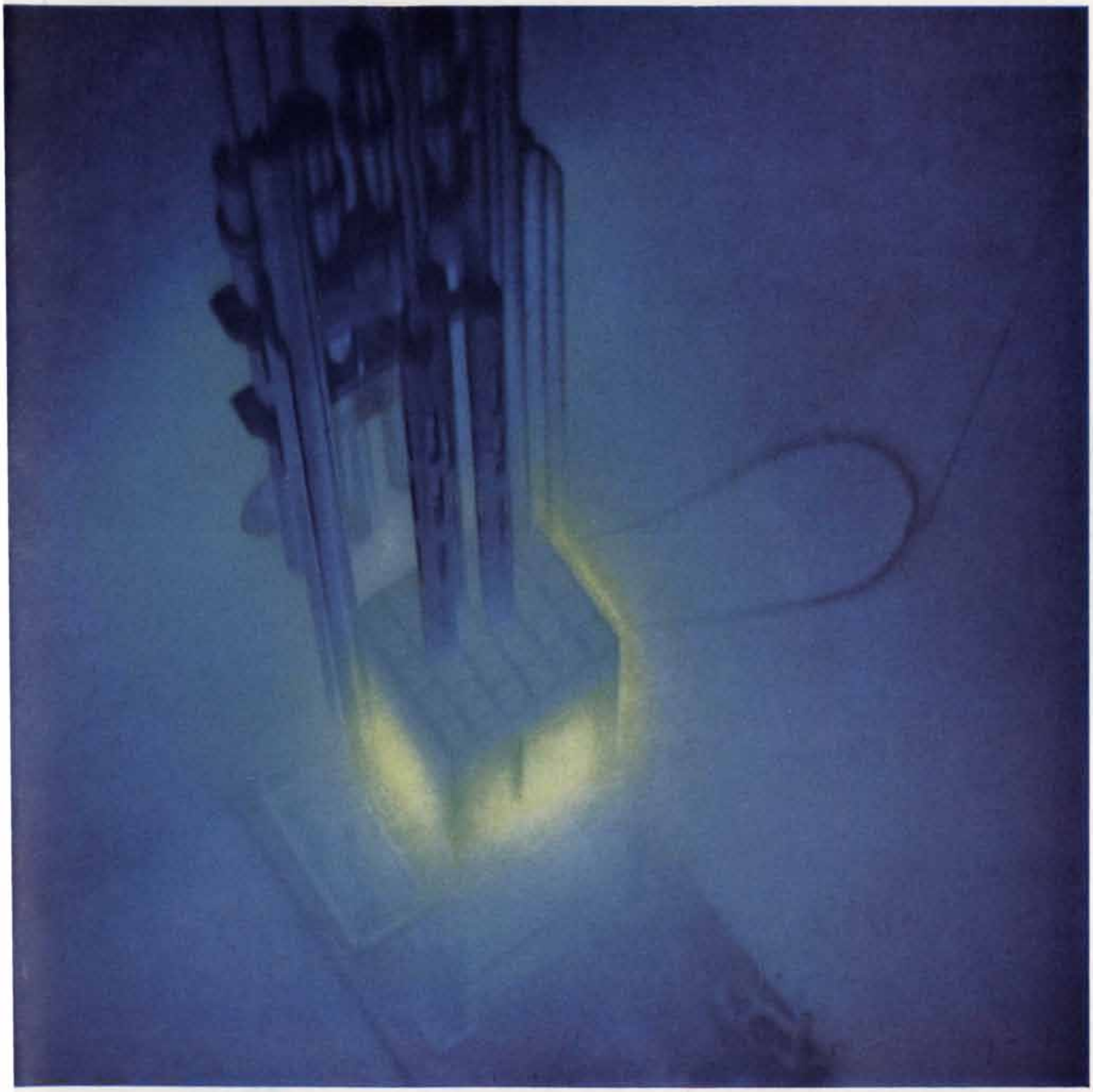
SCIENTIFIC AMERICAN



GENEVA REACTOR

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SEVENTY-FIVE CENTS OUTSIDE THE AMERICAS

October 1955

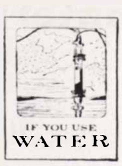
Kidney for an Atomic Fish

Something the Nautilus, U. S. Navy atomic-powered submarine, must have is chemically pure (ion-free) water. A "kidney" like the one shown above, with MONOBED® ion exchange resins as its innards, keeps water used free of even traces of dissolved salts.

What does this mean to you? It means that if you, too, require water of high quality, from a beaker-full to millions of gallons, for research work or for high-pressure boilers, for steam irons or for industrial processing, you can count on MONOBED ion exchange resins.

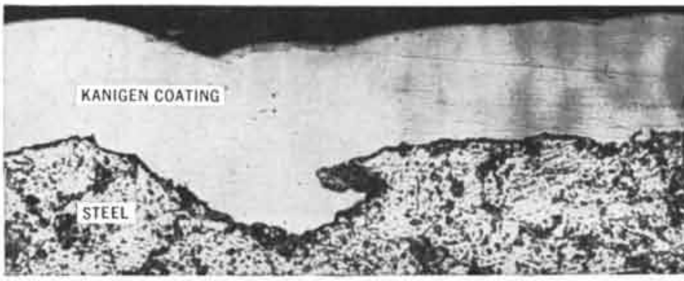
Suppose you don't need the ultimate in ion-free water? Then AMBERLITE® ion exchange resins in conventional deionization units may be the answer. AMBERLITE exchangers may be indicated when you want to soften, dealkalize, or deacidify water—when you want to replace or remove ions in solution . . . economically . . . efficiently.

Ask for "If You Use Water . . .", a 24-page booklet of basic information on the ion exchange treatment of water.

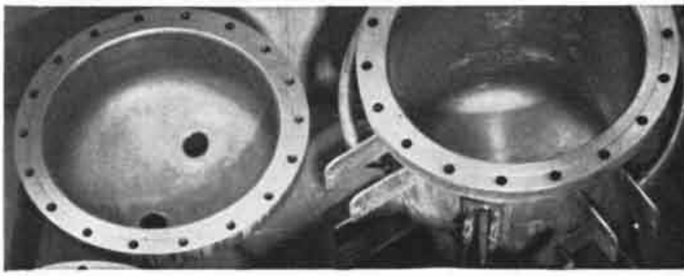


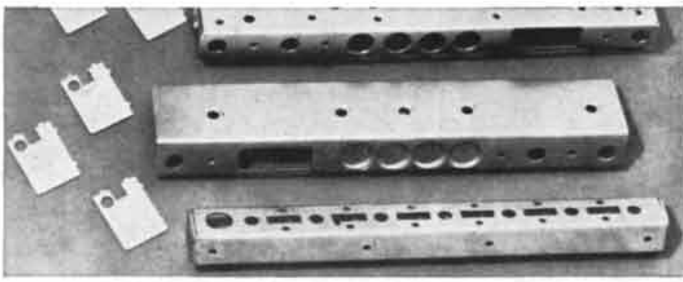
ROHM & HAAS COMPANY

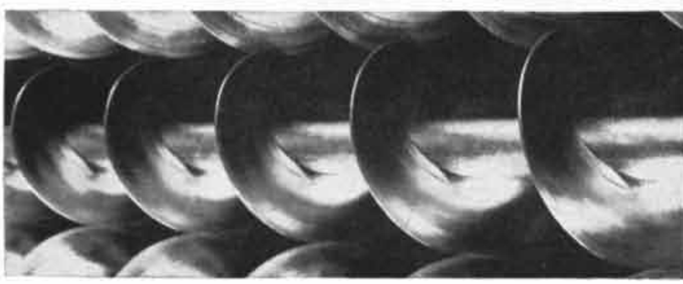
THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA



photomicrograph showing uniformity of Kanigen coating over steel (250X)


Kanigen-coated pressure vessels


Kanigen-coated aluminum electronic assembly ready for soldering


Kanigen-coated screw conveyor: 9″ diameter; 10′ length

Could you use Kanigen* coating to prevent iron pick-up? To form an alkali-resistant surface? To apply a coating of virtually non-porous nickel-phosphorus to many metallic and non-metallic materials . . . without the use of electricity?

