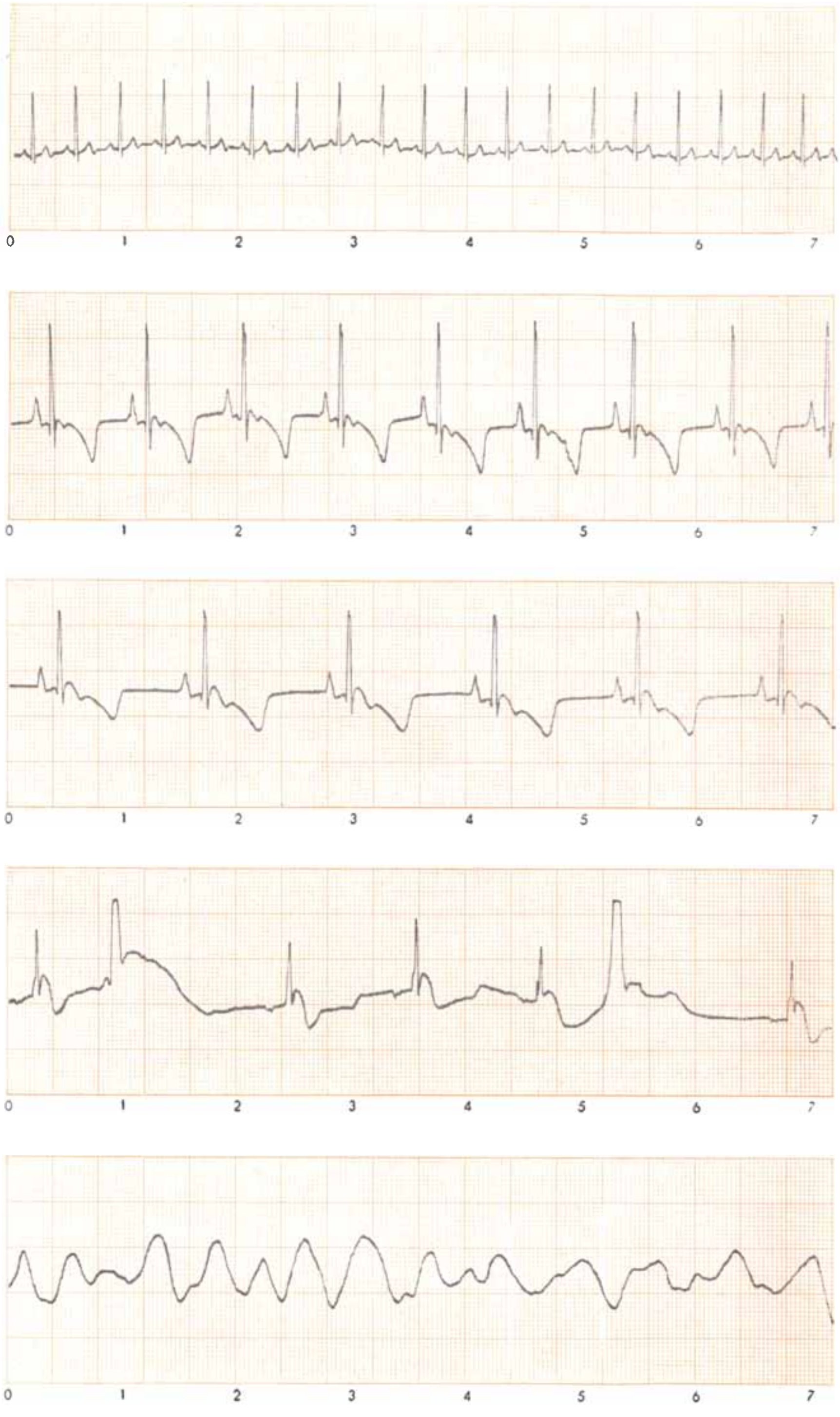
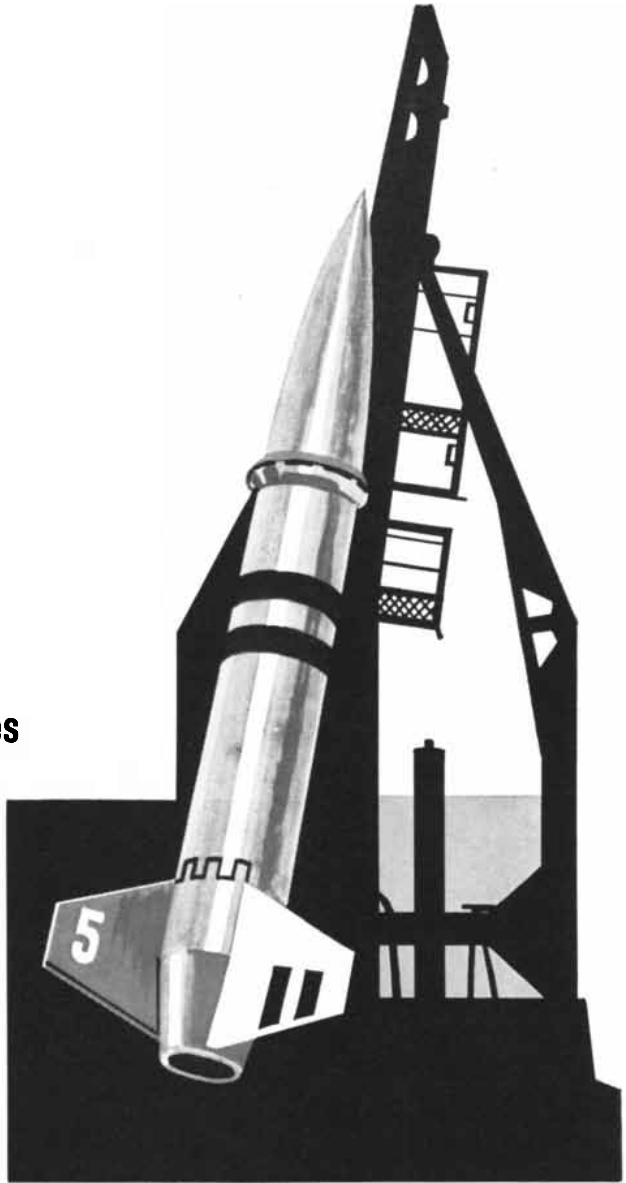
nomic block might be reinforced by further cooling of the patient's body with ice water. This treatment, it was observed, had the additional effect of lowering oxygen demand and inducing a mild general anesthesia. In the Indo-China campaign hypothermia by the drug-and-ice-water method became something of a standard practice in French military medicine, and its users reported a reduction of about a third in the death rate of the severely wounded.

In 1950 W. G. Bigelow of the University of Toronto reported observations on the oxygen consumption of hypothermic dogs. Bigelow was the first to sug-



HEART ACTION during hypothermia is shown in electrocardiograms of a dog. Normal rate of 180 beats a minute slows as temperature drops from 98.4 to 77 degrees (*top, second and third*). At 68 degrees abnormalities develop (*fourth*); at 62.5 degrees total disorganization (ventricular fibrillation) sets in (*bottom*). This condition is fatal if it continues.



medicine and missiles

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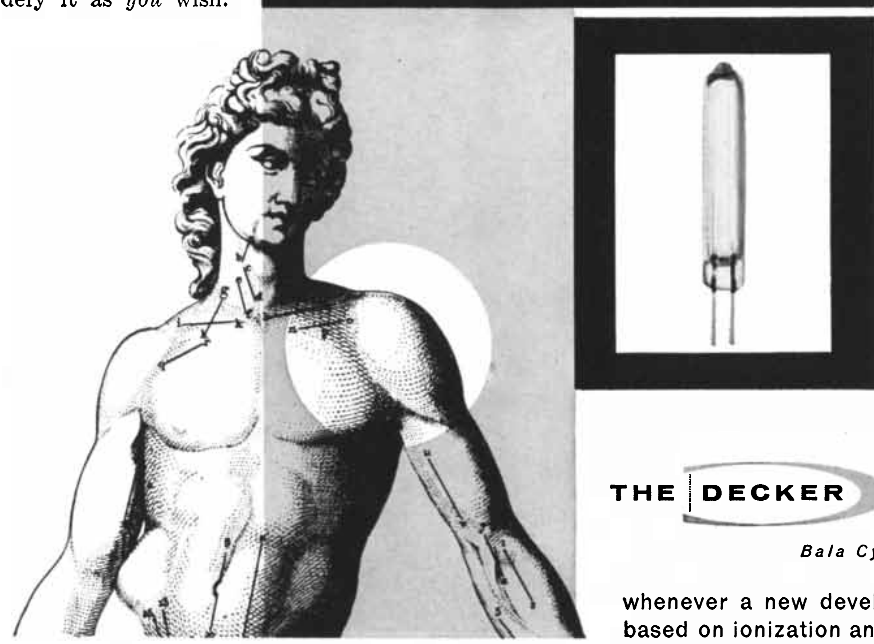

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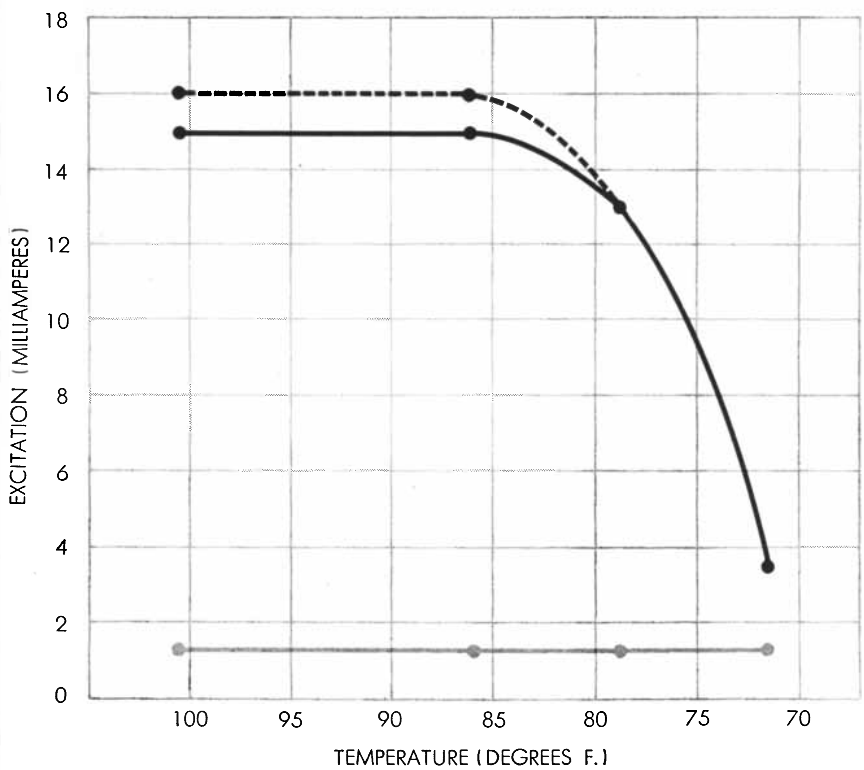
whenever a new development takes place, it is based on ionization and electrical gas discharge gest that this aspect of the hypothermic state gave great promise in situations where open-heart surgery was indicated.

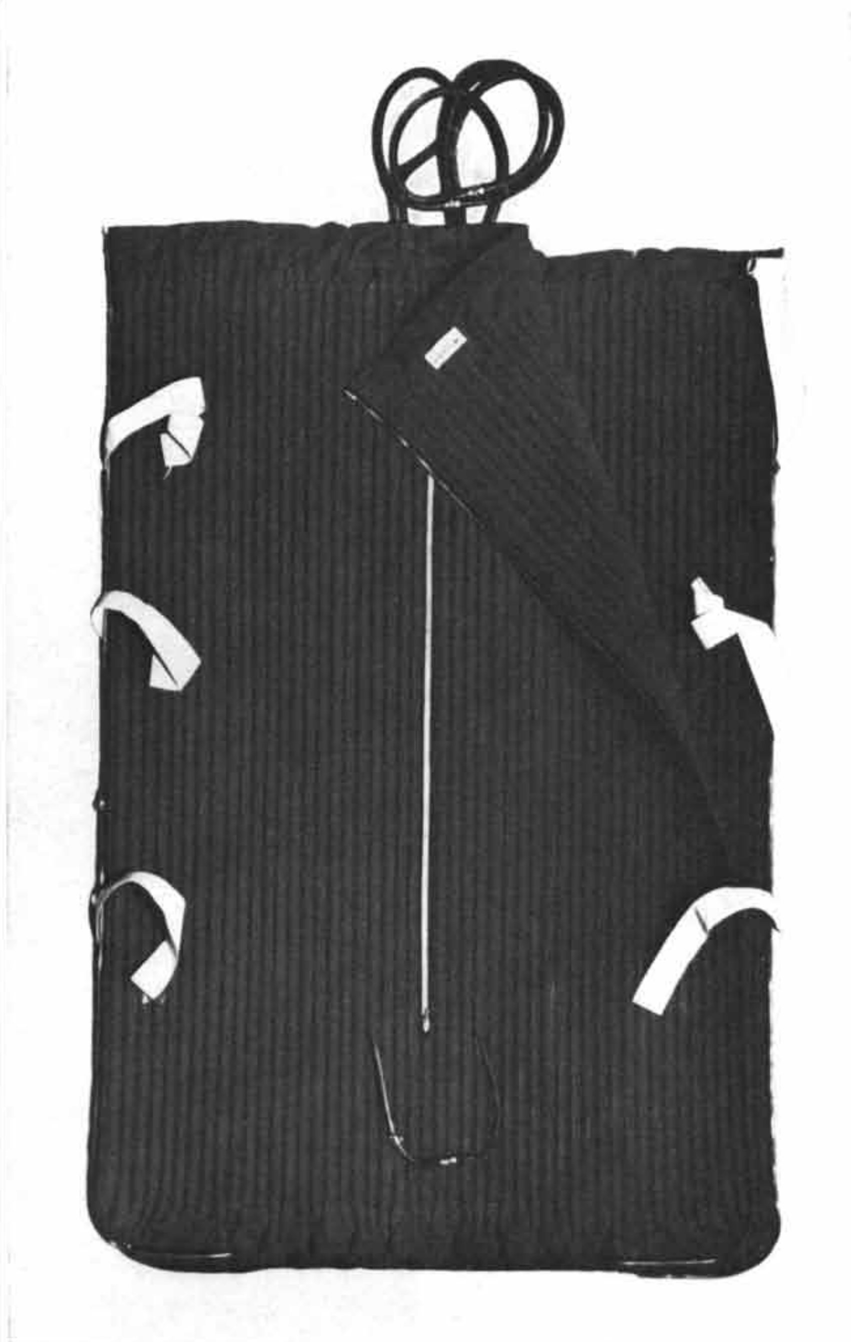
In the U. S. today the accustomed procedure for inducing hypothermia is immersion of the patient in a bath of ice water with a temperature of from 35 to 40 degrees. The patient is usually anesthetized with pentothal or ether (chlorpromazine is not used); shivering, which tends to maintain body heat, is prevented by muscle relaxants such as curare or succinyl choline. The patient's body may also be cooled by wrapping it in a rubber blanket through which a refrigerant is circulated. After two or three hours in the bath or the blanket, the patient has been cooled to 86 degrees and is ready for surgery. Restoration of normal temperature after the operation, by means of a warm bath or by circulating warm water through the rubber blanket, takes another two or three hours.

Another method, "extra-corporeal cooling," has recently come into use: the blood from an artery is passed through refrigerated coils and returned to the circulatory system via the same artery or a vein [*see illustrations on pages 104, 105 and 106*]. A modification of this technique, developed by Kazumi Taguchi of the University of Okayama in Japan, may help solve the problem of cooling the brain for more prolonged shutdown of circulation without overcooling the heart. By cooling blood from the carotid artery, which furnishes the principal blood supply of the brain, Taguchi has cooled the patient's brain down to 65 degrees, while maintaining the rest of the body in a safe range of hypothermia. As a result he has been able to extend the duration of heart operations to as long as 14 minutes.

While hypothermia has been a special help to the heart surgeon, it has proved valuable in other departments of medicine. French physicians in particular, encouraged by the experience in Indo-China, are using it extensively, and the current issues of their journals regularly carry one or more papers on the technique. One dramatic case suggests the wide range of application. This was a Caesarean section undertaken to terminate a pregnancy in a patient suffering from acute convulsive eclampsia. Such operations are performed to save the mother's life and with no expectation of delivering a live infant. In this case, however, the baby survived, having been rendered hypothermic along



SOME HEART ABNORMALITIES are more easily induced at low temperatures. The electrical stimulus needed to produce ventricular fibrillation (*black line*) decreases as body temperature falls; stimulus needed to produce an extra beat (*gray line*) remains the same. Broken line above black line indicates uncertainty in measurements at those temperatures.



REFRIGERATED BLANKET through which a chilled water-alcohol mixture is pumped can be used to induce hypothermia. Warming the mixture restores normal temperature.

with its mother! Hypothermia is now being used to diminish shock and the effects of oxygen deprivation in infants delivered from prolonged labors, and to help pull infants born of Rh-negative mothers through the rigors of having their blood removed and replaced by transfusion. French physicians are also using hypothermia in contending with severe infections in the newborn; in effect the infant is refrigerated while the antibiotics work on the organisms.

Mild hypothermia may find wide use in general surgery as a way of reducing the amount of anesthetic needed to ready the patient for operation. This is an important consideration in surgery on "poor risk" patients, especially the aged. For surgery of the brain, hypothermia offers several specific advantages. Most brain operations are complicated by excessive bleeding; with the patient in hypothermia, the flow of blood is reduced and may even, if necessary, be shut off entirely during the critical moments of the operation.

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A. Leydenfrost

The Microsome

This small particle is found in a fraction of living cells which have been broken up for biochemical investigation. It now seems to be a fragment of an intracellular system which makes proteins

by Paul C. Zamecnik

The biochemist traditionally studies living cells by smashing them to bits and trying to analyze the function of their parts. This rough treatment reduces much of the cell to minuscule fragments, but some of its constituents survive as relatively large particles. One kind of particle is the mitochondrion, in which the chemical reactions that supply energy to the rest of the cell are conducted [see "Powerhouse of the Cell," by Philip Siekevitz; SCIENTIFIC AMERICAN, July, 1957]. Another is the microsome, which appears to be associated with the manufacture of the most elaborate molecules of living matter: the proteins.

But of course cells are not only studied by chemical means. They can also be examined under the microscope, in recent years at the huge magnifications of the electron microscope. Improvements in the preparation of cells for the electron microscope now reveal many details of cellular structure that were hitherto invisible. Today we see the cell not as a little bag of freely interacting molecules in solution, but as a highly organized microcosm.

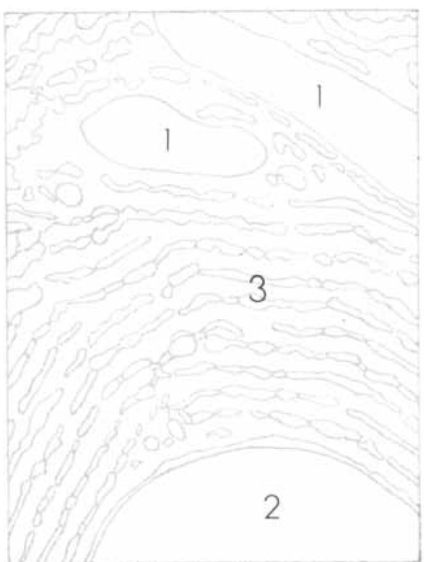
Among the striking features of this microcosm is a system of membranes called by electron microscopists the "endoplasmic reticulum" [*see illustrations on this and the opposite page*]. Studied principally by George E. Palade of the Rockefeller Institute for Medical Research and by Fritiof Sjöstrand of Sweden these membranes are lined with tiny, dense particles. The membranes may form a system of interconnected canals resembling those of an automobile radiator, but this is not yet certain.

The electron microscopists observed that certain cells, notably those of the pancreas, were particularly rich in the membranes and particles of the endoplasmic reticulum. These cells specialize in the manufacture and secretion of enzymes, the protein molecules which catalyze the chemical reactions of life. This suggested that the endoplasmic reticulum might play a role in the synthesis of proteins.

A significant discovery was now made by Palade and in our laboratory at Harvard University and the Massachusetts General Hospital. When the biochemist breaks up his cells, he has a homogenized mixture of, among other things, red blood cells (which resist disruption because of their small size), cell nuclei, mitochondria and microsomes. These various constituents can be separated by placing them in a small vessel and spinning them at high speed in an ultracentrifuge. When the mixture is first spun, the relatively heavy red blood cells and cell nuclei settle out and form a pellet at the bottom of the vessel. When the remaining fluid is removed and spun, the mitochondria settle out and form a second pellet. The fluid can then be spun again to yield a pellet of microsomes. What Palade and we showed was that the microsome pellet of the biochemist was made up of fragments of the shattered endoplasmic reticulum.

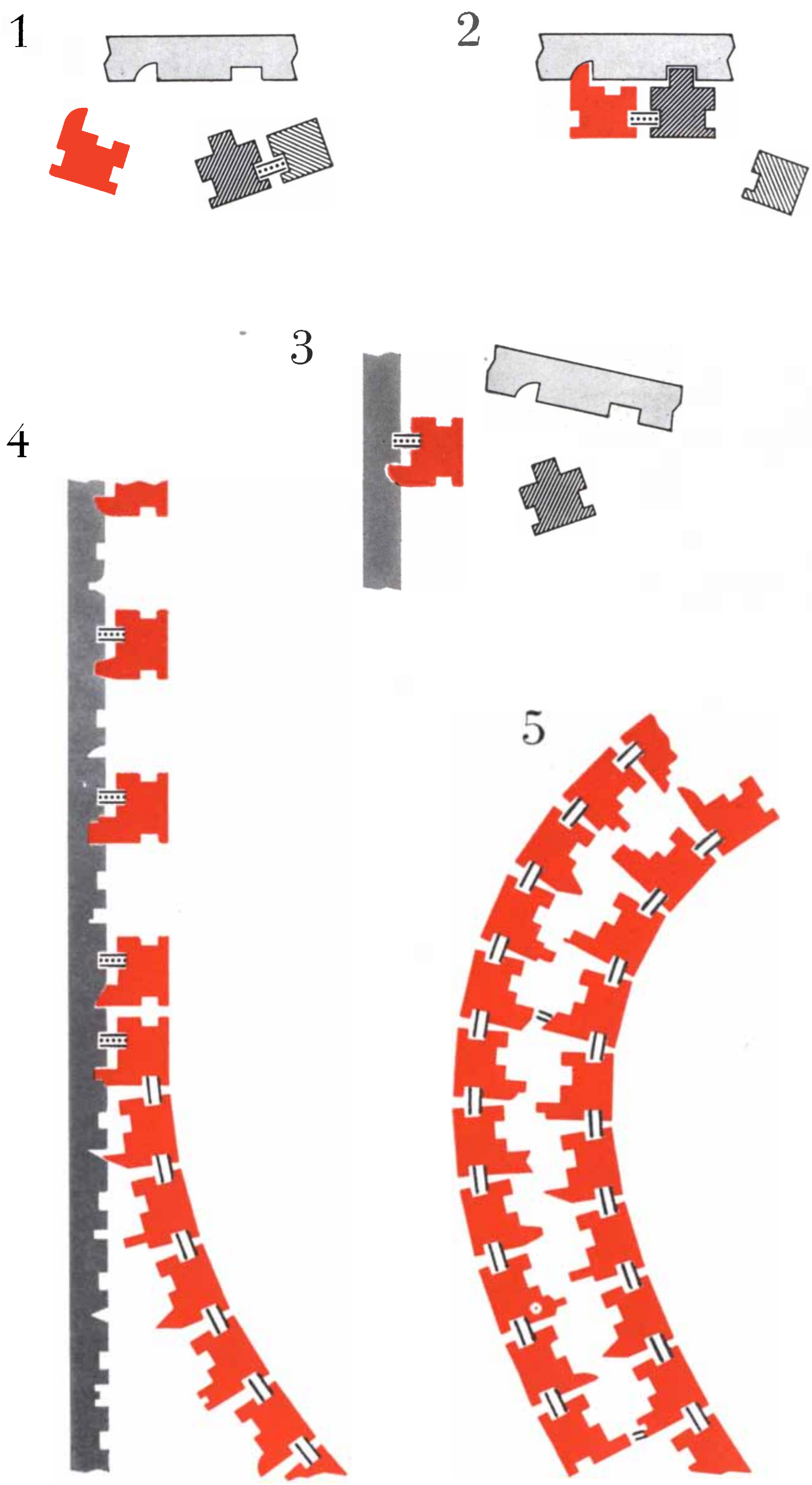
Meanwhile biochemists had begun to suspect from other lines of work that microsomes played a significant part in protein synthesis. As readers of this magazine are well aware, proteins are huge molecules that are constructed from the much smaller molecules of 20-odd amino acids. By labeling the amino acids with radioactive atoms we can follow to some extent their incorporation into protein. In several laboratories (including our own) animal cells were broken up and radioactive amino acids were added to the mixture. When the protein in the mixture was later analyzed, it was found that roughly two parts per 1,000 were radioactive. Presumably the labeled amino acids had been built into new proteins. The amino acids were taken up only for about 10 minutes after the cells had been disrupted, which suggested that this was the last flicker of protein synthesis in the cell.

The mixture was now fractionated in the ultracentrifuge. It was found that not all the fractions contained radioactive protein. The protein of the microsome fraction was, however, nicely labeled with radioactivity. (This observation was first made by Henry Borsook at the California Institute of Technology.) Particularly radioactive were the



ELECTRON MICROGRAPH at right, made by George E. Palade of the Rockefeller Institute for Medical Research, enlarges part

of a cell from the pancreas of a guinea pig 56,000 diameters. The structures labeled 1 in the outline drawing at left are mitochondria. The structure labeled 2 is the nucleus of the cell. In the area between them labeled 3 is an extensive system of membranes and small dark particles called the "endoplasmic reticulum." It is now known that the microsomes are fragments of this system.



PROPOSED SCHEME for the synthesis of a protein molecule is outlined in this drawing. First, an enzyme (*light gray*) combines with an amino acid (*color*) and the energy-rich substance adenosine triphosphate, or ATP (*hatching*). Second, the high-energy chemical bond (*dotted line*) of the ATP is transferred to join the phosphate group of the ATP (*dark hatching*) and the carbonyl group of the amino acid. Third, the "activated" amino acid combines with ribonucleic acid, or RNA (*dark gray*), by transferring the high-energy bond to a phosphate group of the RNA. Fourth, various amino acids line up along the RNA at specific sites. A "zipper" reaction now takes place in which the carbonyl group of the end amino acid is transferred from the phosphate group of the RNA to the amino group of the adjacent amino acid. Fifth, chains of amino acids are cross-linked, coiled or folded.

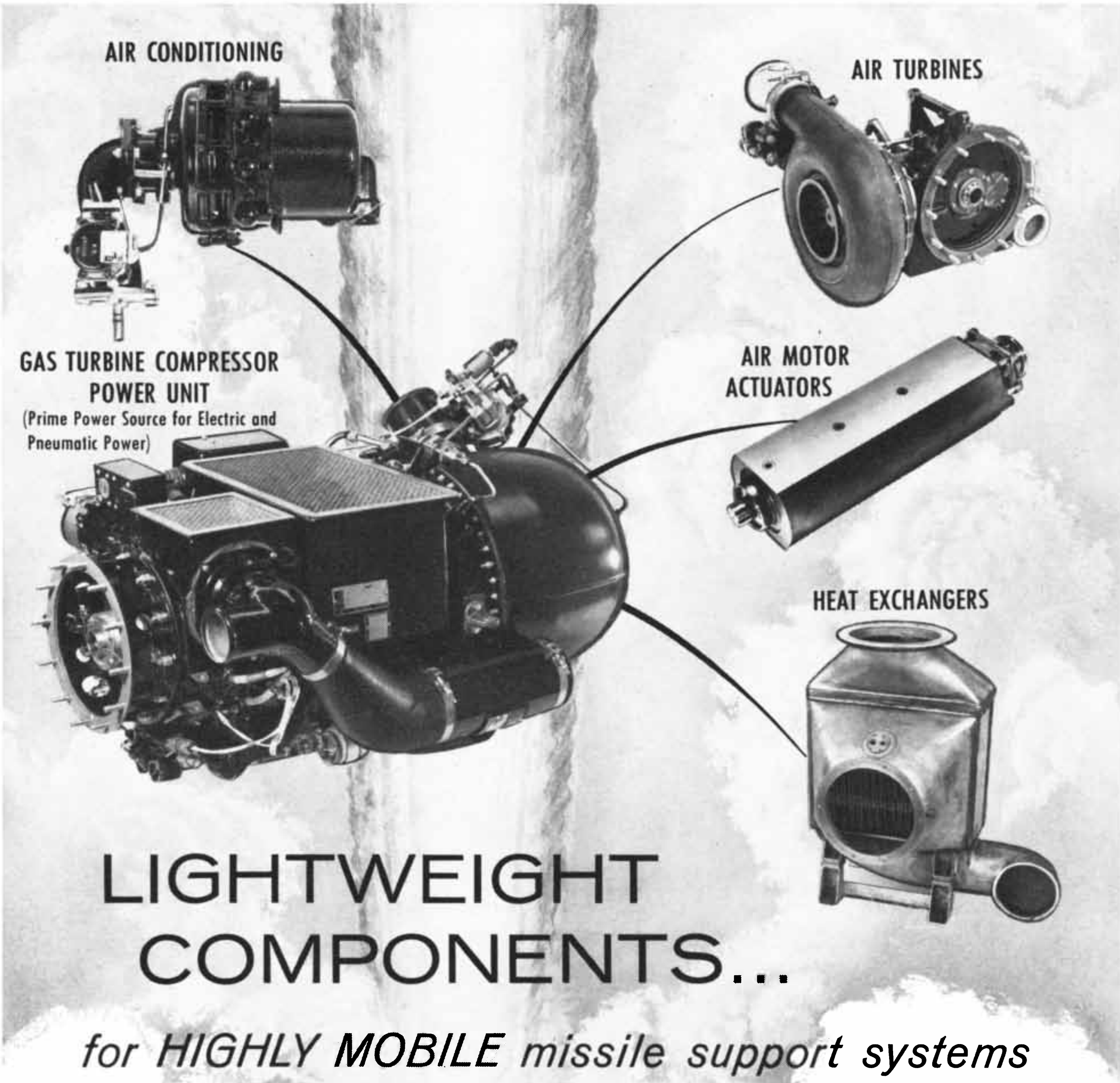
small, dense particles associated with the microsomes.

Here was a finding of especial interest. The small particles of the microsomes consist of roughly equal parts of protein and ribonucleic acid, or RNA. As far back as 1941 it had been independently suggested by Torbjörn Caspersson of Sweden and Jean Brachet of Belgium that RNA is associated with protein synthesis. It is now believed that a molecule of RNA may act as a kind of template for the manufacture of a molecule of protein.

This idea has received support from recent studies of the nature of proteins and similar substances. The trail-blazing work of Frederick Sanger at the University of Cambridge has shown that the protein insulin consists of a very precise sequence of amino acids. Other workers have found that the amino acids in the proteins ribonuclease and papain are equally well ordered. The same is true of oxytocin and vasopressin, hormones which are not proteins but smaller structures built up from amino acids. The latest of these smaller molecules to surrender to complete analysis are the two melanocyte-stimulating hormones (MSH) of the pituitary gland.

We also have the exciting observation that a change in a single amino acid unit can alter the character of an entire protein molecule. Vernon M. Ingram of the University of Cambridge finds that the abnormal hemoglobin which causes sickle cell anemia differs from normal hemoglobin only in that one amino acid is substituted for another at a specific point in a molecular structure made of some 300 amino acid units. It appears that the mutation of a single gene is responsible for this change [see "How Do Genes Act?," by Vernon M. Ingram; SCIENTIFIC AMERICAN, January].

In short, each protein seems to have a molecule of unique construction. It is difficult to see how amino acids could be so precisely lined up in solution. This would be like trying to load cargo into a ship in a heavy sea. Moreover, every living thing makes many molecules of each of its proteins every day. One can hardly avoid the conclusion that proteins are made by some biological equivalent of a printing press. The analogy is imperfect, but if such a press or template exists, it is very likely RNA. It also seems likely that the small particles of the microsome or endoplasmic reticulum are the site at which amino acids are linked. Several schemes have been proposed to explain the action of RNA in protein synthesis. One has been offered by V. V.



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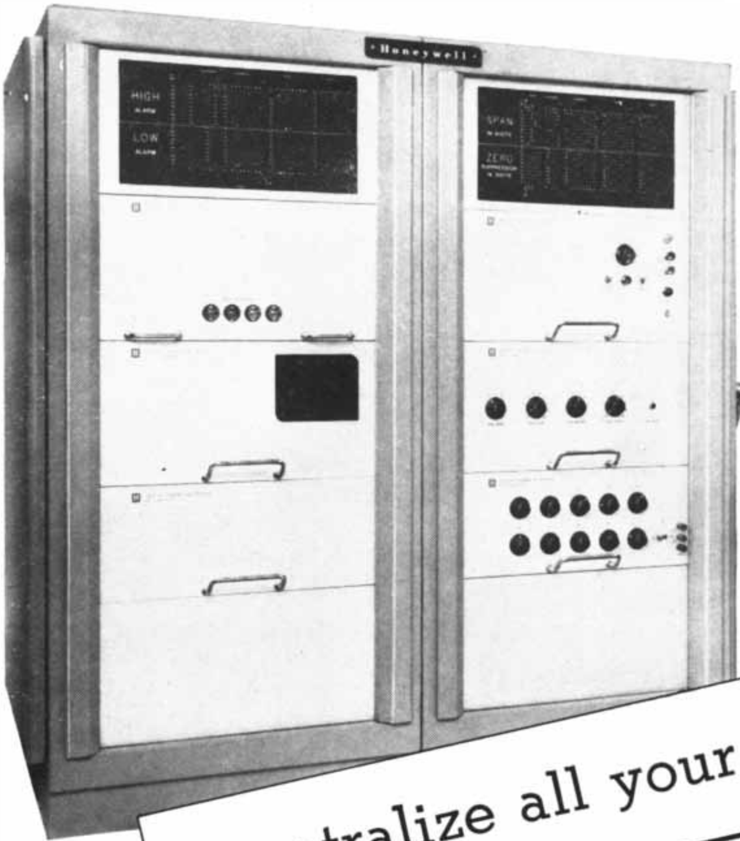
Konigsberger and J. T. G. Overbeek of the Netherlands; its main features are as follows. "Activated" amino acids line up along the RNA in a specific order determined by the structure of the RNA molecule; the carbonyl group (CO) of each amino acid is bound to a phosphate group (PO_4) of the RNA [*see illustration on page 120*]. By a "zipper" reaction the carbonyl group of an amino acid at one end of the chain is transferred from the phosphate group to the amino group (NH_2) of the adjacent amino acid. This causes the same transfer in the next amino acid, and so on down the line. The chain of amino acids separates from the RNA molecule as it grows.