Can your product benefit from the hardness of Kanigen coating? Would coating aluminum to increase surface hardness and permit solderability give your product an advantage?

Is uniformity of coating, even on complex shapes, important? Could you lower your costs with a uniform coating of Kanigen that offers a service life comparable to that offered by costly clad or solid materials?

Does coating on plastics (printed circuits, for example) seem worth investigating? There is nothing like Kanigen. Metallurgically unique—not just a substitute for electroplate—it has many unexplored uses. It is available only from General American and our licensees.

"where can you use this metallurgically-unique material—Kanigen?"

*"KANIGEN" is a mark identifying chemical deposition of a high-nickel, low-phosphorus alloy by General American Transportation Corporation and its licensees, and the coating resulting therefrom.

It pays to plan with General American

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GENERAL AMERICAN TRANSPORTATION CORPORATION

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SCIENTIFIC AMERICAN

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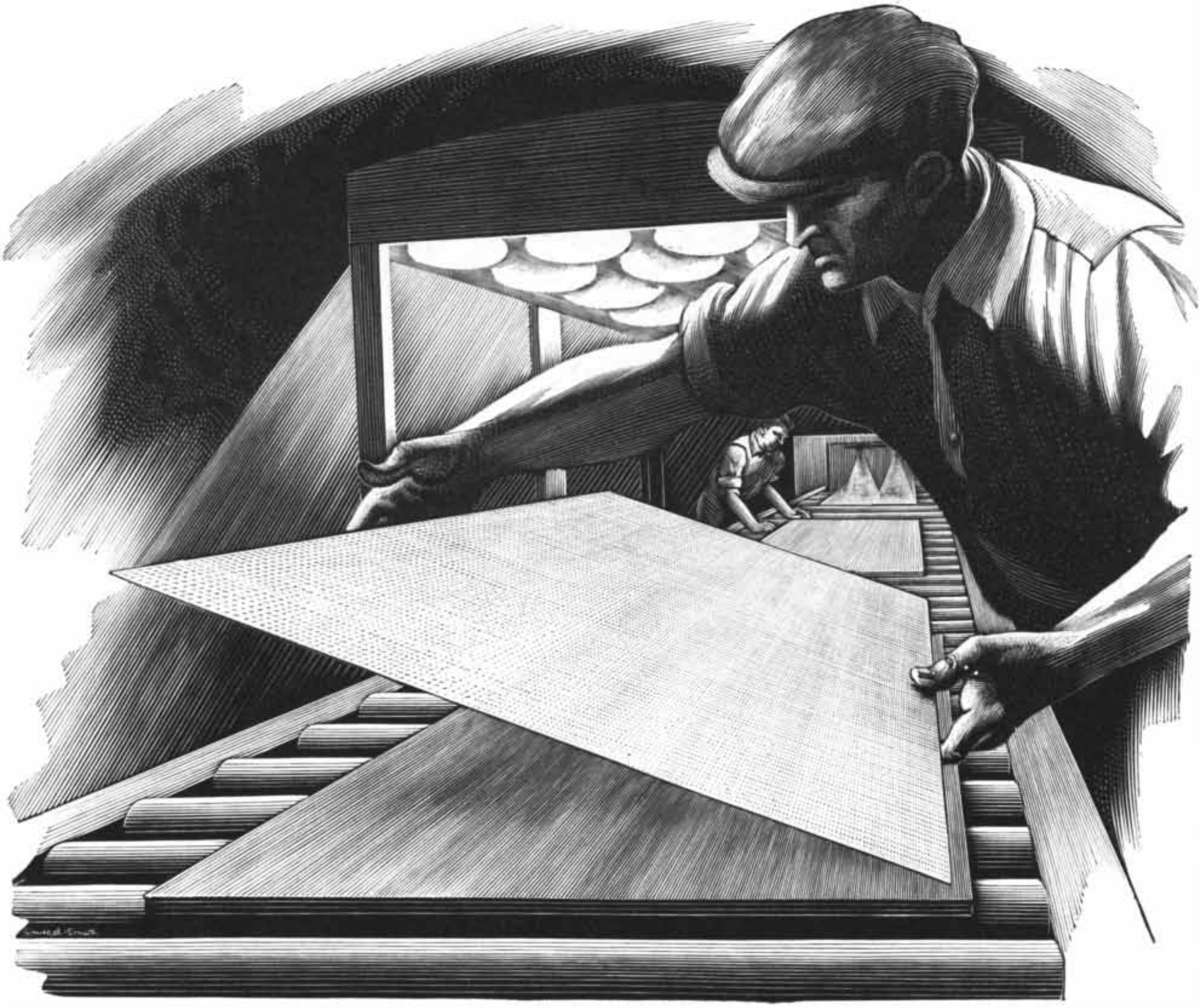
ARTICLES

DEPARTMENTS



Bond plastic laminates quickly with this high-strength adhesive

With Armstrong D-253 Adhesive, you can bond plastic laminates on an assembly-line basis—and bond them for keeps.

This easy-to-use thermoplastic adhesive combines great heat resistance with unusually high dead-load and shear strength.

That extra dead-load strength is particularly valuable because it resists the laminate's tendency to "fight back." And whether used on flat or curved surfaces, D-253 resists constant dead load year after year, holding plastic laminates with a grip you'd expect only from harder-to-use thermosetting cements.

D-253 is exceptionally fast acting, too. Spray it on cores and skins; dry it in seconds under heat lamps; assemble the sandwich and pass it through a pinch roll. It all takes less than three minutes! No time-consuming curing. No jigs, clamps, or presses, either. And the finished laminate can be drilled, cut, or shipped immediately.

For the whole story on D-253—and other Armstrong adhesives—write today to Armstrong Cork Company, Industrial Division, 8010 Inland Road, Lancaster, Pennsylvania. In Canada, 6911 Decarie Boulevard, Montreal.

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LETTERS

Sirs:

In his article on "The Changing American Language" in your August issue, Jotham Johnson not only traces evolutionary changes in the language, but at least implies satisfaction with them. This is the usual attitude of linguistic scholars. Enthusiasm for the detection of the laws of change in language begets enthusiastic welcome of the changes themselves. This is as though a weather forecaster were to rejoice in blizzards and hurricanes, or a physician in pestilence.