How does the RNA determine the sequence of amino acids before the zipper reaction? The question has given rise to much thought and speculation. RNA is one of two types of nucleic acid found in the living cell; the other type is deoxyribonucleic acid, or DNA. Where a protein molecule is a chain of amino acids, both DNA and RNA are chains of sugars linked by phosphate groups; to each sugar, however, is attached a base. Chemically the two nucleic acids are quite similar; architecturally they may differ. J. D. Watson and F. H. C. Crick have worked out a now-famous model of DNA in which two nucleic-acid chains wind around each other like a double spiral-staircase [see "Nucleic Acids," by F. H. C. Crick; SCIENTIFIC AMERICAN, September, 1957]. The bases form the "treads" of the staircase; a base on one chain is joined to the adjacent base on the other chain by a weak chemical bond. The structure of RNA is not so clearly understood, but it is probably a two-chain helix also. Crick has suggested that for the RNA molecule to distinguish each amino acid from all the others requires the proper arrangement in space of three bases. That is about as far as we can go at present. We are much in need of an accurate three-dimensional model of RNA.

Goethe once said that genius was the ability to perceive analogies. When biologists are blocked in an investigation based on one kind of organism, they often turn to another kind. The small particles of the microsome are composed of protein and RNA; so are the viruses which cause the mosaic disease of tobacco. Various investigations of the tobacco mosaic virus show that it is made up of smaller units which resemble lock washers; in the intact virus the "washers" are stacked like coins. By inference the small particles of the microsome are also made up of smaller units, and several labora-



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tories are presently looking into the matter.

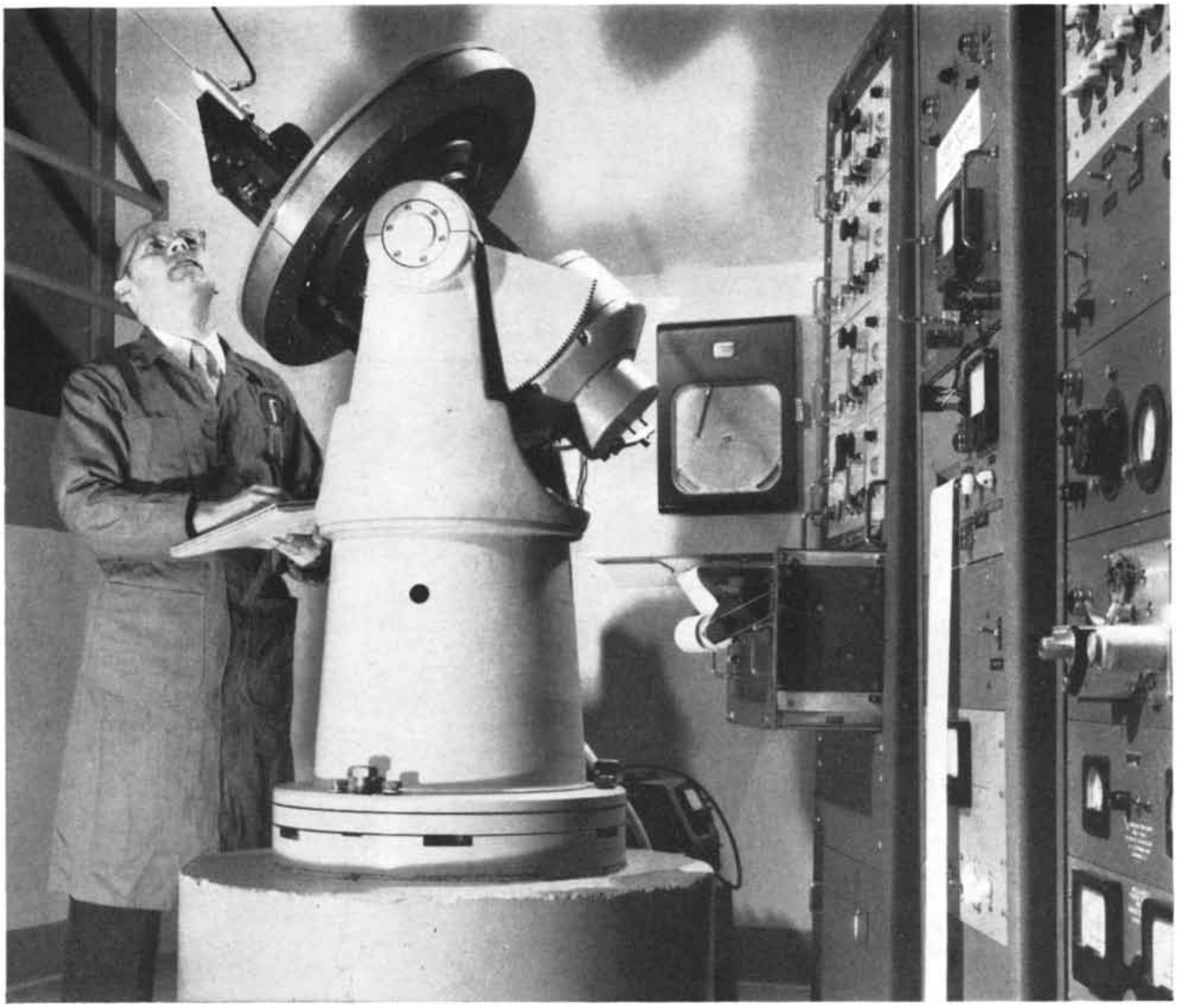
Despite the slow pace of this work we have succeeded in dissecting out three steps of protein synthesis. The first is the "activation" of the amino acids before they are joined. Amino acids will not link spontaneously; energy must somehow be funneled into the process. In 1941 Fritz Lipmann (now at the Rockefeller Institute) suggested that amino acids might be raised to a higher energy level by combining with an energy-rich phosphate group. The activated amino acids could then coast downhill, in the energetic sense, to combine with each other. For years biochemists sought this reaction, without success. Now my colleague Mahlon B. Hoagland has found a similar reaction which appears to supply the long-missing activation step.

In the second step the amino acids are lined up in association with RNA and linked. This does not complete the process; a protein is not a simple chain of amino acids. It may consist of two or more chains joined by secondary chemical bonds, and the chains may be coiled or folded by weaker bonds.

The third step is the establishment of this complex structure. At least part of it seems to take place in association with the membranes of the endoplasmic reticulum, as distinct from its small particles. The membranes are logically located in juxtaposition to the particles. The two components of the endoplasmic reticulum or microsome thus appear to be mutually dependent in protein synthesis.

Between the first and second step lies an active area of research. Evidence from our laboratory and others points toward the possibility that, between the activation of the amino acids and the completion of the amino acid chain, there may be an intermediate amino-acid–RNA compound. There is little doubt that the actual sequence of events is rather more complex than I have outlined it here.

The functions of the microsome are not restricted to protein synthesis. My colleague Nancy Bucher has shown that the membrane of the endoplasmic reticulum is essential to the formation of cholesterol, the steroid found in all cells. Curiously the small particles of the microsome play no part in cholesterol synthesis. Other important substances such as steroid hormones and drugs are oxidized or altered in the membrane; the list of its functions is rapidly growing.



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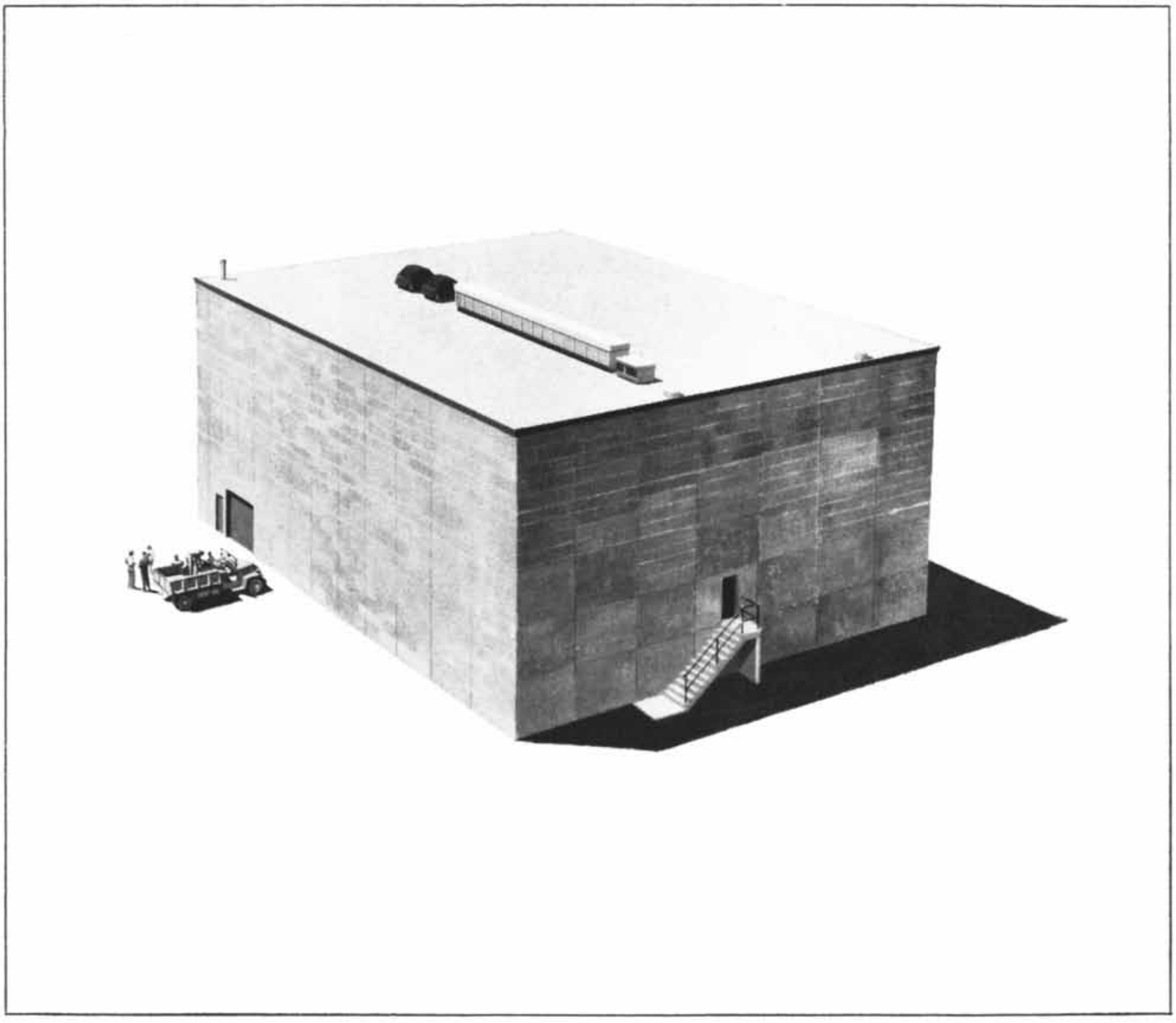

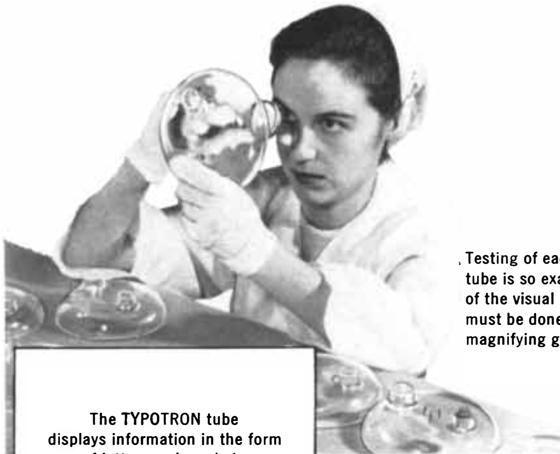

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MATHEMATICAL GAMES

About left- and right-handedness, mirror images and kindred matters

by Martin Gardner

The recent discovery that fundamental particles of physics have a left-and-right "handedness" [see "The Overthrow of Parity," by Philip Morrison; SCIENTIFIC AMERICAN, April, 1957] opens new continents of thought. Do all the fundamental particles in the universe have the same handedness? Will nature's ambidexterity someday be restored by the discovery that some galaxies are composed of antimatter—matter made up of particles that "go the other way," as Alice described the objects in her looking glass? Perhaps we can better understand these speculations if we approach them in a playful spirit.

Mirror reflections are so much a part of daily life that we feel we understand them thoroughly. Most people are nonetheless at a loss for words when they are asked: "Why does a mirror reverse left and right and not up and down?" The question is made more confusing by the fact that it is easy to construct mirrors that do not reverse left and right at all. Plato in his *Timaeus* and Lucretius in *On the Nature of Things* describe one such mirror, made by bending a rectangle of polished metal into the slightly concave form shown in the middle illustration below. If you look into such a mirror you will see your face as others see it. The reflection of a page of type may similarly be read without difficulty.

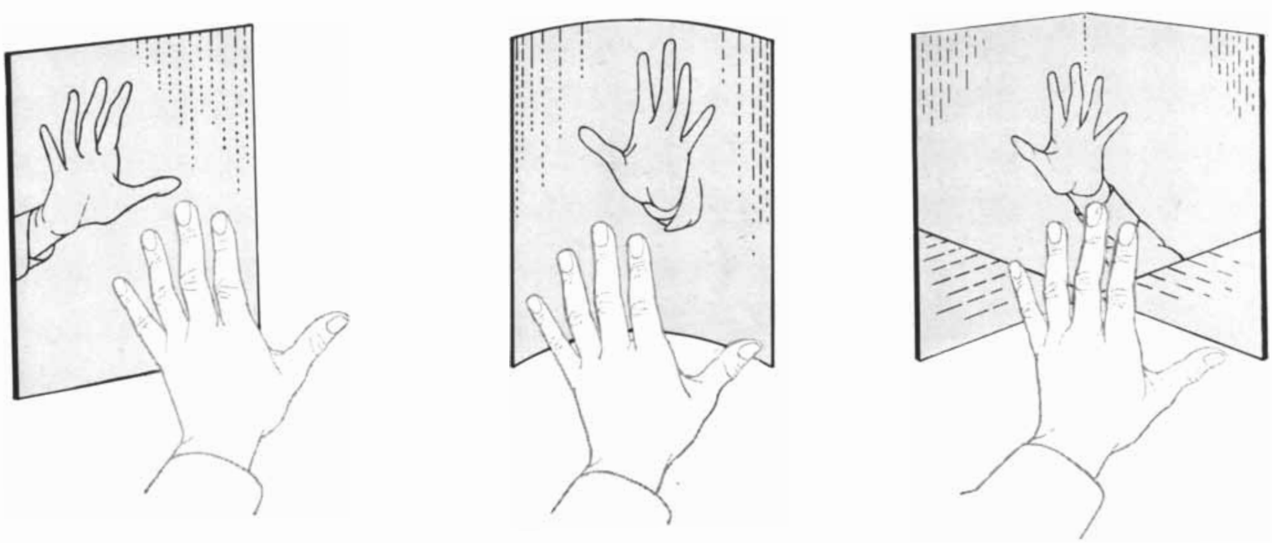
An even simpler way to make a mirror that does not reverse images is to place two mirrors, preferably without frames, at right angles to each other as shown in the illustration at right below. If you rotate this mirror (as well as the one described earlier) through 90 degrees, what happens to the image of your face? It turns upside down.

A symmetrical structure is one which remains unchanged when it is reflected in an ordinary mirror. It can be superposed on its mirror-image, where asymmetric structures cannot. The twin forms of all asymmetric objects are often distinguished by calling one "right" and the other "left." No amount of inspection or measurement of one will disclose a property not possessed by the other, yet the two are quite different. This sorely puzzled Immanuel Kant. "What can more resemble my hand," he wrote, "and be in all points more like, than its image in the looking glass? And yet I cannot put such a hand as I see in the glass in the place of its original."

This curious duality is found in structures with any number of dimensions, including those with more than three. A segment of a straight line, for example, is symmetrical along its one dimension; but if we consider a long segment followed by a short one, the pattern is asymmetric. Mirrored by a point on the linear dimension it becomes a short segment followed by a long one. If we think of printed words as symbols ordered in one dimension, then most words are asymmetric, though there are palindromic words like "radar" which read the same both ways. There are even palindromic sentences: "Draw pupil's lip upward"; Napoleon's fancied statement, "Able was I ere I saw Elba"; and Adam's first remark, "Madam, I'm Adam" (to which Eve appropriately replied, "Eve").