Change in language occurs most frequently and most rapidly among the illiterate and semiliterate. Must language be blithely allowed to drift rudderless, subject only to the winds of illiteracy and the currents of chance? Fatalism is not a scientific concept, and "pure" science has fortunately never been granted a successful divorce from "applied" science.

IRVING T. RICHARDS

Cambridge Junior College
Cambridge, Mass.

Sirs:

Mr. Richards' comments prompted me to reread my recent article to see if in spite of all my comma-plucking I per-

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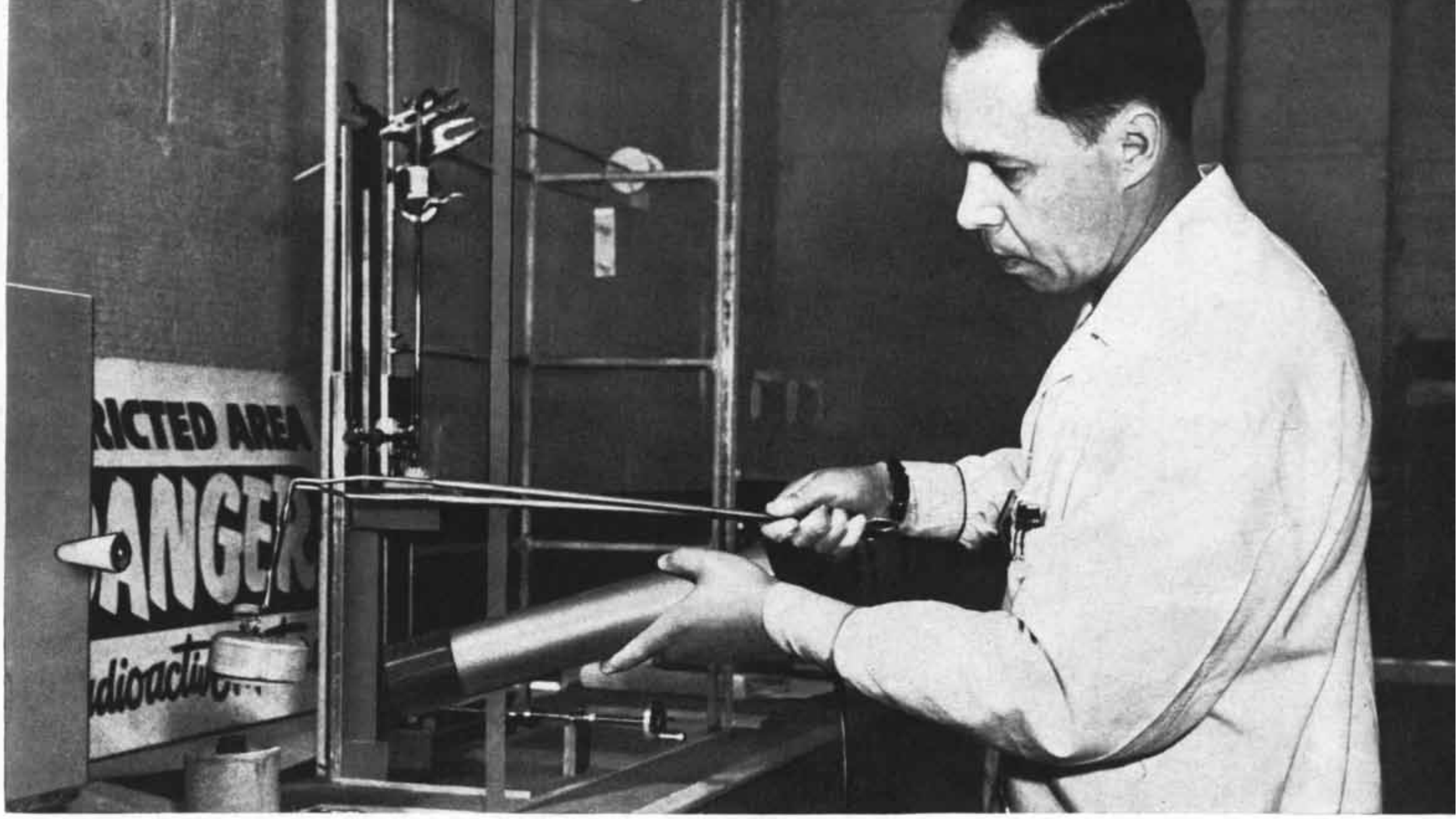

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G-E Portable Probe Selectively Detects α, β, γ, and Thermal-neutron Radiation

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SIMPLE TO CONVERT, the versatile G-E radiation probe can be quickly changed from an alpha detector to a beta, gamma, or thermal-neutron detector. Merely unscrew one cap and replace it with another.

GENERAL ELECTRIC

mitted personal preferences to creep into the text. I find no trace of satisfaction, expressed or implied, with the evolutionary changes at work in the American language, or of dissatisfaction, for that matter.

The purpose of the article was to affirm an often-overlooked point, and to point a moral. The point is that change is normal and, apparently, inevitable. For nearly every example of a change deplored by the purist (family/fambly, governor/guv'ner, uncle/nuncle) we can cite parallel changes which were not stamped out by the purists of a previous generation and yielded forms now regarded as standard (nimel/nimble, cyning/king, ekename/nickname).

If the language is menaced by aphaeresis (human/yooman), syncope (ordinary/ornery), apocope (delicious/delish), metathesis (medieval/medivial), assimilation (understand/unnerstand), dissimilation (February/Febuary), shifting accent (muséum/múseum), analogy (momentous/momentuous), folk etymology (asparagus/sparrow grass), and a dozen other active agents, it has survived similar incursions in the past (Woden's Day/Wednesday, of-ten/offen, exquísite/éxquisite), and it shows no signs of waning vigor. Quite the contrary. Hence the moral: There's no use being upset about it.

To the charge that I welcome change for its own sake, I plead not guilty; but I acknowledge that there are individual variants which I see no need to fight. As for efforts to channel the growth of language by fiat, I take a very bleak view of them; I am sure that this would only retard its development.

JOTHAM JOHNSON

New York University
New York, N. Y.

Sirs:

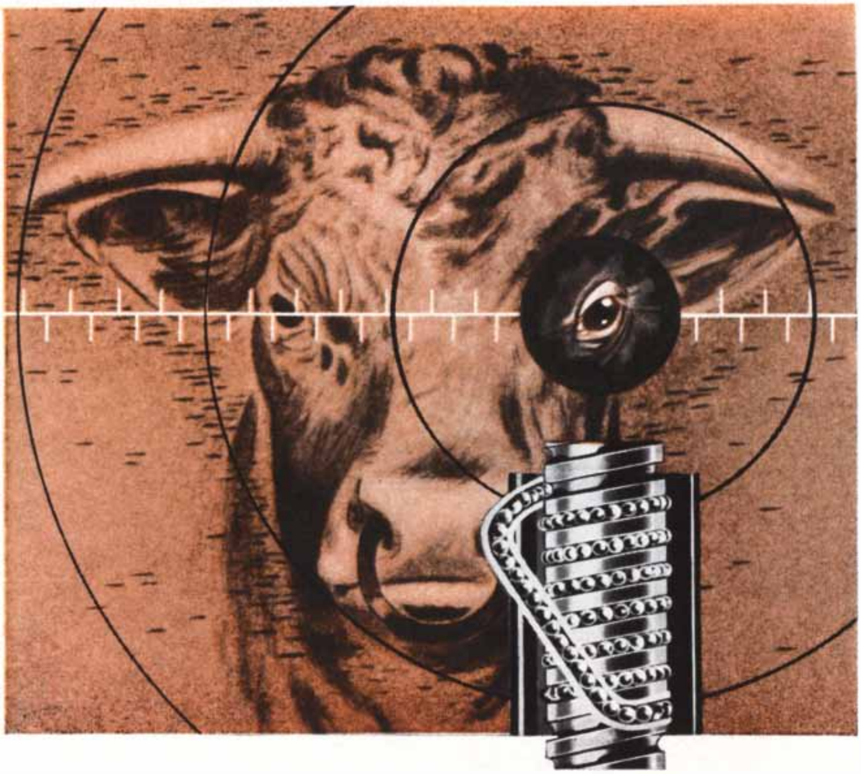
The article "Antibiotics Against Plant Diseases" by David Pramer in June suggested to this lay reader a line of reasoning that seems to be worth considering:

1. Antibiotics have been shown to be absorbed by plant roots and to increase the resistance of the plants to certain diseases when so absorbed.

2. Antibiotics are produced by molds found in the soil.

3. There have been many claims that plants grown in soil with high organic content show high resistance to disease.

4. It would seem that we might be able to attain better control of plant diseases through the use of organic ma-



terials and perhaps inoculation of the soil with selected molds.

F. S. QUINN

Commander, USN
Isle of Palms, S. C.

Sirs:

Commander Quinn's reasoning has a great deal in common with that of a number of plant pathologists.

The incorporation of organic matter into soil is known to encourage qualitative and quantitative changes in the soil microflora and, in some cases, to adversely affect plant pathogens. Cereal root rot diseases have been checked by practices such as crop rotation and applying organic manures. There is, however, no convincing evidence that antibiotic substances are involved. Other mechanisms of biological control appear to be more important; namely, competition for oxygen and nutrients, and decreased parasitic action due to increased carbon dioxide in the micro-environment.

DAVID PRAMER

Rutgers University
New Brunswick, N. J.

Sirs:

Dr. Boring's reminder, in your August issue, of the difficulties of making truly random throws of a Buffon needle in empiricizing π is commendable. But I cannot see that the original article on "The Monte Carlo Method" in your May issue is at fault in this respect. In that article, Daniel D. McCracken merely pointed out that the all-important element of randomicity can be readily supplied from tables of random numbers.

We should bear in mind that Buffon trials yield, not "estimates" of π, but tests of the randomicity of the throwing system. In the days when such trials were thought worthy of publication, a man could apparently throw his needle for a few hours, report π correct to 0.01 per cent, and be applauded for his experimental skill. Yet if, almost equivalently, he were to toss a penny 20,000 times and report 10,000 heads, no editor would have dared to publish the result for fear of ridicule.

N. T. GRIDGEMAN

National Research Council
Ottawa, Canada

THE RARE EARTHS

a report by Lindsay, world's largest producer of cerium, rare earth and thorium chemicals

Let's look back billions of years. Far beyond the beginning of history, back to the very formation of the earth. Here the rare earths were created . . . conceived in the raging inferno of a newborn planet.

Down from the high country trickled the streams, joining into rivers, rolling on to the immense seas that covered much of the globe. On the deltas, the rivers deposited their loads of sand . . . some of it *monazite,* the glassy, brown globules that hold the rich treasures of thorium and that peculiar and wonderful chemical clan . . . the rare earths.

This was the beginning . . . this was the formation of the deposits of monazite that are found today in such widely separated locations as the Union of South Africa, India, Brazil and, domestically, certain southeastern and far western states.

* * *

The rare earths are metals, not earths — and they are by no means rare. Together they comprise approximately five thousandths of one per cent of the earth's surface. This group of 15 elements—atomic numbers 57 through 71—has evolved from a role of interesting chemical oddities to a position of exciting importance in scientific and industrial technology.

Until recently, the rare earths remained virtually untouched by commercial investigation. Many researchers believed them unavailable for large scale use because they were difficult to separate. This is no longer true. Lindsay is refining and separating these unique elements in large volume for commercial use. The rare earths offer a rich field for scientific study and hold significant possibilities for profitable application in a wide variety of industrial processes.

The use of rare earth-thorium ores was born with the invention of the incandescent gas mantle late in the 19th century. The key element in the manufacture of these mantles was thorium, which is found in conjunction with the rare earths in monazite ores. Interest in elements 57 through 71 was aroused and since then, they have become increasingly important in a wide variety of manufacturing processes.

Motion picture projectors, lighter flints, alloy steels, ceramic coloring, glass coloring, glass decolorizing, glass, mirror, television picture tube and granite polishing, photosensitive glass, paint driers, sunglasses, nausea preventatives, reagent chemicals . . . these are but a few of the many commercial applications of Lindsay rare earths.

With the invention of the electric light, the demand for gas mantles dropped sharply, and with it this need for thorium. In 1945, however, interest in thorium again shot upward, for this element holds great promise of becoming important in the development of atomic energy for peacetime use. You see, while thorium alone is not fissionable, it becomes so when combined with small amounts of uranium. Thus reactors, using relatively inexpensive amounts of thorium and uranium can equal the electricity-generating power of thousands of tons of coal. The nation's need for this material has prompted Lindsay to accelerate its search for domestic deposits of monazite ore which is now obtained from the Union of South Africa. As more thorium is extracted from this ore, more rare earths are available for industry.

Rare earth and thorium chemicals have attained new importance through the work of Lindsay scientists who, for 53 years, have pioneered the research and development of these chemical tools for industry. This, coupled with extensive raw material sources, has helped Lindsay develop the world's largest facilities for the production of rare earths. Salts of thorium and rare earths are available for prompt shipment—a gram or a carload.

We have noted a few of the industrial applications of rare earth chemicals. There are others and certainly many more as yet undiscovered. If you are curious about the possibility that rare earths may have useful applications in your industrial processes, or would like more information from us, we welcome your inquiry. Technical data is available and the facilities of our research staff may be helpful to you.

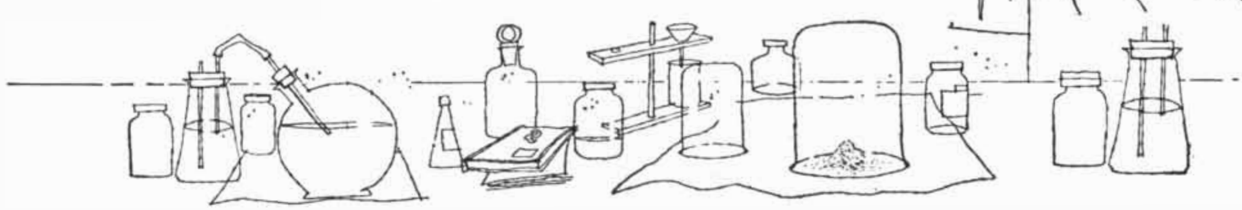
Please address your inquiry to:
Dr. Howard E. Kremers, *Director of Research.*

LINDSAY CHEMICAL COMPANY
264 ANN STREET, WEST CHICAGO, ILL.