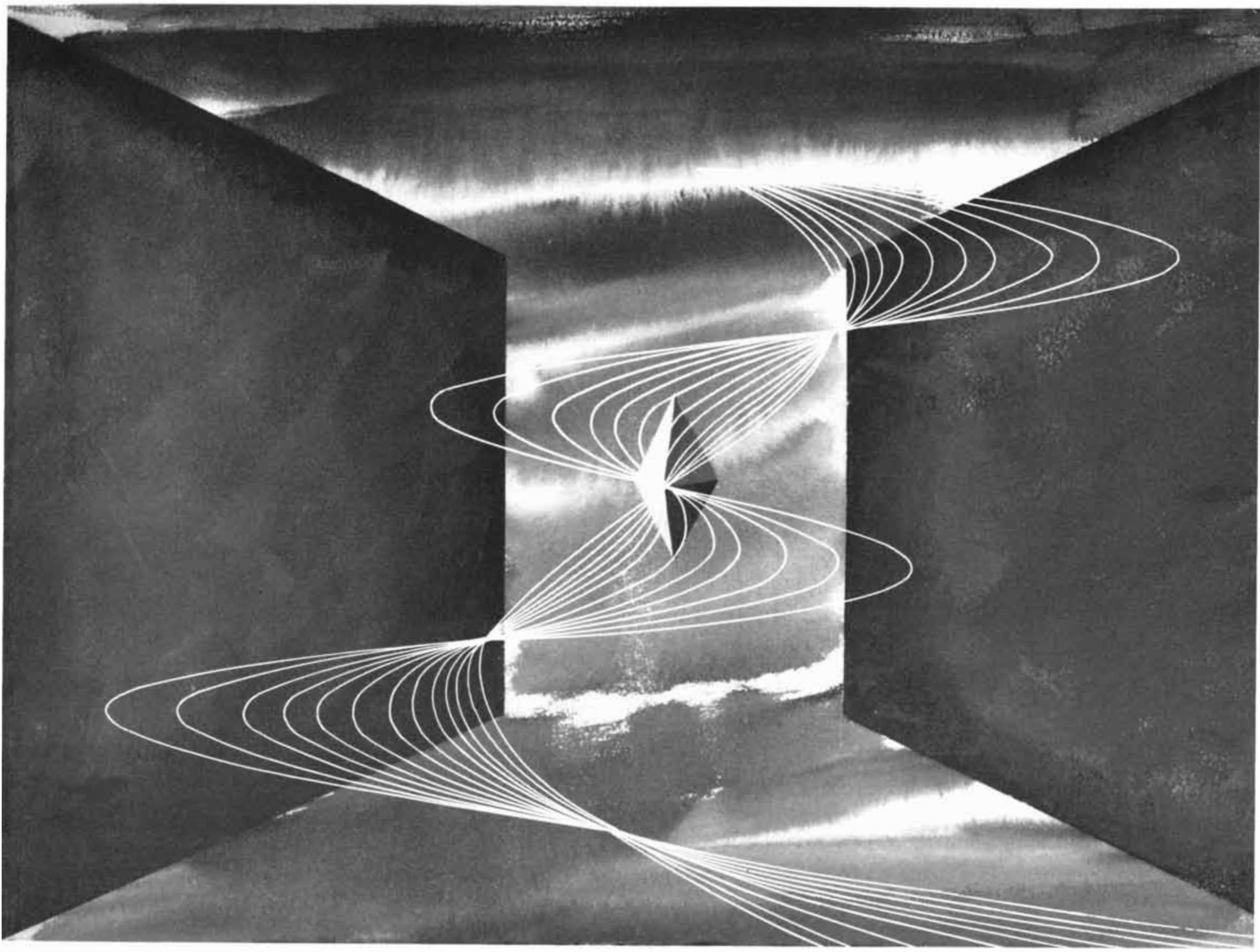
Melodies may similarly be regarded as tones ordered along the single dimension of time. During the 15th century it was fashionable to construct palindromic canons in which the imitating melody was the other melody backward. Many composers (including Haydn, Bach, Beethoven, Hindemith and Schönberg) have used the device for contrapuntal effects. Most melodies, however, grate on the ear in retrograde form.

Many amusing experiments in musical reflection can be performed with a tape recorder. Piano music played backward sounds like organ music because each tone begins faintly and swells in volume. Particularly weird effects may be obtained by playing music backward inside an echo chamber while recording it on another tape. When the second



An ordinary mirror and its image (left) *and two mirrors whose images are not reversed* (center and right)

REPORT FROM IBM YORKTOWN RESEARCH CENTER, NEW YORK



An inquiry into anisotropy

Magnetocrystalline anisotropy *or the variation of magnetic energy as a function of the direction of magnetization in a crystal,* is the subject of careful study at IBM Yorktown Research Center. Currently, the investigation of this property of magnetic crystals has been greatly furthered by an apparatus developed at IBM.

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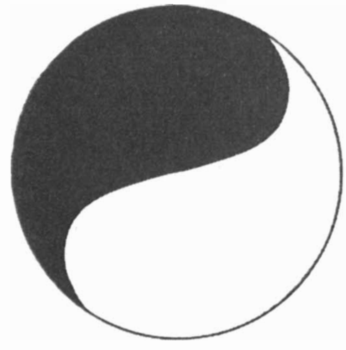


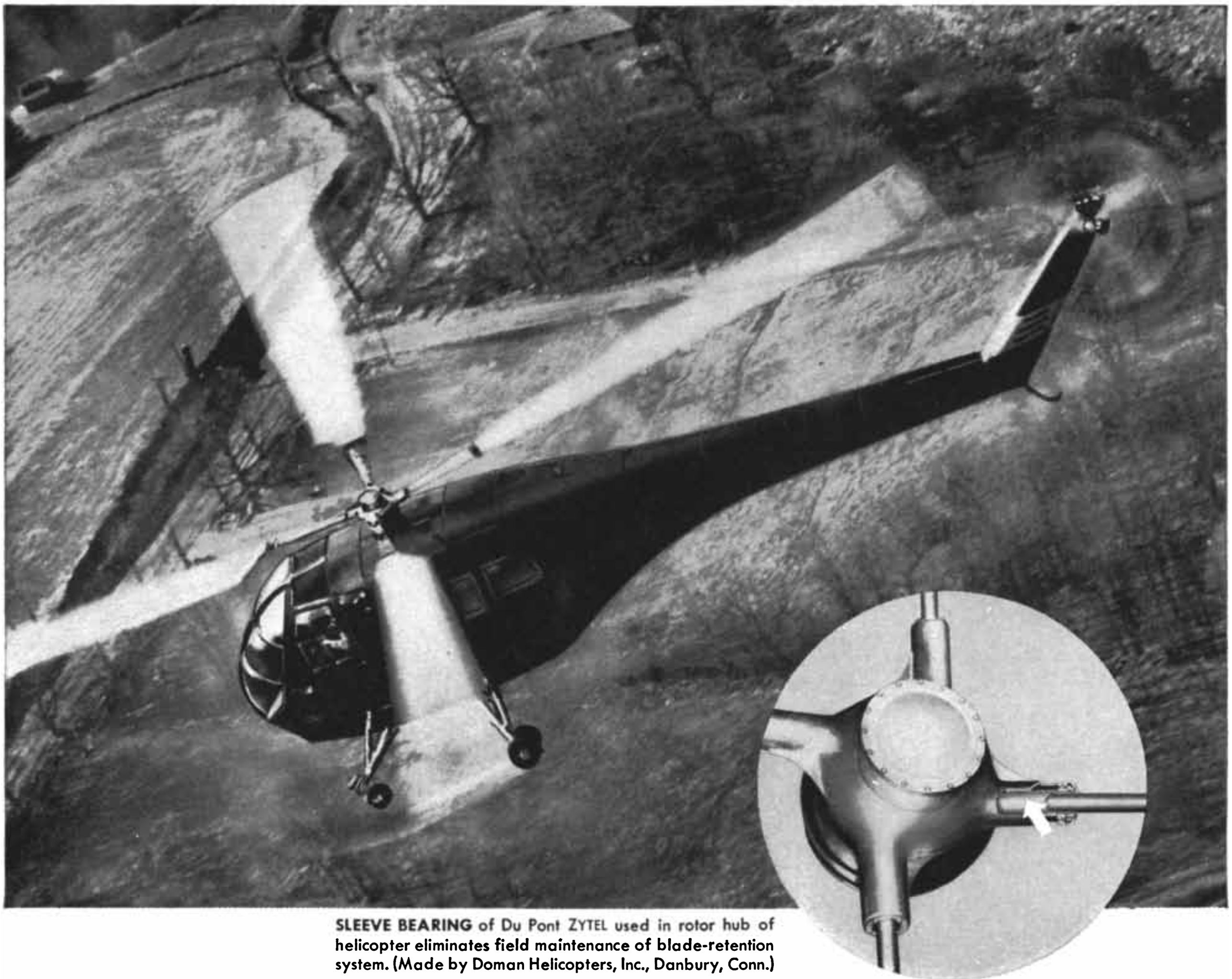
The Chinese monad

tape is reversed, the notes regain their original order but the echoes precede the sounds.

Another type of musical reflection is produced by turning a player-piano roll around so that it plays forward but with high and low notes reversed—the inverted music a pianist would produce if he played in the normal manner on a looking-glass piano. The melody becomes unrecognizable, and there is an unexpected transposition of minor and major keys. This device was also used in Renaissance canons and in the counterpoint of later composers. The classic example is in Bach's *Die Kunst der Fuge,* in which the 12th and 13th fugues may be inverted. Mozart once wrote a canon with a second melody that was the first one both backward and upside down, so that two players could read the same notes from opposite sides of the sheet!

A configuration such as the Christian cross is of course symmetrical in two dimensions. The monad, an ancient Chinese religious symbol [*see illustration above*], is not. The dark and light areas, called Yin and Yang, symbolize all the fundamental dualities, including left-right and its combinatorial basis in even and odd numbers. The monad's pleasing asymmetry makes singularly appropriate the fact that it was two Chinese physicists (one of them named Yang!) who received the Nobel prize last year for their theoretical work which led to the overthrow of parity. Unlike music, all asymmetrical designs and pictures can be "flopped" (to use the graphic-arts term for "reflected") without losing esthetic value. In fact, Rembrandt once made a flopped etching of his famous *Descent from the Cross.*

Because most printed words form asymmetric patterns, reflections of printed matter are usually unreadable, but not always. If you look at a mirror reflection of the words "CHOICE QUALITY" on the side of a Camel-cigarette package, holding the pack so that its top points to your right, you will be startled



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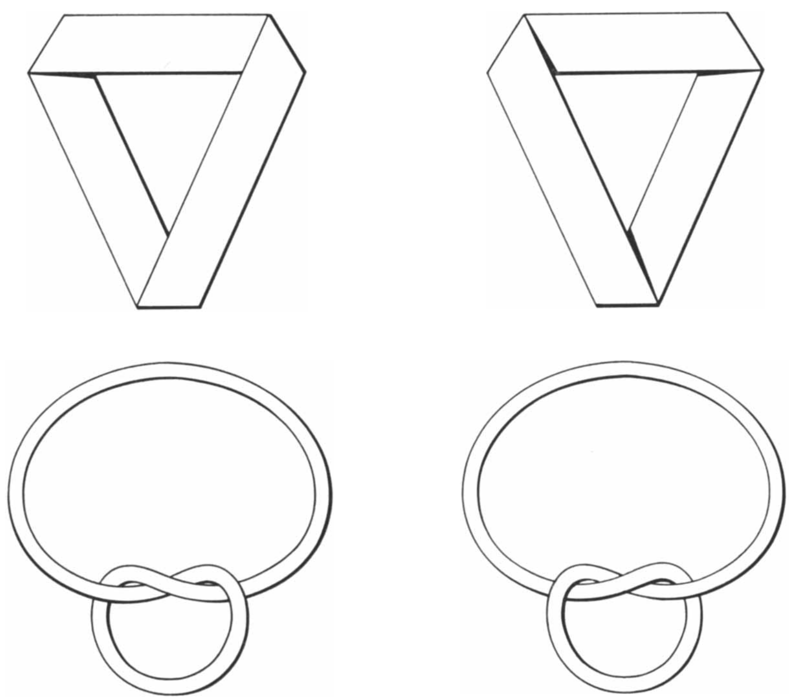
When we consider familiar structures of three dimensions, we find that they are a pleasing mixture of symmetry and asymmetry. Most living forms are symmetrical in their outward appearance, with such notable exceptions as spiral shells, the pincers of the lobster, the crossed bills of the crossbill and the unilateral eyes of flatfish. Even behavior patterns are sometimes asymmetric; for example, the counter-clockwise gyrations of bats swarming out of Carlsbad Caverns. Most man-made objects are likewise symmetrical, though some that seem to be so prove to be asymmetric when inspected more closely—for instance, scissors, Moebius strips, hexaflexagons and simple overhand knots. The two knots in the illustration below have identical topological properties, yet one cannot be deformed into the other. Dice also have two distinct forms. There are two ways of placing spots on a die's faces so that the spots on opposite sides always total seven; one way is a mirror image of the other.

Since folding your arms is the same as tying them in an overhand knot, it follows that there are two distinct ways to fold arms, though we are all so conditioned to one method that it is annoyingly difficult to execute its mirror twin. Fold your arms as you normally do, grasp the two ends of a string, unfold your arms, and you will transfer the knot from your arms to the string. Repeat the experiment with your arms folded the other way and you get a knot that is a reflection of the first one. A fascinating (and unsolved) topological problem is to prove that a pair of mirror-image knots in a closed curve cannot be made to cancel each other by deforming the curve. No one has succeeded in doing it, though it is easy to push one knot into the other and form a square knot, which is symmetrical. If you do this with two knots of the same handedness, you get an asymmetric granny.

These are not trivial matters. Now that certain particles are known to be asymmetric in some as-yet-unknown spatial sense, physical theory will have to account for the fact that when a particle meets its antiparticle, the two annihilate each other and create symmetrical energy. Alice looked into her mirror and wondered if looking-glass milk was good to drink. For some time it has been known that such milk would not be digested, because the enzymes of the body, designed to act on left-handed molecules, could not cope with right-handed ones. Now it would seem that the situation might be a good deal worse. If Alice tried to drink the mirror-image milk, there might be a violent explosion as left- and right-handed particles annihilated each other. It is safe to predict that we will be speculating right and left for a long time to come.



Left- and right-handed knots (bottom) *and their equivalents in Moebius strips* (top)

THE AMATEUR SCIENTIST

How to cultivate harmless bacteria and perform experiments with them

Conducted by C. L. Stong

One of the most active fields of experimental biology deals with organisms that are too small to see. Yet microbiology attracts few amateur experimenters. The reasons are doubtless that experiments with microorganisms seem to require advanced techniques and elaborate apparatus, and even to involve the risk of dangerous infection. Actually the amateur can perform rewarding microbiological experiments with modest equipment and, given simple precautions, with a high degree of safety.

The cultivation of microorganisms resembles farming in miniature. The soil in which the organisms are grown consists of nutrient solutions or jellies; the climate is provided by artificial means. By manipulating this environment the characteristics of a microorganism can be sharply defined. The experiment described here demonstrates how certain bacteria are affected by bacteriostatic agents. It is presented by Robert Lawrence and Henry Soloway, students in the College of Medicine of the State University of New York.

"The experiment," they write, "is designed to demonstrate how certain drugs retard the growth of selected bacteria. Such drugs are called bacteriostatic.

"In testing such substances one first cultivates a selected bacterium in an environment which encourages its growth, subjects it to the bacteriostatic agent and then measures the result. Bacteria, like other forms of life, have preferences in foods, temperature, moisture and so on. Hence no universal culture medium, in which all organisms thrive equally, has been developed. Media must be compounded according to the preferences of the bacteria under study. However, one medium in which some thousands of organisms thrive consists of beef broth, the familiar consommé of the dinner table, which has been refined and specially treated. It is used both in liquid form and, when thickened by the addition of agar, as a stiff jelly.

"As in ordinary farming, 'weeds' must be kept down. One is often interested in the characteristics of a single species of bacterium, and since the size of the organism makes 'weeding' impractical, intruders must be prevented from gaining a foothold in the first place. This is accomplished by killing all microscopic life in the environment of the experiment except the desired organism. The culture medium and all equipment is sterilized, exposed only to sterilized air and otherwise kept scrupulously aseptic during the experiment.

"These conditions can be maintained if the amateur provides himself with an aseptic transfer chamber in which all critical operations are performed. This can be a simple wooden box two feet high, two feet wide and three feet long. It is fitted with a glass top, a small door and a pair of holes in one side large enough to admit the hands and forearms comfortably. The cracks should be calked with cotton or sealing compound. A short pair of muslin sleeves may be tacked around the holes to serve as barriers against the outside air. Inside the box one should place, among other things, an alcohol lamp or Bunsen burner, and a small atomizer of the nose-spray type containing Lysol or Clorox.

"Glassware should include two dozen Petri dishes, which have flat bottoms about four inches in diameter, sides about half an inch high, and are fitted with covers. The experimenter will also need three Erlenmeyer flasks of one-liter capacity and half a dozen of the quarter-liter size, a half-dozen test tubes of 20-milliliter capacity and a rack for supporting them, a dozen one-milliliter pipettes and a special rubber bulb or syringe for filling them, a 50-milliliter graduated cylinder, a wax pencil for marking the glassware, a dissecting needle fitted to a pencil-sized wooden holder, a small loop of thin wire fitted to a similar handle, a glass stirring rod about eight inches long, and a pair of tweezers. All these things should be assembled, together with the special wooden box or transfer chamber, on a substantial bench located where the materials will not be disturbed.

"All the materials are then sterilized. Petri dishes and pipettes are tightly wrapped in lots of six in brown paper. Larger items are wrapped individually. Test tubes and Erlenmeyer flasks may be plugged with wads of absorbent cotton instead of being wrapped in brown paper. The glassware is then placed in an oven and heated to 325 degrees Fahrenheit for at least two hours. None of the packages should be opened nor the cotton removed until the glassware is used.

"Dehydrated culture medium, both plain and in the form of an agar infusion, may be purchased from the Difco Laboratories, Detroit, Mich., or from the Baltimore Biological Laboratory, Baltimore, Md. A principal object of the experiment, however, is to provide the amateur with experience in the basic techniques of culturing bacteria. The beginner is therefore urged to prepare his own culture medium.

"Stir a pound of freshly ground hamburger into a liter of distilled water and put it in the icebox (at about 40 degrees F.) for 10 hours. Then skim off the fat which rises to the top and filter the remaining liquor through a single thickness of clean muslin. Add distilled water to bring the liquor back to a full liter, then add five grams of peptone and five grams of ordinary table salt and stir until the salt is dissolved. Pour 50 milliliters into a second flask and set it aside. Then add 15 grams of agar to the 950-milliliter portion.