Latest addition to Lindsay monazite processing plant at West Chicago.

Part of 12,000,000 pound stock pile of monazite in Lindsay warehouse.

Small section of filtration floor in new plant addition.



Two-part die placed in press—ready to use without time-consuming scraping and finishing.

"SETTING-UP" EXERCISE

New amines mean faster cure for epoxies

New time and labor savers are now cast from epoxy resins. Epoxy dies, like the drop-hammer die illustrated, can often be made in hours, instead of the usual days to weeks of work required by previous materials. Dies are made by Teicher Manufacturing Co., Flushing, N. Y., using resins supplied by the Marblette Corp., Long Island City, N. Y. Rapid curing at moderate baking temperatures, or even at room temperature, is secured through proper selection of casting material and curing agent.

For such casting applications, and for adhesives and coatings, Cyanamid has developed four new amines as curing agents: Dimethylaminopropylamine, Diethylaminopropylamine, Dibutylaminopropylamine, and Iminobispropylamine. Fastest cure is obtained with Dimethylaminopropylamine and longer pot life with those having higher substituents. These amines also are valuable intermediates for products such as surface active agents, pharmaceuticals and dyestuffs.
(New Product Development Department)

Top half or punch of drop-hammer die is poured. Epoxy resin with curing agent "sets up" in a few hours.

Blank of aluminum sheet is inserted between punch and die.

Stamped part after being formed by plastic die.

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50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

OCTOBER, 1905: "Some time ago Messrs. Capitan and Breuil discovered some remarkable drawings of animals executed by the men of the reindeer epoch, in several caves of the Dordogne region in France. In continuing their researches they found other drawings which are of great interest. They found some 30 representations of the mammoth, which is well characterized by its rounded forehead, high skull and the long hairs with which it is covered. In some figures the hair even drags on the ground. This is an indication of the great cold which then existed, and is shown by the thickness of the animal's fur. One very curious drawing seems to represent a great cave lion, and in front of him are four horses which are admirably executed. Another drawing on the walls of the Combarelles cave shows the front of a feline, the rest of which has disappeared under a stalagmite formation. Very remarkable is the figure of a two-horned rhinoceros which is drawn in red at the back of the Font de Gaume cave. The front horn is much longer and thicker than the rear one. On the top of the head is figured a kind of mane of short hair, and there are indications of hair on other parts of the body. We recognize in this figure the *Rhinoceros tichorhinus* with its furry covering, like the specimens which are found in the frozen quaternary earths in the extreme north of Siberia. The figures we mention have a great interest as up to the present there were no drawings of the felines or the rhinoceros, and it was even supposed that the *Rhinoceros tichorhinus* no longer existed at the reindeer epoch."

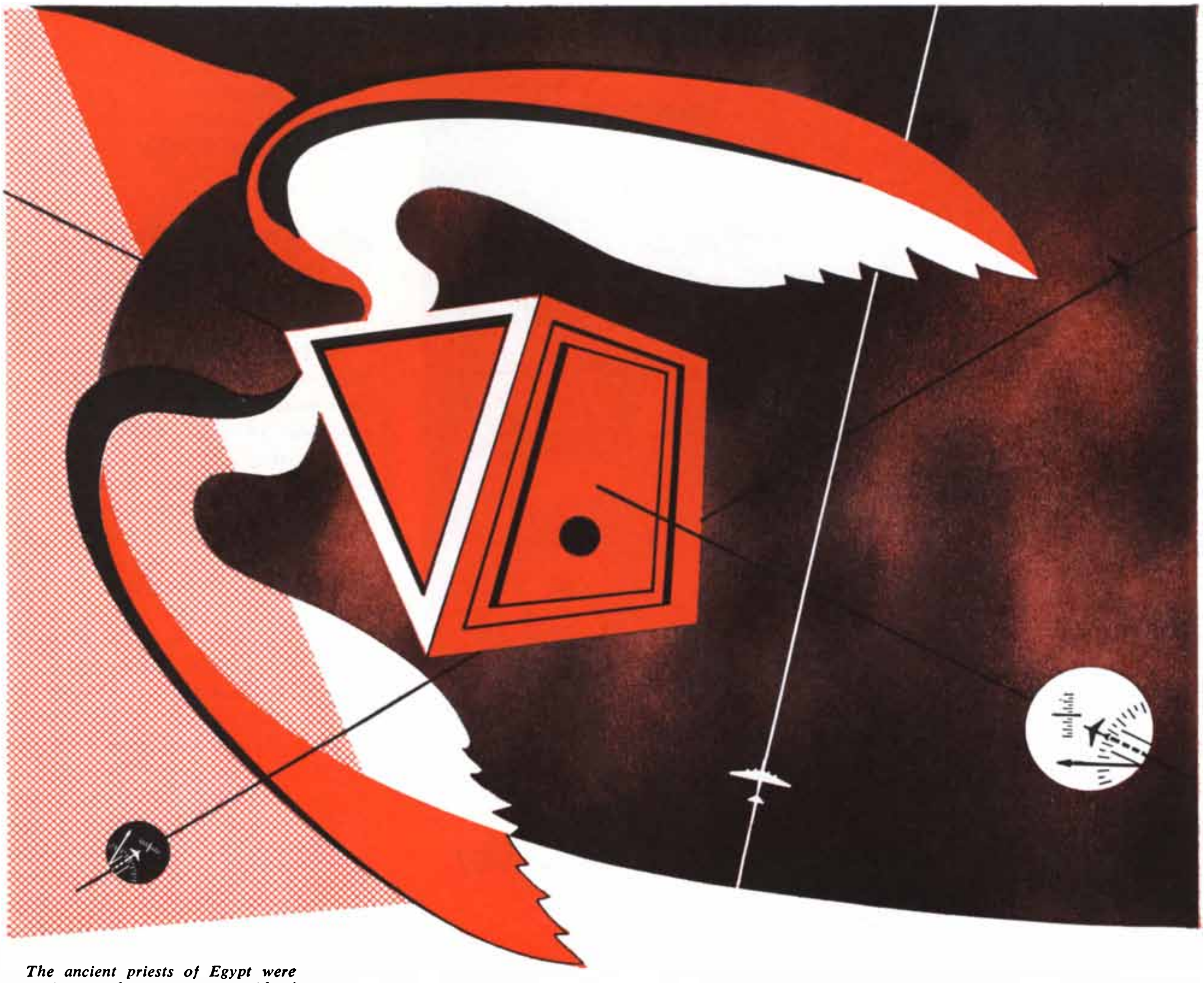
"The recent long-distance balloon race from Liége resulted in a victory for the English competitor, *Vivienne III*, carrying Mr. Leslie Bucknall and Mr. Stanley Spencer. Owing to the unpropitious weather only three vessels started. The English aeronauts had an adventurous journey, the most remarkable circumstance being that for the major part of the journey an altitude of over 16,000 feet was maintained, which constitutes

a record height for a balloon under such circumstances. Even at the altitude of 16,000 feet the aeronauts could distinctly hear the clanging of machinery and the roar of the blast furnaces when passing over the Belgian and German iron districts. At nightfall the aeronauts descended below the clouds to ascertain their bearings, as they were traveling rapidly toward the North Sea. They discerned a large city, and deeming it wise to descend, as they were uncertain of their true position, came to earth near a small village which proved to be Jülich in the Rhenish provinces. Owing to cross currents, they had crossed and recrossed the river Rhine during the journey. This proved to be the greatest distance covered by a balloon in the race."