"Bacteria, like other organisms, are sensitive to the acid-base balance of the medium in which they grow. Those grown in this experiment prefer a neutral medium. The two solutions just prepared will be slightly acid; they must accordingly be adjusted to neutrality (pH 7) by adding precisely enough sodium hydroxide to counteract the acid. Mix 10 grams of sodium hydroxide in a liter of distilled water. Test the beef broth with a piece of blue litmus paper. An acid broth will turn the blue paper red. The sodium-hydroxide solution will turn red litmus blue. Add a drop or two of sodium hydroxide to the liquor, stir, and with the glass rod put a drop of the solution on a piece of blue litmus. The paper in contact with the drop will probably turn pink. Add more sodium hydroxide to the liquor and test again. Continue this until the test drop causes no change in the color of either red or blue litmus.

"Each container of liquor is then heated almost to 212 degrees F. for half an hour. This will precipitate the proteins in the liquor. The proteins are removed by passing the hot liquor through coarse filter paper. Each filtrate is again brought up to volume by adding distilled water.

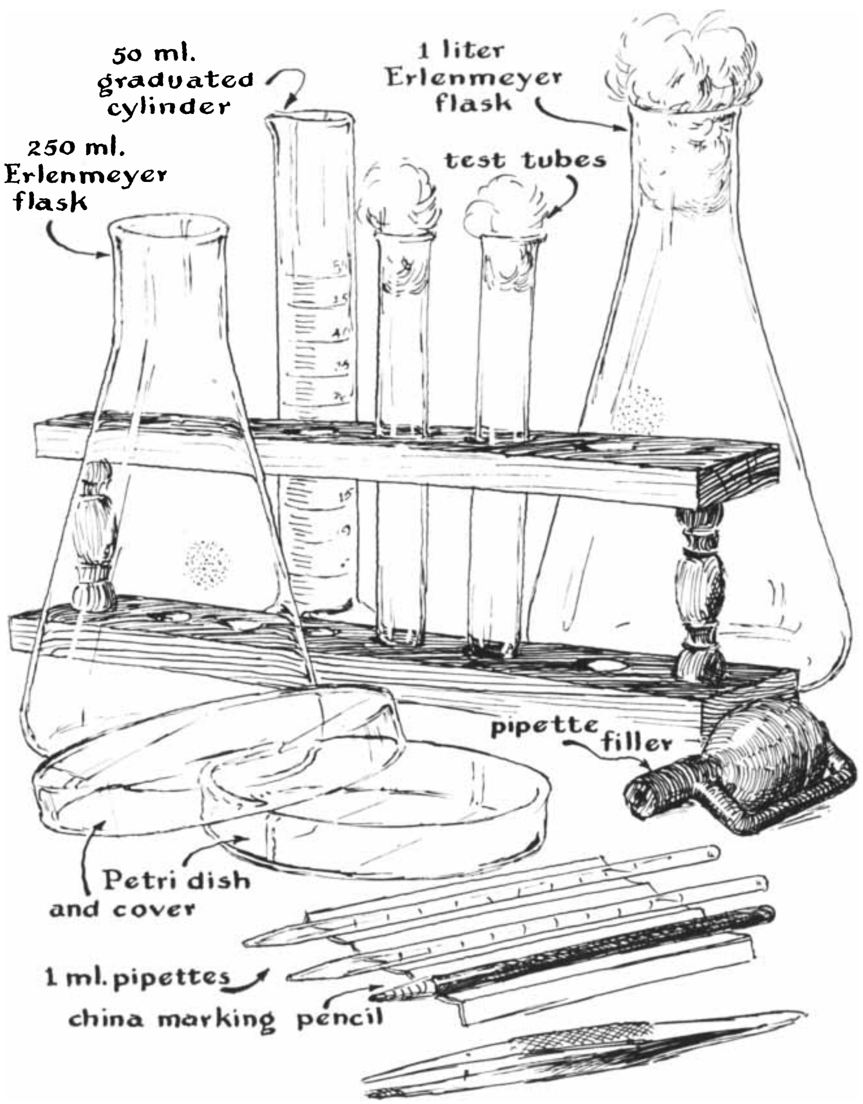
"One hundred milliliters of the hot agar medium are poured into each of six Erlenmeyer flasks, which are then stoppered with wads of absorbent cotton. Five milliliters of the liquor containing no agar are poured into each of 10 test tubes, which are similarly stoppered.

"The media are now sterilized. The containers may be placed in boiling water for half an hour on each of three successive days. They may alternatively be sterilized in a pressure cooker. Put the containers inside the cooker, add two inches of water and pressure-cook for 20 minutes. Be sure to cool the cooker slowly. Rushing the job by quenching the cooker with cold water will cause the internal pressure to drop suddenly and the vessels of hot medium to boil over. Stoppered tubes of tap water and other solutions may be sterilized by either of these methods.

"Any nonpathogenic strain of bacteria may be employed for the demonstration of bacteriostasis. *Micrococcus pyogenes* var. *albus, Proteus vulgaris* or *Alcaligenes faecalis* can be used in the experiment and may be purchased at low cost from the American Type Culture Collection, 2112 M Street, N.W., Washington 6, D.C. Amateurs may wonder why one should go to the expense of buying bacteria if they are plentiful in the air. You can, of course, grow your own simply by exposing a quantity of the culture medium to the air and incubating it for 24 hours. Let us emphasize that this is both pointless and extremely dangerous. It is pointless because the average amateur has no means of identifying the microbes he has caught. It is dangerous because he is likely to capture and cultivate deadly disease organisms. Incidentally, media that have been used should be sterilized and discarded immediately. Otherwise the experimenter runs a serious health risk. The strains recommended are inoffensive and have the further advantage of being accessible to all workers. Results of experiments may accordingly be compared. Purchased cultures can be perpetuated indefinitely by keeping them in beef broth at room temperature and inoculating a fresh tube of medium (by putting a drop of the old culture into it) every other day. If the culture can be stored at 40 degrees F., the growth of the bacteria is slowed and new media need be inoculated only once every six days.

"To perform the bacteriostasis experiment, first place a test tube of sterile beef broth, the tube containing the flourishing culture, and the wire loop inside the transfer chamber. The chamber is sprayed thoroughly with germicide and the droplets are allowed to settle for five minutes. The alcohol lamp or Bunsen burner is lit and the wire loop heated to redness as far as the handle. Hold both test tubes obliquely in the left hand and the sterile wire loop in the right. Remove both cotton plugs from the tubes with the last two fingers of the right hand. The mouths of both tubes are passed slowly through the flame. The wire loop is then dipped into the flourishing culture for about a second, withdrawn and inserted into the tube containing the sterile broth. Both cotton plugs are replaced and the wire loop is again sterilized by heating to redness. To avoid contaminating the pure culture the beginner should run through these operations with empty tubes a few times for practice.

"The freshly inoculated tube is per-

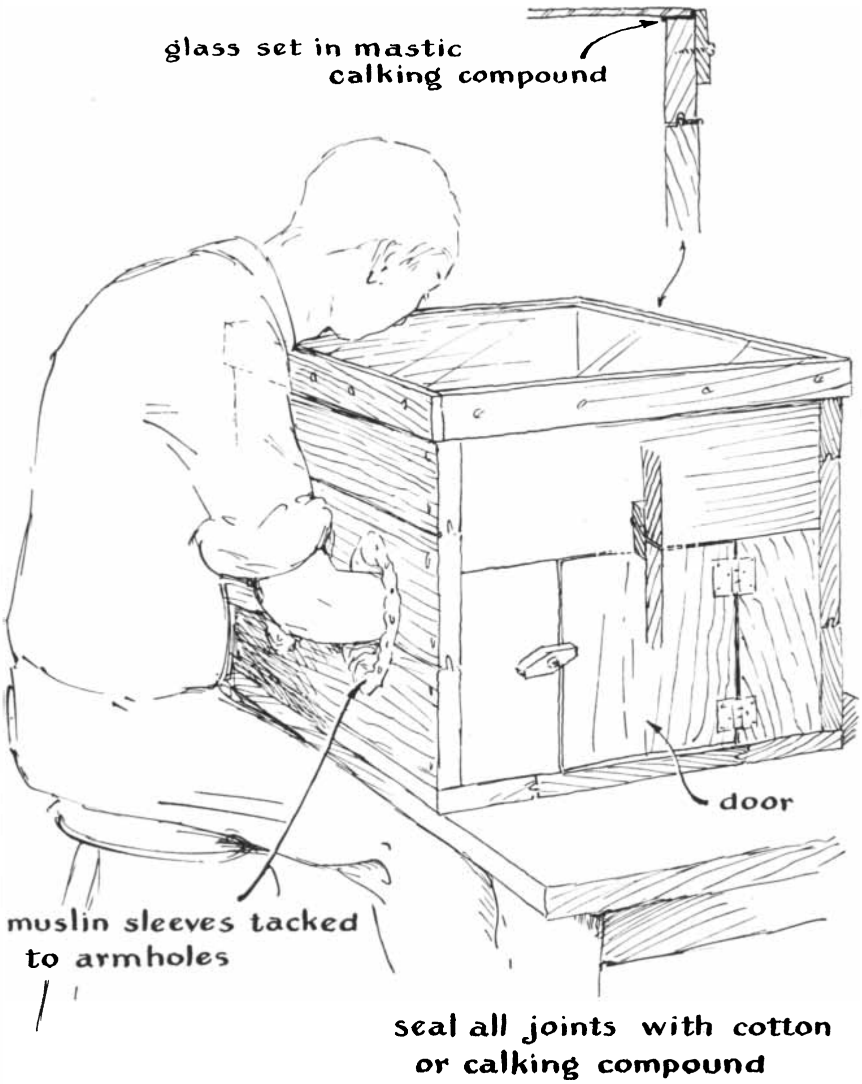


Glassware and other materials required for experiments with bacteria mitted to incubate for two hours at room temperature and is then stored at 40 degrees F. At the end of 24 hours the tube is swirled in front of a light. The presence of sediment indicates that the inoculation has 'taken.' The purchased culture may then be sterilized and discarded. If at the end of 24 hours there is no sediment, the procedure should be repeated. It is useless to wait another 24 hours.

"Antibiotics for diagnostic purposes may be procured in sterile containers with the trade name of Dia-Discs. They are manufactured by Reed and Carnrick of Jersey City, N.J. The assortment includes pellets of penicillin, bacitracin, streptomycin, Chloromycetin, Aureomycin and Terramycin in two strengths, the stronger having 10 times the potency of the weaker.

"The bacteriostasis test consists in exposing a series of increasingly concentrated cultures of bacteria growing on plates of agar medium to the action of the drugs. A duplicate set of plates is used as a control for detecting contamination. Begin the experiment by placing the following materials in the sterile transfer chamber: (1) a liter of sterilized tap water, (2) two packages of sterile Petri dishes, (3) a dozen sterilized one-milliliter pipettes and the sterilized rubber squeeze bulb, (4) a water bath heated to 112 degrees F. in which has been placed six Erlenmeyer flasks of agar medium, (5) a test-tube rack containing six test tubes, (6), the wax pencil and (7) an open bowl of germicide.

"The packaged glassware is opened and the cotton stoppers removed from the culture and test tubes. A small tuft of sterilized cotton is placed in the neck of each pipette. Nine milliliters of sterile tap water are poured into each of the six test tubes. The following operations are then carefully performed, each piece of



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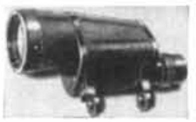

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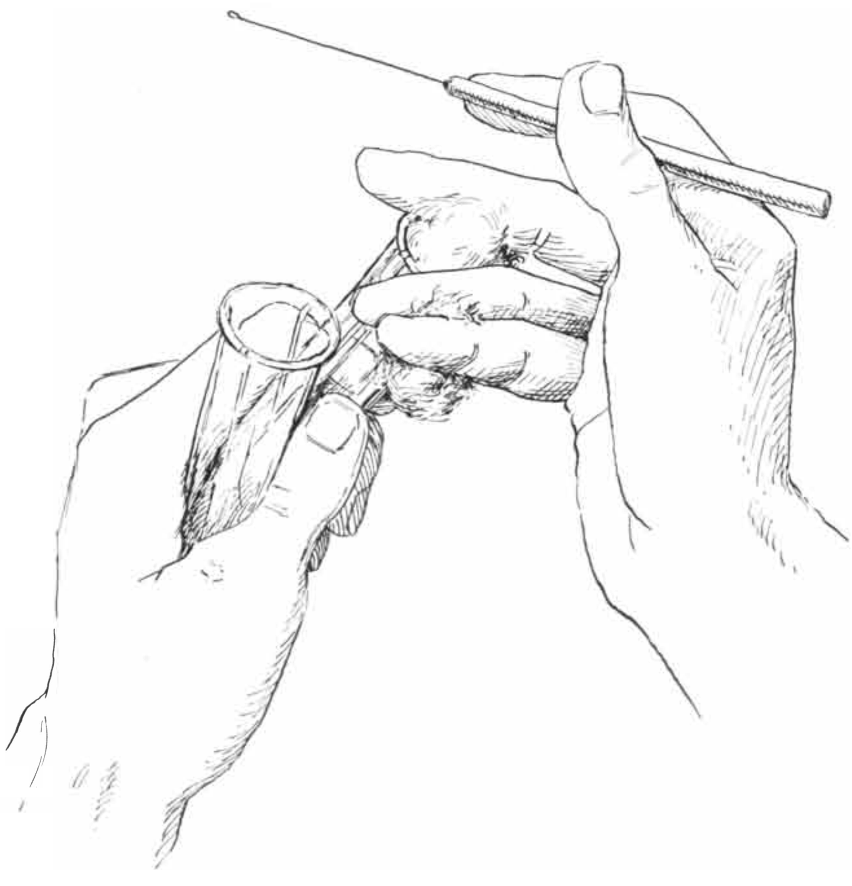
glassware being labeled or coded as it is used. Fit the squeeze bulb to a pipette and with it transfer one milliliter of the culture to a test tube of tap water. This tube is labeled 1:10, indicating that it contains one part of culture in 10 by volume. The tube is swirled for 30 seconds to assure thorough mixing. Remove the squeeze bulb from the pipette and drop the used pipette in the bowl of germicide. Select another sterile pipette and transfer one milliliter of the 1:10 mixture to a tube of tap water. Mark this tube 1:100. Again swirl the 1:100 mixture for 30 seconds, drop the used pipette into the germicide and with another sterile pipette transfer one milliliter of the 1:100 mixture to the third tube of tap water. Mark this tube 1:1,000 and proceed in the same way with the remaining tubes, labeling them 1:10,000, 1:100,000 and 1:1,000,000.

"A specimen of melted agar medium is now poured from each of the six Erlenmeyer flasks into six Petri dishes, each dish being labeled to correspond with the flask from which it is poured. The dishes are then covered with their glass tops and set aside to harden. After these control plates have been poured, each batch of melted medium remaining in the flasks is inoculated with one of the dilutions in the test tubes. Pipette one milliliter of the dilution into the appropriately labeled flask. Drop the used pipette into the bowl of germicide. The flasks are stoppered with cotton and swirled gently for 30 seconds to mix their contents. The water dilutions are sterilized and discarded.

"The control plates are incubated two days at 80 degrees F. The transfer box can be made to double as an incubator by fitting it with a 100-watt bulb controlled by a thermostat of the type used in tropical-fish aquariums.

"Twelve Petri dishes, the Dia-Discs and a pair of forceps are next introduced into the transfer chamber. The chamber is sterilized as before. Two Petri dishes are then filled from each of the six inoculated flasks, each pair being labeled to show the culture dilution. The dishes are permitted to stand for about 20 minutes until the agar solidifies. The forceps are then passed through the flame, the box of Dia-Discs opened and the discs placed carefully on the agar medium by means of the forceps. The weaker discs are placed on one plate of the pair and the stronger on the other. One way to keep track of the discs is to draw a radius



How to hold test tubes while transferring bacterial cultures with a wire loop

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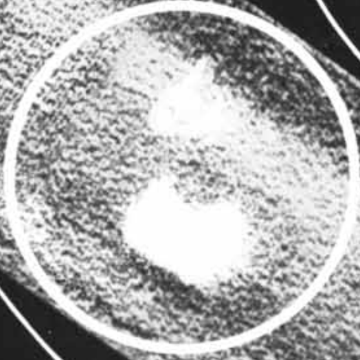
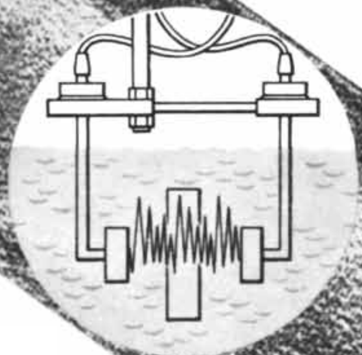


NUCLEAR REACTOR TECHNOLOGY
demands precise, reliable procedures for testing fuel elements. The ultrasonic system developed at Argonne is typical of the advancements being made in this field.



In the ultrasonic scanning and recording system developed at Argonne, pulsed energy in the megacycle range is transmitted through reactor fuel elements to reveal bond defects and other internal faults. Two piezoelectric transducers mounted on an automatic scanner traverse across and along each fuel plate. An electrosensitive paper recorder is used to make a permanent two-dimensional record of changes in the transmitted ultrasonic energy. At Argonne, over a thousand fuel plates for the Experimental Boiling Water Reactor were tested by this method in an average time of 12 minutes each. Some firms that manufacture fuel elements commercially now use this system to insure quality.