"A chain device has been invented by Mr. H. D. Weed which can be quickly attached to the wheel of an automobile, and which will effectually prevent its slipping or skidding on muddy, greasy or icy roads, or in deep snow. The chain grip is made up of two circular chains—one on each side of the wheel—connected together by a number of transverse chains which are laid over the tread of the tire. In order to attach one of the grips to a wheel, it is only necessary to lay it carefully upon the tire, and connect together the two ends of each circular chain at the bottom."

"It is surely a sign of the great magnitude of the engineering works of the present day, and the multiplicity of such works, that the magnificent cantilever bridge which is now being thrown across the St. Lawrence at Quebec should have attracted so little attention. The true test of the magnitude of a bridge is not its total length as made up of many individual spans, but the length of the individual span itself, and in this respect the Quebec Bridge is pre-eminent. It reaches across the St. Lawrence River in a single span of 1,800 feet. This is nearly 100 feet greater than the spans of the Forth Bridge cantilevers, which measure 1,710 feet in the clear. Next in length is the Williamsburg suspension bridge, which is 1,600 feet in the clear, and then follow the Brooklyn Bridge, 1,595 feet, and the new Manhattan Bridge adjoining it, which will be 1,470 feet in the clear."

"In the *Comptes Rendus de l'Académie des Sciences* J. Rehns and P. Salmon describe two cases of successful treatment of mild cancerous growths, one being an epithelioma of the lower lip, another a nasal growth. Treatment



The ancient priests of Egypt were engineers whose great pyramid of Cheops was sextant, compass and slide rule—all in one. From sighting the Pole Star, to squaring the compass, to the mathematics of pi—it's all there in the pyramid of Gizeh.

flying pyramids

Wonder of the world for ages, Gizeh's pyramid was a fount of mathematical data—a tool to check measures, an aid to celestial navigation. Today's aircraft are "flying pyramids"—collecting and integrating instantaneous measurements for orientation and control. Kollsman activities cover these seven fields:

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was by application of a radium preparation for 15 to 60 minutes daily for two or three months. The preparation was contained in a box manipulated by the patients themselves. The authors point out the convenience of radium preparations as against Röntgen tubes."

SCIENTIFIC AMERICAN

OCTOBER, 1855: "J. C. Stoddard, of Worcester, Mass., has taken out a patent on a musical instrument that consists of a number of steam whistles of proper relative size, to produce any musical scale, arranged in any convenient manner, and provided with separate valves, by the opening of which they are caused to receive steam or air from any suitable pipe, chamber, or generator."

"The Electric Telegraph is now becoming very generally employed in Europe, and it is gratifying to our countrymen to know that Morse's American system is generally adopted. Certain restrictions, unknown in this country in the use of this wonderful invention, exist on many parts of the European continent, and it is thus made an instrument in the hands of Governments, and not a means of social and commercial promotion. In France all messages to be sent by telegraph must be submitted to the Government authorities at the stations, who have full power to refuse or permit their transmission. In Prussia there are special signs for the use of the officers of the army, and also for civil functionaries, differing from each other, and understood only by them."

"The Twenty-seventh Annual Exhibition of the American Institute opened at the Crystal Palace in New York last month, and is now in the height of its glory. Among the novel machines there shown is the 'Ignition Engine,' invented and patented by Alfred Drake of Philadelphia. This is the first exhibition of the machine; the apparatus consists of a horizontal cylinder of 16 inches diameter, with piston, crank and a large fly-wheel—the whole resembling in size and appearance a steam engine of say 25 horse power. Mr. Drake admits a mixture of gas and air into his cylinder, and then touches it off with a hot iron. An explosion is the result, and the piston is driven to the other end of the cylinder. This operation constantly repeated gives rotary motion to the fly-wheel."

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If you're looking for improvements that start with better working chemical materials, send for a copy of the new Celanese product index. You'll find that Celanese "double-teaming" has been working in your direction.

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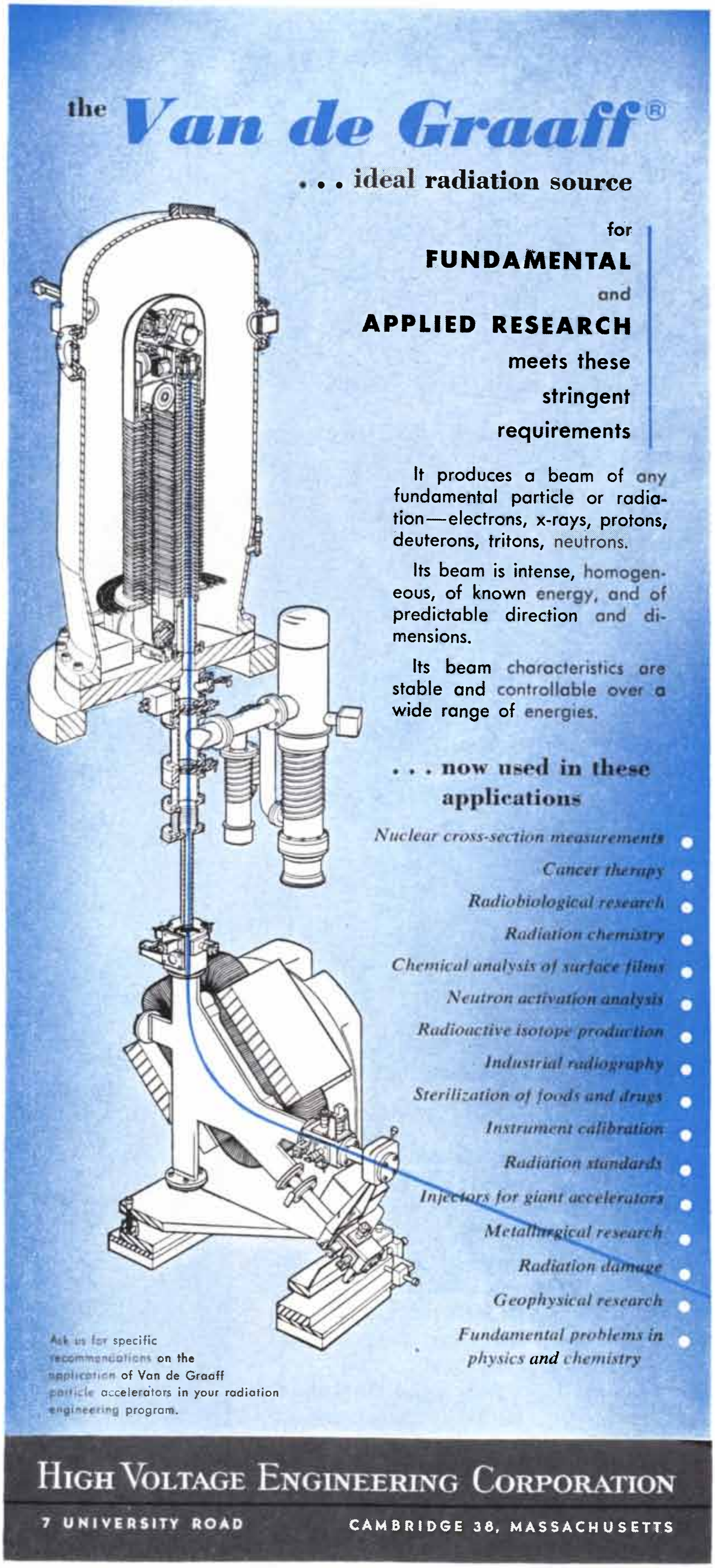
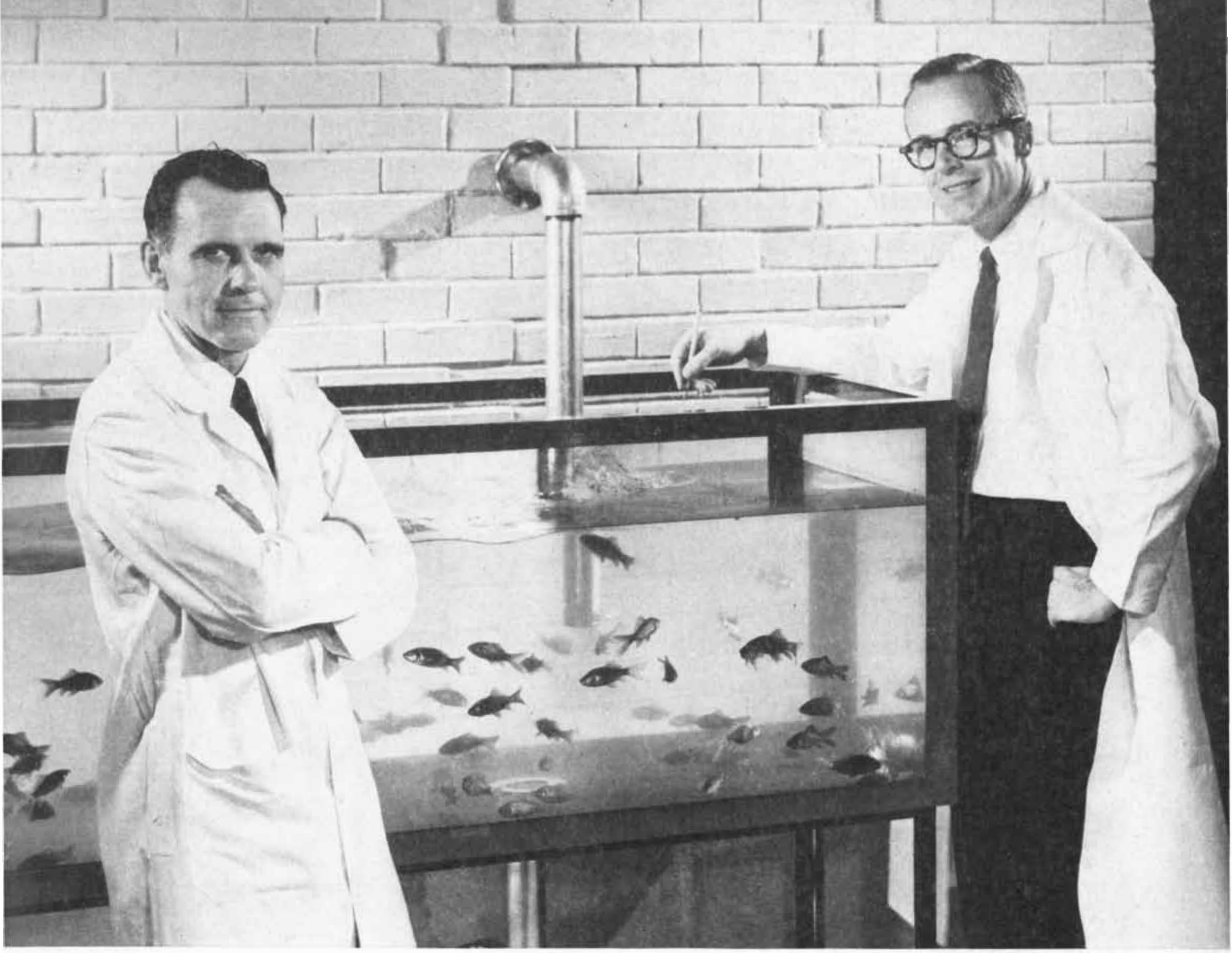


THE AUTHORS

ROBERT A. CHARPIE ("The Geneva Conference" and "Geneva: Reactors") is, at the age of 30, assistant director of research at the Oak Ridge National Laboratory. He represents a new generation—probably the third—in nuclear physics. While the second generation was working on the atomic bomb during World War II, Charpie, a Cleveland boy, was serving in the infantry in Italy. He returned to the U. S. in 1946 and attended the Carnegie Institute of Technology. He also took a D.Sc. in theoretical physics there in 1950, having in the meantime worked as a physicist at the Westinghouse Research Laboratories. He joined the Oak Ridge National Laboratory in 1950. For the past few months, as scientific secretary to the Geneva International Conference on the Peaceful Uses of Atomic Energy, he has been editing the several hundred papers submitted to the Conference. He was instrumental in setting up the Geneva meeting and in building its most popular exhibit—the swimming-pool reactor.

J. M. FLETCHER and F. HUDSWELL ("Geneva: Chemistry") are members of the chemistry division of the Atomic Energy Research Establishment at Harwell, England. Both participated in the Geneva Conference. Fletcher attended Balliol College, Oxford, where he took first class honors in natural science. He later took a Ph.D. at the University of California, which he attended as a Commonwealth Fund Fellow. While there he lived for about a year with Willard F. Libby, the present U. S. Atomic Energy commissioner, who was then at the University of California. From 1934 to 1936 Fletcher was assistant master at Eton College. He joined the Harwell staff in 1948, and is deputy chief scientist in its chemistry division. Hudswell, who has an M.A. from Cambridge University, was formerly a member of the Armament Research Department at Woolwich. He came to Harwell in 1946.

C. A. MAWSON ("Geneva: Biology"), a member of the Canadian delegation to the Geneva Conference, is in charge of the biochemistry section of Atomic Energy of Canada Ltd. at Chalk River, Ontario. He was educated at Victoria University of Manchester, where he took a B.Sc. with honors in chemistry, an M.Sc. in organic chemistry and a Ph.D.