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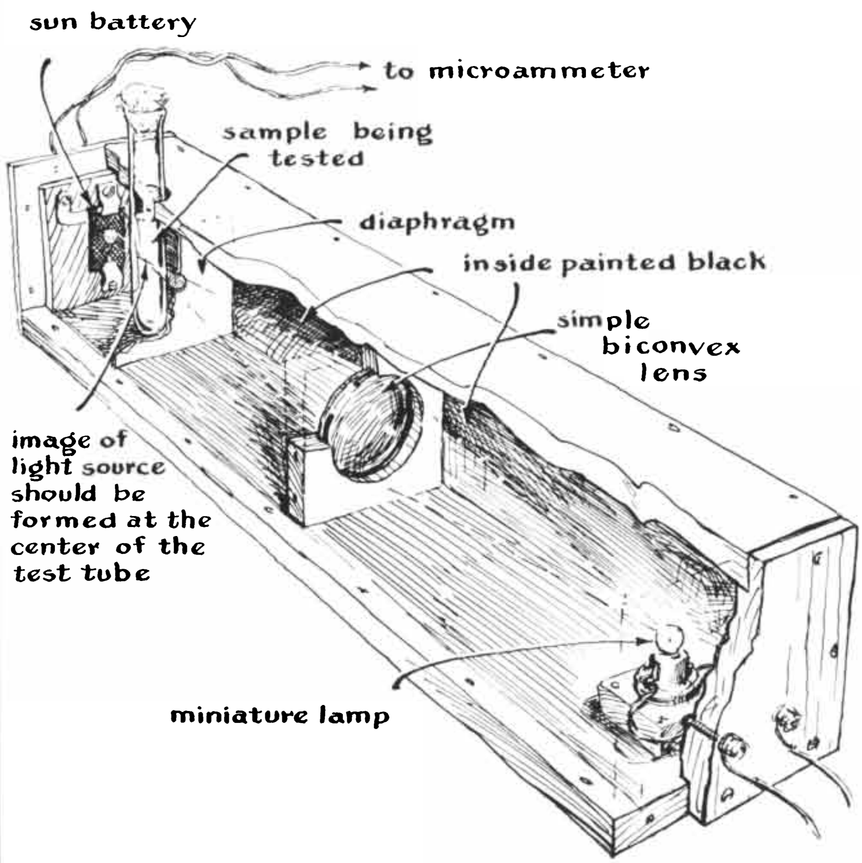
on the back of each Petri dish with the wax pencil. The disc of Aureomycin is then placed on this line. All other discs are placed alphabetically, according to the name of the drug, in a clockwise circle. Crowding should be avoided; if space is limited, the last disc can be placed in the center of the plate. Covers are then placed on the dishes, and the culture is left to incubate for two days at 80 degrees F.

"The effects of the several drugs on the various concentrations of bacteria are then evaluated by observing the growth on the plates and the diameter of the rings around each drug where growth has been inhibited. The larger the ring, the greater the bacteriostasis. The results may be tabulated by using a minus sign to indicate no growth, a plus-and-minus sign for minimum inhibition, a plus sign for marked inhibition and two plus signs for extreme inhibition. Any growth on the control plates indicates contamination and invalidates the experiment. The test plates should be reread after four days of incubation, then sterilized and discarded.

"An interesting modification of the test permits the experimenter to chart the effect of the drugs with respect to time. Thus he can study the interval following inoculation at which each antibiotic exerts its greatest action, and the rate, if any, at which it loses its effect. This requires the construction of a relatively simple light-meter capable of reading the relative transmission of light through a test tube. Bacterial growth in beef broth increases the turbidity of the broth and reduces its transparency. When the broth is placed in a test tube its turbidity—and hence its population of bacteria—can be measured by the light-meter. The device consists of a lamp and lens for focusing a beam on the side of a test tube, a photocell on the other side of the tube for receiving the transmitted light, and a microammeter for reading the output of the cell. The light source, lens assembly, test tube and photocell are mounted in an appropriately compartmented and light-tight box [*see illustration below*].

"Here the operations are conducted in test tubes rather than agar. A tablet of antibiotic is dissolved in 10 milliliters of sterile tap water (in the aseptic transfer chamber). Dilutions of this solution are prepared as before, so that six dilutions span the range from 1:10 to 1:1,000,000. Observe that in this case it is the drugs, not the cultures, which are diluted. One milliliter of each of the dilu-



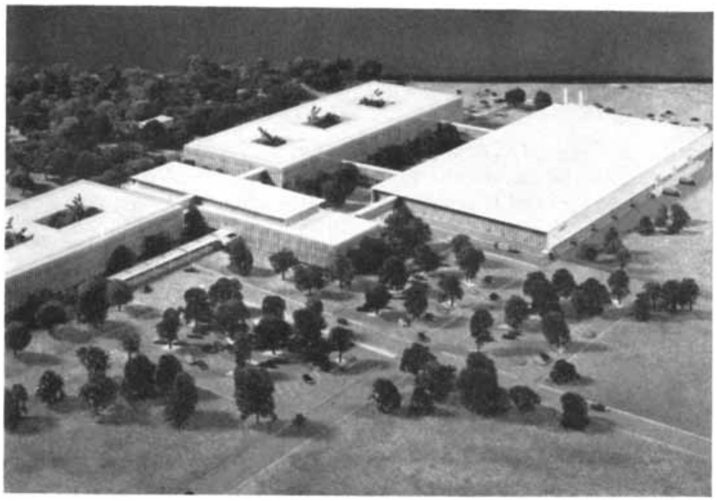
A homemade light-meter for measuring the density of a bacterial culture

tions is added to a sterile test tube which contains four milliliters of beef broth. The tubes are then inoculated with one loop of bacteria from a two-day-old beef-broth culture and left to incubate at 80 degrees F. At equal intervals during the incubation, say every three hours, the tubes are gently swirled and their turbidity is measured by means of the light-meter. Turbidity is then plotted against time. The result is a set of graphs showing bacteriostatic activity. The test tubes should be inspected for optical uniformity by means of the light-meter before they are used. Professional light-measuring instruments used for this test are usually calibrated in accordance with Beer's law, which states that, for solutions of a given substance in a given solvent, light will be absorbed in proportion to the thickness of the solutions. Graphs made with instruments calibrated arbitrarily will show accurate rates of bacteriostatic effect, although the curves will not necessarily conform to those drawn with the aid of professional instruments. Tests which employ light-measuring devices can have great practical value because they show which antibiotic can be employed most effectively against a bacterium about which no data has been collected. They also disclose whether a known bacterial strain has mutated to become more resistant to a given drug.

"In the course of experiments employing plates of agar medium one may occasionally observe a small colony flourishing within the circle of inhibition. The chances are that this is a contaminant. There is always the possibility, however, that the organism is a mutant, a new strain which has been naturally selected over the original strain susceptible to the drug. All such unusual colonies should be isolated and cultured. (A portion of the colony is lifted from the plate with the tip of the dissection needle and transferred to fresh medium for incubation.) Tests can then be performed to learn if it is in fact a mutant or merely a contaminant.

"Radiation is known to increase the mutation rate of all living organisms; thus it is possible to develop new strains by exposing cultures to X-rays. The homemade X-ray machine described in this department by Harry Simons ["The Amateur Scientist," July, 1956] is capable of inducing such mutations. The experimenter is cautioned, however, to avoid exposure to the X-rays. The culture should be placed in front of the tube and the machine operated by remote control from behind a shield, as suggested by Simons."

Dennis W. Holdsworth



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IDEALS AND PRACTICALITY

"Science and Philosophy mutually criticize each other and provide imaginative material for each other."... Alfred North Whitehead.

In the increasing preoccupation of science with material things and progress, the truth of this statement by one of our greatest philosophers is often overlooked and forgotten. The scientific philosopher is a rare being and is becoming rarer still, nor can he be adequately replaced by the group technique or the 'brainstorm' session.

It should be one of the noblest aspirations of all our sciences to provide for the true contemplation of the inner meaning of facts and to stimulate that interplay of mind on mind by which alone we may progress.

In all these things, however, we cannot forget the problems peculiar to research and development in private industry. The obligation to work to otherwise-determined time-scales poses a nice problem in balancing ideals against the practicalities of everyday life.

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D.W. Holdsworth

Dennis W. Holdsworth,
Manager, Computer and Electronic Systems Department

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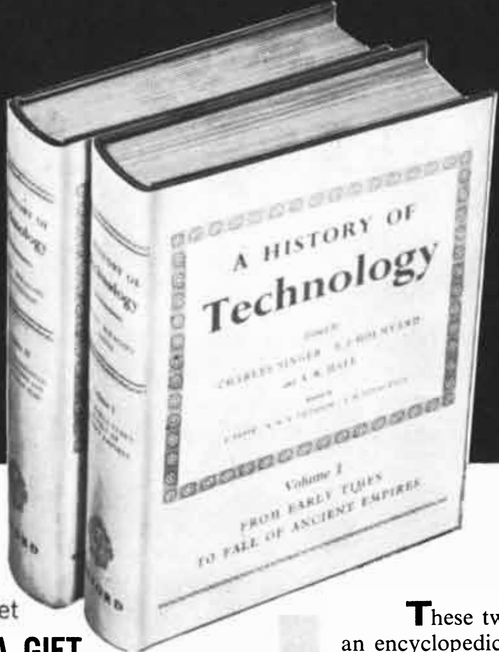

A HISTORY OF
Technology

BOOKS

An Australian symposium on war as a disease of societies

by James R. Newman

PATHS TO PEACE: A STUDY OF WAR, ITS CAUSES AND PREVENTION, edited by Victor H. Wallace. Cambridge University Press ($3.75).

War is much too serious a thing to be left to the human race. Talleyrand was against leaving war to the military, which was sensible, but he could not have been expected to foresee the evil day when it might have to be renounced altogether. The globe is now too small; the weapons are too large; man is too frail. And reason itself, as George Santayana once wrote, has abdicated in a world which is "the sport of cruder powers."

It is often said that men desire peace but don't know how to get it. If they expended a modest effort on studying the causes of war they might learn. The preamble to the United Nations Charter opens with the words: "We the peoples of the United Nations determined to save succeeding generations from the scourge of war," but in the last dozen years no notable progress has been made in furthering this determination. Future generations may be spared simply by not arising. The fact is that people do not always believe what they profess to believe. It is not true that a great majority of people "passionately believe that war is the worst of all alternatives." When one is not suffering it is hard to imagine suffering, especially if one has never suffered. Men are apt to be entranced by heroic images and caught by phrases. "Better death than dishonor" is a cry of the living; the dead have no opportunity to reconsider. A passage of G. K. Chesterton (in his book *The Flying Inn*) refers to "one of the worst tricks of modern journalism; the trick of dismissing the important part of the question as if it could wait, and appearing to get to business on the unimportant part of it." His illustration is: "Whatever we may think of the rights and wrongs of the vivisection of pauper children, we shall all agree that it should only be done, in any event, by fully qualified practitioners." The same trick is today practiced in discussing war and peace: Whether or not it is true that another war would mean world suicide, we must be prepared to win if war breaks out.

This book presents a different outlook. A symposium edited by the distinguished Australian physician Victor Wallace, it attempts a dispassionate analysis of the causes of war. The assumption is that if we desire peace we must do more than sigh for it; we must gain an understanding of the forces and circumstances which thwart peace. War is a social and economic problem. It is appropriate therefore to solicit the views of those who study the ways of society—historians, investigators of economic conflict, students of cultural patterns and social tensions, of frustration and aggression, of ideologies, of propaganda, of power politics, of population. Wallace has gathered a notable company of many specialists. His contributors are Australian leaders of thought: in law, social studies, diplomacy and politics. Jawaharlal Nehru has written a foreword. It is often a fault of symposia that they are diffuse and repetitious. This work is both, yet it has great value. It contains an impressive set of civilized affirmations. It makes clear as few other books have done the main causes of war, and it exposes misconceptions, misleading analogies, false dogmas and prejudices.

Some ages have obviously been more warlike than others. Our own, says the University of Melbourne historian R. M. Crawford in his introductory essay on the problem of recurrent wars, "bears marked resemblances to the long and troubled age which is commonly taken as the threshold of the modern era, the age which began with Charles VIII's invasion of Italy in 1494 and culminated in the disastrous Thirty Years' War, 1618-1648." In some respects it is also like the much shorter age which saw the wars of the French Revolution and Napoleon. What is to be learned from examining these periods and the intervals between, during which, while the world was not altogether peaceful, warfare was comparatively limited and "considerations of war did not dominate all else"? The Thirty Years' War was exceptionally ferocious. Whole cities were sacked and destroyed, starvation was widespread and there was even cannibalism. A long night of barbarism and misery descended upon a large area of Central Europe. After a time Europeans began to sicken of the slaughter, and slowly established a tradition of limited warfare which no longer required armies to resist to the point of death. But the tradition could be established, says Crawford, only when men came to value peace more than what they had fought for.

In the 18th and 19th centuries it was assumed that, since war was an instrument of policy, annihilation need not be the objective. The foe was not subhuman, some meaning attached to the notion of a community of Europe, and war did not have to invade all spheres of human activity. Thus, for example, intellectual intercourse continued between nations at war. Without hesitation Napoleon granted to Humphry Davy, the distinguished English chemist, a travel permit for himself and his party so that they could visit France and other European countries in 1813, though other Englishmen in France were held prisoner. And when Captain Ross set out in 1839 to explore the Antarctic he carried instructions from the Lord Commissioners of the Admiralty stating that if England should become involved in war during his absence he was "not to commit any hostile act whatever." The Commissioners wrote: "The expedition under your command [is] fitted out for the sole purpose of scientific discoveries, and it [is] the established practice of all civilized nations to consider vessels so employed as exempt from the operations of war."

In ages of unlimited warfare the sense of community has, as Crawford points out, been broken. Deep ideological divisions have led to the abandonment of moderation and the collapse of moral restraints. In the Thirty Years' War the embittering element was religion; in the age of the French Revolution and Napoleon, it was politics; in our own age, it is politics and economics. Two points, however, should be noted. Ideologies have rarely, if ever, ruled the outlook of leaders of government; and an ideology, whatever its form—religious, political or economic—has always in "these ages of savagery" been held as a religious faith by its adherents, and has been able "to inspire a devotion that has frequently extended into fanaticism."

It is easy to find historical examples of strongly held ideological convictions outweighed by self-interest and expediency. Political considerations have usually had more effect on relations between governments than religious faiths, even fighting faiths. It is true that in our age popular education, the multiple channels of communication and the prodigal use of new techniques of propaganda have been singularly successful in whipping up mass feeling. Sometimes they have created waves of passion which restricted the movements of the very governments that set the waves in motion. Nevertheless, even constitutional governments have found it possible to turn popular fears and hatred on and off as the occasion required. Soviet Russia and Nazi Germany suddenly fell into each other's arms and just as suddenly went to war; a common loathing of communism did not make friends of the British Tory Government and Germany, and a bitter ideological cleavage did not prevent the alliance of the Western powers with the U.S.S.R.

The well-buttressed argument that ideological antipathies are brushed aside when national interest seems to require it bears directly upon U. S.-Soviet relations. For political and economic reasons each of these powers considers the other a threat to its security. In discussing the conflict of ideologies P. H. Partridge, professor of social philosophy at the Australian National University, deflates a good deal of nonsense. Between Russia and the U. S. there would be suspicion and tension even if a Czar ruled Russia, the churches were thriving and capitalism were sacred. To be sure, communist ideology differs, as Partridge states, from any other ideology that has been important historically, in embracing doctrines of permanent world revolution and of an inevitable struggle between communism and capitalism. These doctrines are the basis of an ideological split which is a prime source of unrest. But this split is subsidiary to the real clash of interests in many parts of the world.

Why is communism popular in Asia? Not, by any means, because of ideology alone. It is the existence of Russia as a formidable power, as well as the protagonist of world revolution, that attracts adherents. Is it reasonable to consider all communist countries as forming a single bloc? Evidently not, Partridge argues, even though for the time being Russia and China appear to be bound together in what they conceive a common struggle against the West and "capitalism-imperialism." Yet this common ideology is not necessarily a strong or lasting cement, since Russian and Chinese interests do not always run parallel and in time may diverge even more. "It follows from this that if the Western democracies take communism as such to be their enemy, if they base their foreign policies on the postulate that wherever communism is, it is to be resisted or attacked, they will reinforce the binding properties of a common communist ideology."

In Partridge's view it is a mistake to imagine that democracy as an ideology has much appeal in Asian countries and other parts of the world where communism has become a major force. This is not to question the values of democratic institutions and practices, but simply to recognize that there are large areas where the economic and social conditions are unfavorable to democracy, and where its liberal methods and institutions are not adapted for the sort of "revolutionary social surgery" which the masses of people are willing to support to remake their economy and raise their standards of life. Undoubtedly the U. S. has great influence because of her economic resources, and can play a significant part in the transformation of backward and largely peasant societies; but this depends on the actual assistance given rather than on the advocacy of a gradualist democratic model of social change. The Asian countries, Partridge is convinced, will follow the Soviet pattern of revolution.

A psychiatrist, the late Reginald S. Ellery, and a psychologist, O. A. Oeser of the University of Melbourne, examine the relation between human drives and cultural patterns and war. Ellery tackles the "complementary fallacies" that war is rooted in a "human nature" which cannot be changed, and the "soothing notion that so long as a nation remains adequately defended no other nation is likely to make war upon it." The danger in these beliefs, he says, is that they contain beguiling half-truths. Men have been quarreling for a long time, and it is not easy to imagine the elimination of their combative instincts. Moreover, in

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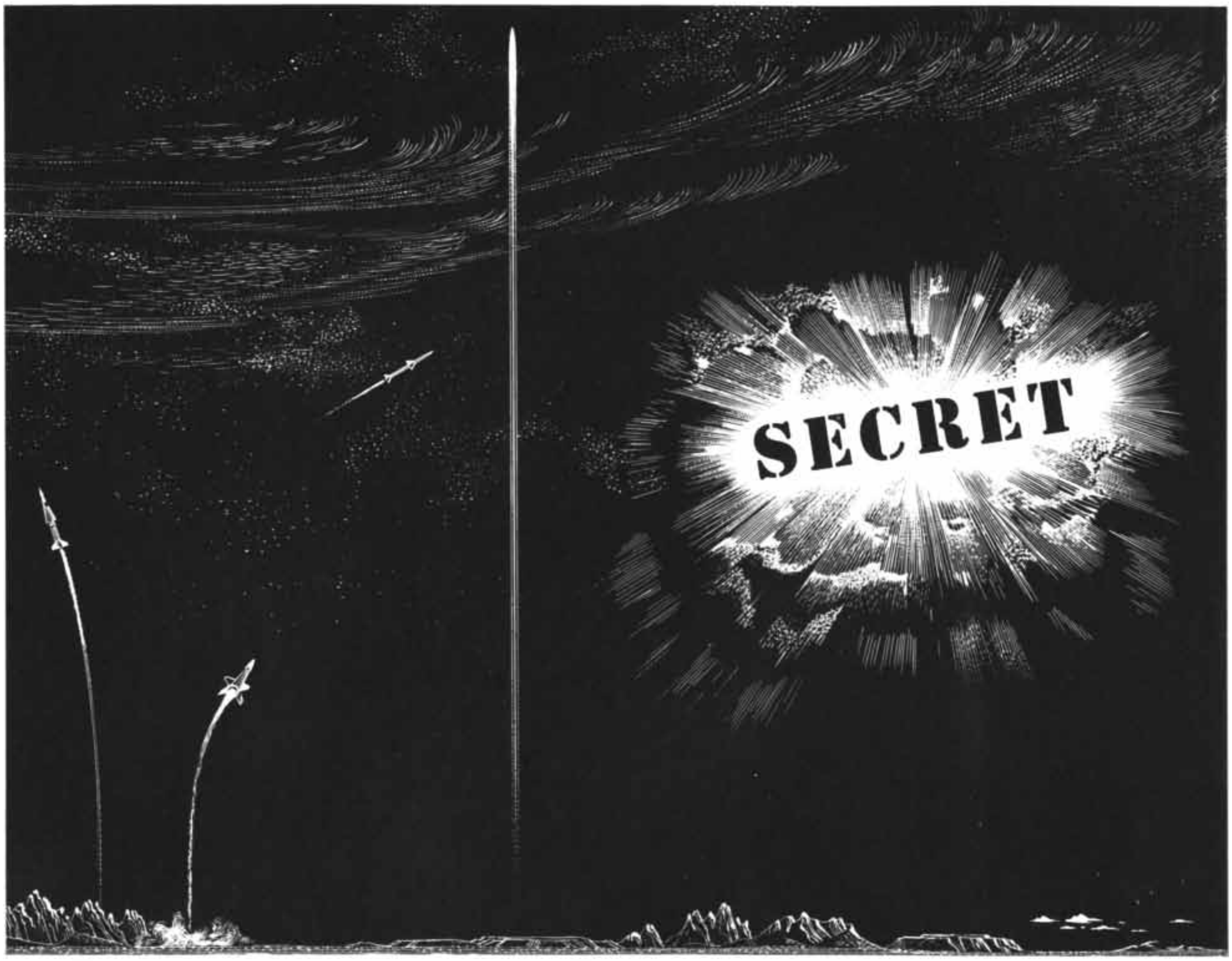

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most societies a high value is placed on warriorship and soldierly virtues. It is true that a good supply of ammunition and rifles discouraged marauding Cheyennes, and that a large policeman is a wonderfully effective scarecrow against burglars and footpads. But a man's willingness to fight for a woman or a bone is not the same as a willingness to fight over issues of principle against men with whom he has no personal quarrel, whom he has never seen and will not see even in combat; and keeping one's powder dry is not quite the same as assembling stocks of nuclear weapons. The deterrent may not deter, and once it is used all is lost. The deterrents of our day are somewhat overgrown for their purpose; the hydrogen bomb, as Nehru remarks, is not an instrument of persuasion.

Ellery points to the frustrations and aggressions of society as one of the main causes of war. These twins (resembling action and reaction in physics) are among the fundamental components of behavior. Frustration produces aggression. The reaction may occur on a conscious level, or it may take strange forms in the complicated interchange of psychological forces. Aggression, though it has an ugly sound, is when properly controlled a "serviceable implement" of behavior; without it a man is a noodle. Ellery shows how social and economic circumstances often turn men into sick, hostile, belligerent individuals, burdens to themselves and to society, subversive of the natural inclination toward peace.

Do we know enough about social tensions within a group and between groups to bring under control "the violent manifestations of group hostility"? Oeser says we do, however difficult it may be to apply what we know. Hens peck at each other to establish a hierarchical order in the barnyard, and many animals will fight for food or to protect their young; but there is no evidence to support a biological theory of war. (W. C. Allee and others have shown that cooperation is far more common and necessary in the animal world than competition, let alone organized warfare.) War is a culture trait; the propensity to practice it has nothing to do with genes. In some societies women hold economic or political power; in some, competitiveness is regarded as antisocial; in others, men have to be forced to assume leadership positions. (Oeser gives two amusing examples: Arnhem Land children, who cannot be tested individually in tests which contain problems because all problems are discussed only in groups; and the Zuñi Indian, who never wins a race twice because "that would be indelicate, if not immoral.") Certain societies regard war as an ennobling opportunity, but others hold it "literally unthinkable that men should band themselves together to kill people of another tribe, whether for glory or for gain."

War is a disease of societies. People see social reality "through the more or less ready-made spectacles of group experience and group ideologies." It is the rare man who can put these spectacles aside and escape the group myopia which determines likes and dislikes, prejudices and stereotypes, appraisals of self-interest and class interest. How one sees the world and its social tensions affects one's willingness to choose war as the solution of international crises. By combining what is understood about group tensions and hatreds with what is known about the distortions of personality that drive men to seek power and to vent their destructive impulses on society, one is in position to make sound diagnoses of the causes of war.

Of course diagnosis is a long way from prevention or cure. Much that men have been taught to believe is glorious has to be thrown on the rubbish heap. New heroes are needed. Bertrand Russell recently suggested that if one compared the height of the Nelson monument in Trafalgar Square with the height of statues of Shakespeare, Newton or Darwin, one got a pretty good idea of the heroes the English most admire. The study of social interaction demands the intensive cultivation of many disciplines, from psychology to economics. Training in these is at least as important as training in physics or biology or engineering. If the welfare of mankind is the first goal, education in the ways of society is the first requirement. Not everyone needs to be a nuclear physicist, but everyone is obliged to be a human being.

Among other articles in Wallace's book which deserve mention is W. Macmahon Ball's discussion of nationalism as a cause of war. One of his acute observations relates to the real meaning of self-government: for example, when the British work for Malaya's self-determination, where is this "self" to be found in a plural society of Chinese, Malays and Indians? Does it consist of the majority of the people, who are mostly illiterate? Or is the "self" to be identified with "Chinese big business" or Malay sultans? Self-determinism is easier in Europe, but even there plebiscites and elections do not always express the popular will; and when they do, they achieve it at the expense of minorities. W. G. K. Duncan, a historian and political scientist at the University of Adelaide, presents a very sensible analysis of the much-misunderstood and overused concept of balance of power. The idea behind the principle is expressed in the old phrase that "one sword holds another in its sheath." In practice, balance of power turns out to be "a chimera, a myth, an ideology, a cloak to disguise the realities of foreign policy from critics, at home as well as abroad." If it works at all, even temporarily, it depends on an outside power holding the balance between opposed groups of nations, and tilting it against a potential aggressor. But with the world divided between two giants there is no outside balancer, and the slightest move by either giant can produce an immediate, dangerous tilt. Frederick E. Emery and James F. Cairns consider economics and war; the noted agriculturist Sir Samuel Wadham, population and food production in relation to world peace; the physicist M. L. E. Oliphant, the threat to civilization from atomic warfare (he makes it devastatingly clear that there is no effective defense, and none in prospect, against atomic weapons, and that shelters are useless unless men are prepared to shift life permanently underground). Sir Frederic Eggleston's essay considers the U.N. as an instrument for preserving peace. Most thoughtful persons would agree with Sir Frederic that the U.N. deserves the strongest possible support. It has failed often but it has probably averted irretrievable disaster.

Whether one is hopeful or despairing of the future is at bottom a matter of temperament. For even if we assumed we could know all about the causes of war, we might discover that situations arise which "are intractable in themselves." The University of Cambridge historian Herbert Butterfield has spoken of the "tragic element in modern conflict, . . . the absolute predicament and the irreducible dilemma." The greatest war in history, said Butterfield, could be set off between two powers "both of which were moderately virtuous and desperately anxious to prevent a conflict." Such a struggle "would be embittered by the heat of moral indignation on both sides, just because each was so conscious of its own rectitude, so enraged with the other for leaving it without any alternative to war. It is the peculiar characteristic of the situation I am describing . . . that you yourself may vividly feel the terrible fear that you have of the other party, but you cannot enter into the other man's counterfear, or even understand why he should be particularly nervous. For you know that you yourself mean him no harm and that you want nothing from him save guarantees for your own safety; and it is never possible for you to realize or remember properly that since he cannot see the inside of your mind, he can never have the same assurance of your intentions that you have."

As a companion to this penetrating observation I mention a memorable paragraph from an address given to the American Legion in 1955 by General of the Army Douglas MacArthur. (The quotation appears in W. Glanville Cook's essay on propaganda in the present volume.) MacArthur said that present tensions were "kept alive by two great illusions. The one, a complete belief on the part of the Soviet world that the capitalist powers are preparing to attack it; that sooner or later we intend to strike. And the other, a complete belief on the part of the capitalist countries that the Soviets are preparing to attack us. Both are wrong. Each side, so far as the masses are concerned, is equally desirous of peace. For either side, war with the other would mean nothing but disaster. Both equally dread it. But the constant acceleration of preparation may well, without specific intent, ultimately produce a spontaneous combustion."

Wallace's symposium is patchy and uneven. Certain critical political and economic issues are scantily treated, the majority of the essays dealing with the uses of diplomacy and the prevention of war are unimpressive. But the book as a whole must have great impact on open minds. It often speaks directly and incisively. It is not unfriendly to the U. S., but it says many things we do not like to hear. Australians do not wear our kind of glasses. They see things we do not see, although they are well aware that they are tied to our fate. It is an omen not to be disregarded that these expressions come to us from the Pacific. And the spirit of the undertaking recalls some words of Gilbert Murray: "Man has in the last issue only one weapon for dealing with the innumerable problems which bewilder and which may destroy him, the weapon of thought. Thought may go wrong; but it is the best guide we have, if it is patient, if it is based on study, if unwarped by personal interests and moved by the spirit of goodwill."

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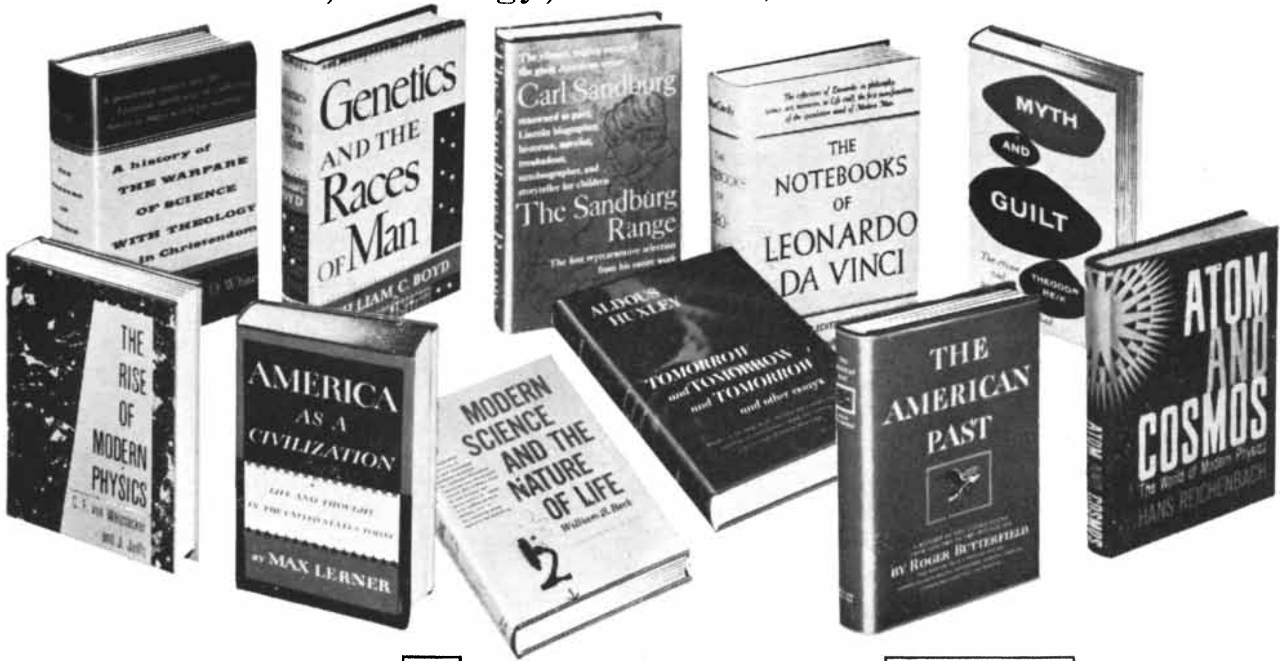

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first a chronicle; the second a historical review of Freud's contributions to medicine, psychology, anthropology and sociology, and his attitudes on lay analysis, art, literature, religion and occultism. The concluding chapter is a brief general assessment of his influence on the world. It cannot be said that the last phase of Freud's long life was a quiet tapering off, a change from vigor, creativeness and conflict to peacefulness and decay. At the end of World War I Freud was 63. He was penniless, his country was ruined, his practice was shattered, his friends were scattered. Everything had to be rebuilt. Fortunately he had the energy for rebuilding and a spirit which could not be broken. Psychoanalysis won increasing recognition. His consulting hours soon were filled, many with patients from foreign lands who could pay their fees in hard currency. In Vienna a separate publishing house was founded for psychoanalytic literature. Freud's own output was astonishing. *Group Psychology, The Ego and the Id, Beyond the Pleasure Principle, Moses and Monotheism* were among his books of the period; also numberless technical essays, and writings on war, religion and civilization. With Ambassador William C. Bullitt he collaborated on a life of Woodrow Wilson, which will be published "at a suitable time." Freud's fame spread: distinguished visitors, pupils, letters, honors came from all parts of the world. Vienna made him a professor; the Royal Society, a corresponding member. But together with the triumphs and satisfactions grief and suffering fell upon him in full measure. Dissension plagued the psychoanalytic movement. His closest collaborator, Sandor Ferenczi, gradually turned from him, as did Otto Rank. Old friends died. He had to bear the loss of his beautiful daughter Sophie, whom he called his "Sunday child," and of his beloved little grandson Heinz—a blow which brought Freud to tears (the only known occasion of this kind in his life, according to Jones) and from which he never recovered. In 1923 Freud underwent a major operation for cancer of the jaw. Thereafter he had to wear a huge prosthesis—called "the monster"—which at best was uncomfortable and for long periods miserably painful. Over the next 16 years 30 other operations were performed on him until finally the malignancy could not be contained. All this he bore with exemplary stoicism. He rarely complained. His work in all departments went on steadily. He would take no drugs, preferring, as he said, to think in torment than not to be able to think clearly. It is a terrible and an inspiring story. Jones handles the final installment of his biography with the skill and devotion we have learned to expect from him. He imposes graceful order on a prodigious amount of material. The narrative, the delicate and difficult analysis of professional relationships, the exposition of the theories—all come off very well and are a tribute to his own largeness of spirit. There are many revealing anecdotes. Freud had a patient who almost converted him to bolshevism. Under the new order, the patient said, there would be some years of misery and chaos but these would be followed by universal peace, prosperity and happiness. Freud said: "I told him I believed the first half." On refusing to attend a festival in his honor, he remarked: "When someone abuses me I can defend myself, but against praise I am defenseless." After his first meeting with Einstein in 1926 he wrote: "He is cheerful, sure of himself and agreeable. He understands as much about psychology as I do about physics, so we had a very pleasant talk." As the years passed the admiration each man had for the other increased; in 1939 Einstein wrote Freud a superb letter saying that, while he could not always follow the older man's ideas, he was glad at least "to be able to grasp the structure of the thoughts expressed." It is perhaps ungrateful to complain about what this book does not give, when it gives so much. Yet it must be said that for all its riches the Jones biography is a work of grandeur which only rarely penetrates to the deeper levels of its hero. What he said or did is carefully reported, but somehow, whether because of the biographer's veneration and reticence or because Freud shielded himself too well, the inner man of tears, qualms, doubts and passions eludes our understanding.

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population shrank from 5,000 to 500. Oglethorpe's rules were abandoned: slavery was introduced, liquor was imported and lands were held in fee simple. Rice and indigo fields were worked by numerous slaves; exports rose from 15,000 pounds in 1755 to almost half a million dollars in 1791. The rise of a prosperous class was accompanied by the construction of many splendid homes and other architectural monuments, as well as less glamorous structures. This stunning book, beautifully designed, and illustrated with superb pictures by the distinguished architectural photographer Frances Johnston, is a survey of the early architecture of Georgia. The great body of existing architecture, says Nichols, dates from the Early Republican or Federal period, which began about 1790. Germans, Swiss, "a few Jews from England" and Italian Piedmontese were among the mixed population which settled Georgia. The diversity of the people influenced the architecture, as did the diversity of topography—mountains, coastal plains, sand hills, swamps. There are discussed and displayed in this survey the elegant houses and the tenements of the coastal towns, the famous Classical Revival structures of the Piedmont, the mountain cabins and log houses of the Appalachian region, the simple coastal "plantation plain-style buildings," the spacious brick or tabby homes of the great swamp where the prosperous rice and indigo plantations were located. Seen together these make a fascinating social and architectural record. In every way worthy of its subject, this volume is an ornament of bookmaking, illustration and scholarship.

THE LIFE OF BACTERIA, by Kenneth V. Thimann. The Macmillan Company ($13.50). The tiniest living things rule us. Their power lies in their number. A handful of soil contains as many microorganisms as there are human beings in the world. A noted 19th-century botanist, Ferdinand Cohn of Breslau, gave a very graphic illustration of the size of bacteria: "If one could inspect a man under a similar lens-system he would appear as big as Mont Blanc or even as Mount Chimborazo. But even under these colossal magnifications the smallest bacteria look no larger than the periods and commas of good print; little or nothing can be distinguished of their inner parts, and of most of them their very existence would have remained unsuspected if it had not been for their countless numbers." For some 200 years many men have labored to develop methods for studying these "smallest members of creation." The remarkable progress that has been made is shown in this excellent book, which presents a summary of what is known today about the growth, metabolism and relationships of bacteria. After tracing a brief history of microbiology, the book discusses the internal structure of bacteria, the conditions of their culture, the relationship of the bacterial cell to other organisms, the role of microorganisms in the nitrogen cycle, the different kinds of fermentation, growth and protoplasm formation, assimilation, the autotrophic mode of life, bacterial photosynthesis, the inhibition of bacterial growth by antibiotics and other means, the evolution of bacteria. This work fully justifies the 15 years the author devoted to it. Many illustrations.

ON NUCLEAR ENERGY, by Donald J. Hughes. Harvard University Press ($4.75). In the few years since Hiroshima nuclear energy has emerged as a force of almost unlimited promise for human welfare and as the greatest threat of all time to human survival. This book is concerned only with the promise. The principal topics with which the author deals are the potentialities of atomic power; the different kinds of reactors; the possibility of controlling fusion; the applications of radioisotopes in technology, agriculture, medical diagnosis and therapy; the uses of neutrons from reactors as tools for penetrating other particles and learning more about the fundamental structure and binding forces of matter. He also explains the scientific elements of nuclear energy, and discusses the work of the international atomic energy agency and some aspects of the safety and security matters handled by the U. S. Atomic Energy Commission.

A HISTORY OF LUMINESCENCE, by E. Newton Harvey. The American Philosophical Society ($6). The emission, under various circumstances, of light without heat was well known to the ancients. The firefly is, of course, the very symbol of the phenomenon. From the beginning certain types of reflection, such as the glowing eyes of cats and humans and the apparent light that appears when the eyeball is pressed or struck, were confused with true luminescence; but the ancients also recognized instances of the latter, among them the aurora borealis, the light of the sea, luminous animals, phosphorescent wood and flesh, and *ignis lambens*, a silent electrical discharge in air. The isolation of phosphorus in 1669, and the observa-

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A message from Dr. Mortimer J. Adler,
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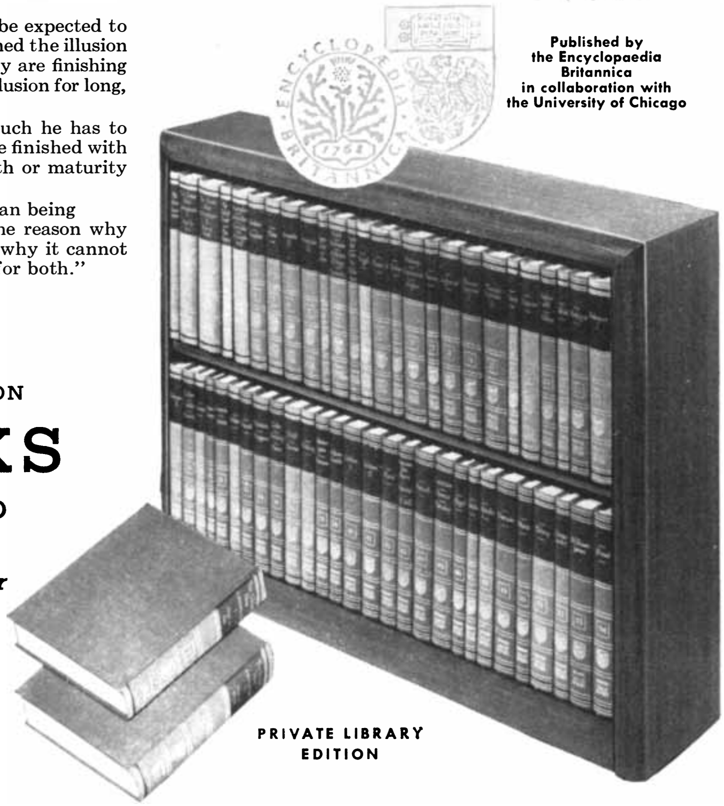

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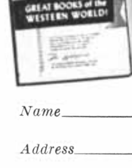

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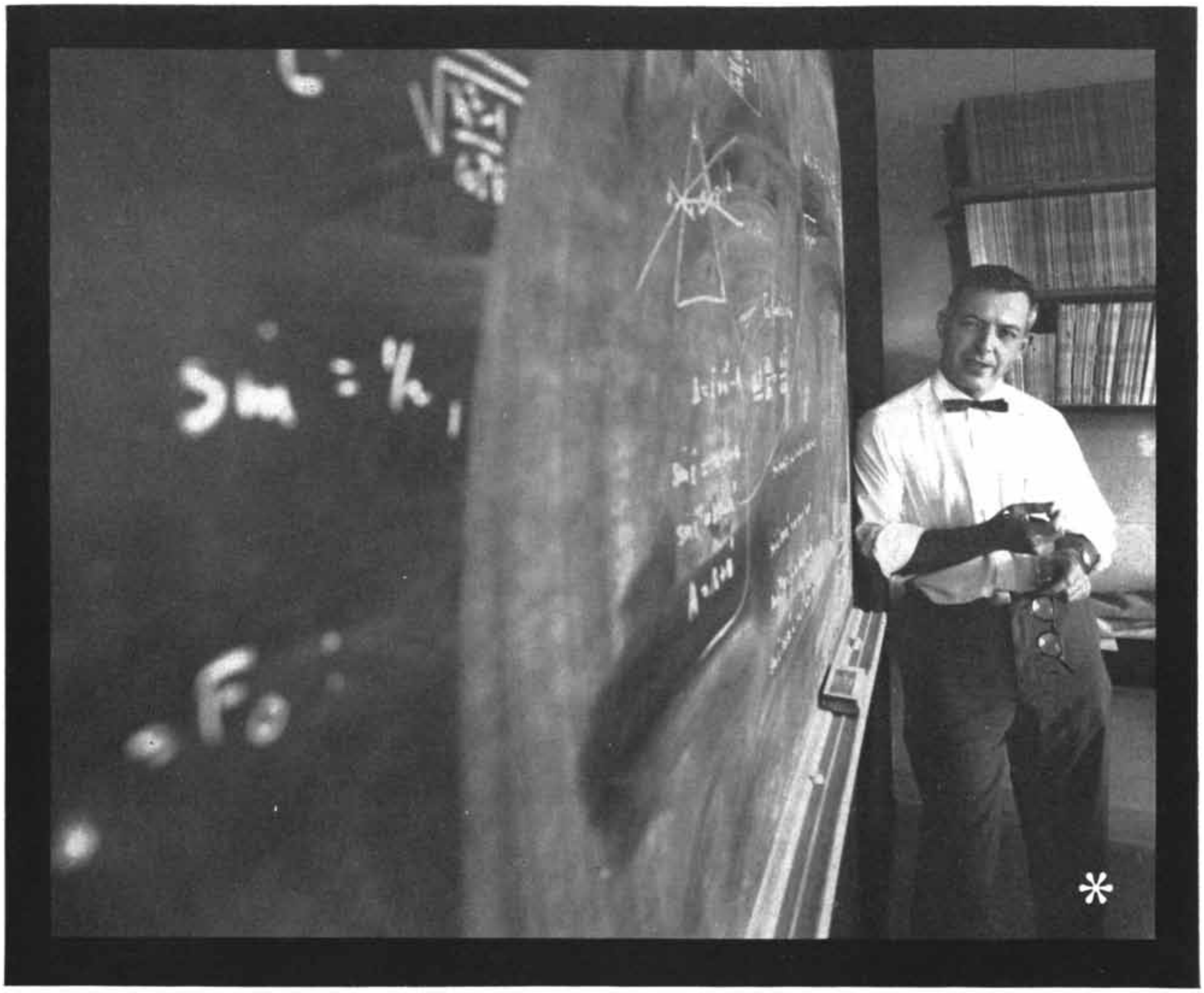
City __________ *Zone* _____ *State* _____ tion of the glow in partially evacuated vessels brought near an electrical machine, added other examples of the phenomenon. In 1888 the physicist E. Wiedemann recognized luminescence "as the antithesis to incandescence" and invented a classification, expressing the method of excitation, which has not been improved upon. He defined the categories of photoluminescence, where light itself is the exciting agent, which is divided into fluorescence and phosphorescence; thermoluminescence, which is light from gentle heating; electroluminescence, characteristic of gases in electrical fields; crystalloluminescence, occurring when solutions crystallize; triboluminescence, the emission of light on rubbing or crushing organic or inorganic crystals; chemiluminescence, which accompanies chemical reactions. (Bioluminescence, a property of many living animals and plants, is recognized as a form of chemiluminescence.) Since the formulation of the quantum theory and the development of atomic physics, a comprehensive theoretical basis has been laid for every type of luminescence. The postulated explanation is that when an atom or molecule acquires excess energy, one of its electrons is displaced to a higher energy level. The source of this energy may be light, X-rays, various particles (including other electrons), mechanical or chemical energy. After a time, depending on the cause of the displacement, the electron returns to the lower level and a quantum of light is emitted; the total of these quanta constitutes luminescence. Harvey, a foremost authority who has written many papers and books on the subject, has devoted 10 years of special study to the preparation of the present work, a detailed and fascinating survey from the earliest times until the discovery of the electron. As he points out, the modern era of physics ushered in by Max Planck has added a new dimension to the study of luminescence. With the help of sensitive instruments many phenomena have been detected which were hitherto invisible to the human eye, so that the "historian of the future will have a wholly new world of unseen luminescence with which to contend."

ARTIFICIAL INSEMINATION IN THE HUMAN, by A. Schellen. Elsevier Press, Incorporated ($14). To the majority of readers it will probably come as a surprise to learn that more than 100,000 children were born in the U. S. during recent years as the result of artificial fertilization with the semen of a donor. Many more children were conceived in intermarital artificial insemination. The growth of A.I., as it is called, led to the present monograph by a young Dutch physician who, in addition to studying the subject abroad, observed the methods used in sterility clinics throughout the U. S. Intermarital A.I. raises only medical and physiological questions; donor insemination, however, also has legal, social and theological implications. All of these are discussed by Schellen. He concludes, after long and soul-searching analysis, that while barren marriages are a misfortune, and donor insemination "may in many cases produce the desired result, a child," the means by which the result is achieved is "encumbered with many immoral, asocial and unnatural elements," which outweigh its advantages. This book proves once again that theology and science make an awkward pair.

LE CIEL ET LA TERRE, edited by André Danjon, Pierre Pruvost and Jules Blache. Librairie Larousse (8,850 francs). LA PHYSIQUE, edited by Louis de Broglie. Librairie Larousse (9,600 francs). These two books constitute Volumes II and III of *Encyclopédie Française*, 12 volumes of which have already appeared. *Le Ciel et la Terre* consists of articles by 36 leading French astronomers, geologists and geophysicists, embracing the present state of knowledge about the earth and the solar system, the sun and stars, galaxies, the terrestrial globe, the earth's crust, the formation of the earth's topography. To the volume on physics some 50 specialists contribute comprehensive and succinct surveys of such topics as measurement, the uses of mathematics in physics, symmetry and dissymmetry in physical phenomena, relativity theory, classical mechanics, electromagnetic theory, thermodynamics, elasticity, optics, acoustics, the structure of matter, crystallography, radar, fundamental particles, wave and quantum mechanics, nuclear physics. The articles are clearly written for a professional audience; there are many illustrations, and rather skimpy bibliographies.

DISCOVERY OF THE UNIVERSE, by Gérard de Vaucouleurs. The Macmillan Company ($6). An outline of the history of astronomy from its origins to 1956. The author, who is on the staff of the Lowell Observatory in Flagstaff, Ariz., states that he is less concerned with biographical details than with the evolution of ideas. But even in this department he traverses whole periods at high velocity. All of pre-Copernican



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astronomy, for example, is disposed of in a few pages, with a single—and that not very helpful—sentence devoted to the system of deferents and epicycles. Modern developments, including galactic studies, solar-system and stellar physics, and radio astronomy are more deliberately served.

Notes

The Hypercircle in Mathematical Physics, by J. L. Synge. Cambridge University Press ($13.50). Professor Synge here describes a technique, to the development of which he has devoted 10 years, for the approximate solution of certain boundary value problems of mathematical physics.

Mathematics for Everyman, by Egmont Colerus. Emerson Books, Inc. ($3.95). An English translation of a popular German survey of mathematics, from number systems to the calculus.

Survey of Biological Progress, edited by Bentley Glass. Academic Press, Inc. ($7.50). Reviews of topics in biology: embryological concepts in the 20th century, trends in systematic botany, chemoreception and the behavior of insects, the mechanisms of action of hormones on cells, respiration and cellular work and the regulation of the respiration rate in plants.

Biographical Memoirs of Fellows of the Royal Society, Vol. II. The Royal Society (30 shillings). The 1956 obituary volume contains memoirs of 22 fellows, among them Walter Adams, Gleb Anrep, Alexander Fleming, Edmund Whittaker, Robert Wood.

Set Theory, by Felix Hausdorff. Chelsea Publishing Company ($6). An English translation from the third German edition of an authoritative work on the theory of sets.

Vertebrates of the United States, by W. Frank Blair, Albert P. Blair, Pierce Brodkorb, Fred R. Cagle and George A. Moore. McGraw-Hill Book Company ($12). An identification manual containing taxonomic keys, check lists, geographic ranges and descriptions of all known U. S. vertebrates.

Heat Transfer, by Max Jakob. John Wiley & Sons, Inc. (Vol. I, $13.50; Vol. II, $15). The second volume of the late Max Jakob's treatise completes a monumental survey of the concepts (including their historical development), fundamental topics, basic analyses and applications of heat transfer.

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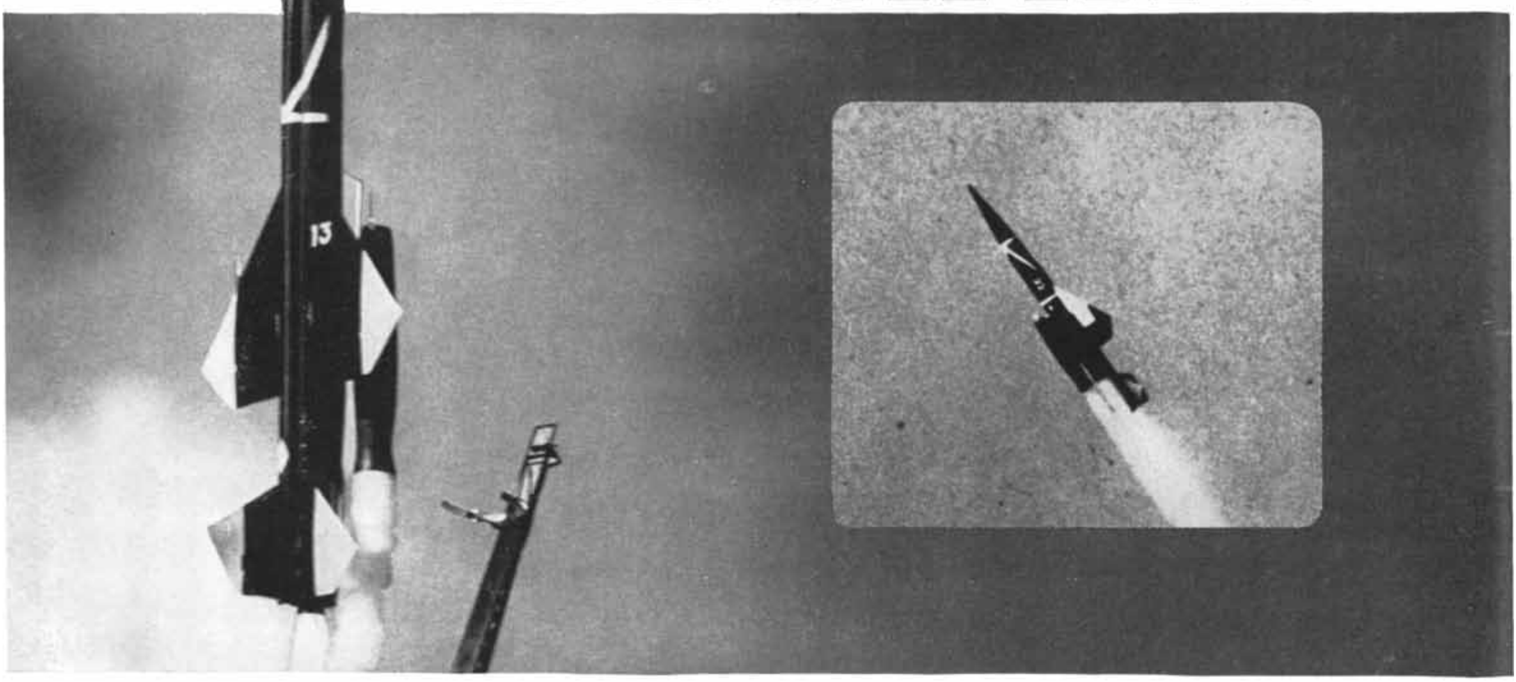

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