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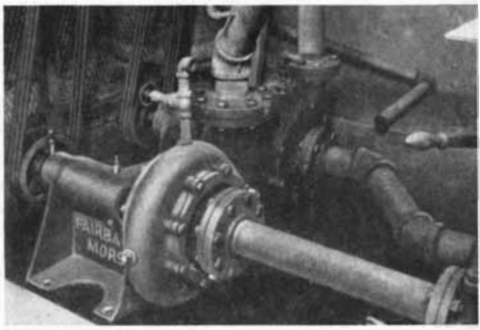

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PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY • RAIL CARS • HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS in physiology. Later he worked on fellowships at the Royal Cancer Hospital and the Westminster Hospital, both in London. His research was on the biochemistry of cancer tissue. From 1937 to 1949 he was in charge of the biochemistry laboratory at the Royal Berkshire Hospital at Reading in the south of England. Since 1949 he has been at Chalk River, where he has been concerned with the increasingly serious problem of disposal of radioactive waste products and with the use of isotopes in forestry and entomology. (Insects, he has learned, have a phenomenal resistance to radiation.) He has also been looking into the body's use of trace quantities of metals, notably zinc. Certain tissues such as the prostate, he finds "concentrate zinc in much the same way as the thyroid concentrates iodine, and we are looking into the possibility that radioactive zinc might be applicable to the treatment of cancer of the prostate. However, there are many technical difficulties still unsolved."

GEORGE GAMOW ("Information Transfer in the Living Cell") is the well-known originator of the pixie 20th-century explorer "Mr. Tompkins." Gamow is professor of theoretical physics at the George Washington University in Washington, D. C. Most of his studies have been in nuclear physics and cosmology, but he frequently forays into other fields. He has contributed articles to SCIENTIFIC AMERICAN on subjects ranging from glaciology to "Modern Cosmology," published in the issue of March, 1954. Gamow believes that new advances in fundamental biology "are transforming it from a mostly descriptive into an exact science, thus opening new fields for theoretical studies." He notes that his attention has been wandering from atomic nuclei and protons to nucleic acids and proteins.

HAROLD E. HIMWICH ("The New Psychiatric Drugs") is director of research at the Thudichum Psychiatric Research Laboratory in the Galesburg State Research Hospital in Illinois. He grew up in New York, where both his parents were physicians, and was graduated from the College of the City of New York in 1915. After taking his M.D. at Cornell University in 1919, he interned at the Bellevue Hospital in New York City. From 1926 to 1946 he taught physiology and pharmacology at the Albany Medical College in New York State, then became chief of the Clinical Research Division of the Army Chemical Corps Laboratories in Maryland. His current

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research program ranges from basic studies of drugs to clinical evaluation of their effects.

H. N. SOUTHERN ("Nocturnal Animals") is senior research officer in the Bureau of Animal Population at the Botanic Garden at Oxford, England. He writes that he cannot remember the time when he was not fascinated by birds, mammals and flowers. He studied classics at Oxford University and spent some time in a London publishing house. But the pull of natural history was so strong that he returned to Oxford, graduated a second time in zoology and joined the staff of the Bureau of Animal Population. During World War II he worked on the control of rabbits, rats and mice. Since then he has turned to examining the role of birds of prey in controlling populations of voles and mice.

H. BENTLEY GLASS ("Maupertuis, a Forgotten Genius") is professor of biology at The Johns Hopkins University and Associate editor of *The Quarterly Review of Biology.* A note about him appeared in the August, 1953, issue of SCIENTIFIC AMERICAN, along with his article on "The Genetics of the Dunkers." He has been president of the American Institute of Biological Sciences since 1954 and was appointed this year to a six-year term on the Advisory Committee in Biology and Medicine of the Atomic Energy Commission. He went to Rome last April as an official U. S. delegate to the General Assembly of the International Union of Biological Sciences.

ALFRED McCORMACK, who reviews Charles P. Curtis' book, *The Oppenheimer Case,* is a member of the New York law firm of Cravath, Swaine and Moore. Born in Brooklyn, N. Y., he graduated from Princeton in 1921 and then went to the Law School of Columbia University for his LL.B. He began his career as law clerk to U. S. Supreme Court Justice Harlan F. Stone. After the surprise attack on Pearl Harbor had exposed defects in the communication of military intelligence, Secretary of War Henry L. Stimson called McCormack into service as a special assistant with the assignment of cutting military red tape. He was commissioned a Colonel to organize and head a special branch of the Military Intelligence Division of the Army General Staff. For his war service he received the Distinguished Service Medal. McCormack is chairman of the Board of Visitors of the Columbia Law School and a trustee of the Practicing Law Institute in New York City.

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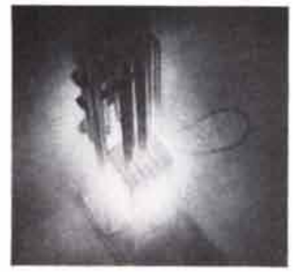

THE COVER

The picture on the cover is a photograph of the swimming-pool reactor showing its uranium fuel load, bathed in the blue glow known as the Cerenkov effect. This reactor was the star attraction among the exhibits at the International Conference on the Peaceful Uses of Atomic Energy in Geneva. Its core, immersed in a large tank of water, consists of 23 fuel elements of a new type—curved plates of uranium alloyed with aluminum. The total amount of uranium is 18 kilograms (about 40 pounds) of which 3.6 kilograms is the fissionable fuel uranium 235. The tank, 10 feet in diameter and 22 feet deep, contains 13,000 gallons of water cleared to the purity of distilled water. The water acts both as a moderator and as a shield protecting bystanders from radiations in the reactor. This reactor is ideal for research and for instruction in reactor technology.

THE ILLUSTRATIONS

Cover photograph by Union Carbide and Carbon Corporation

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37-42	Kryn Taconis
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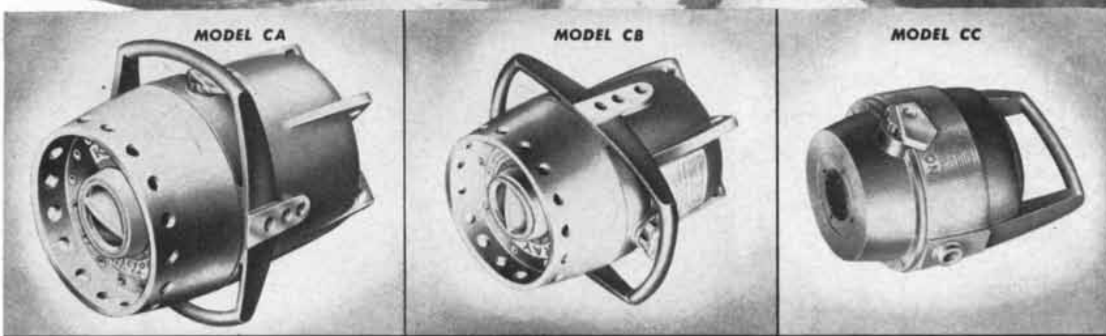

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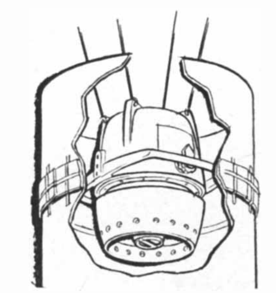

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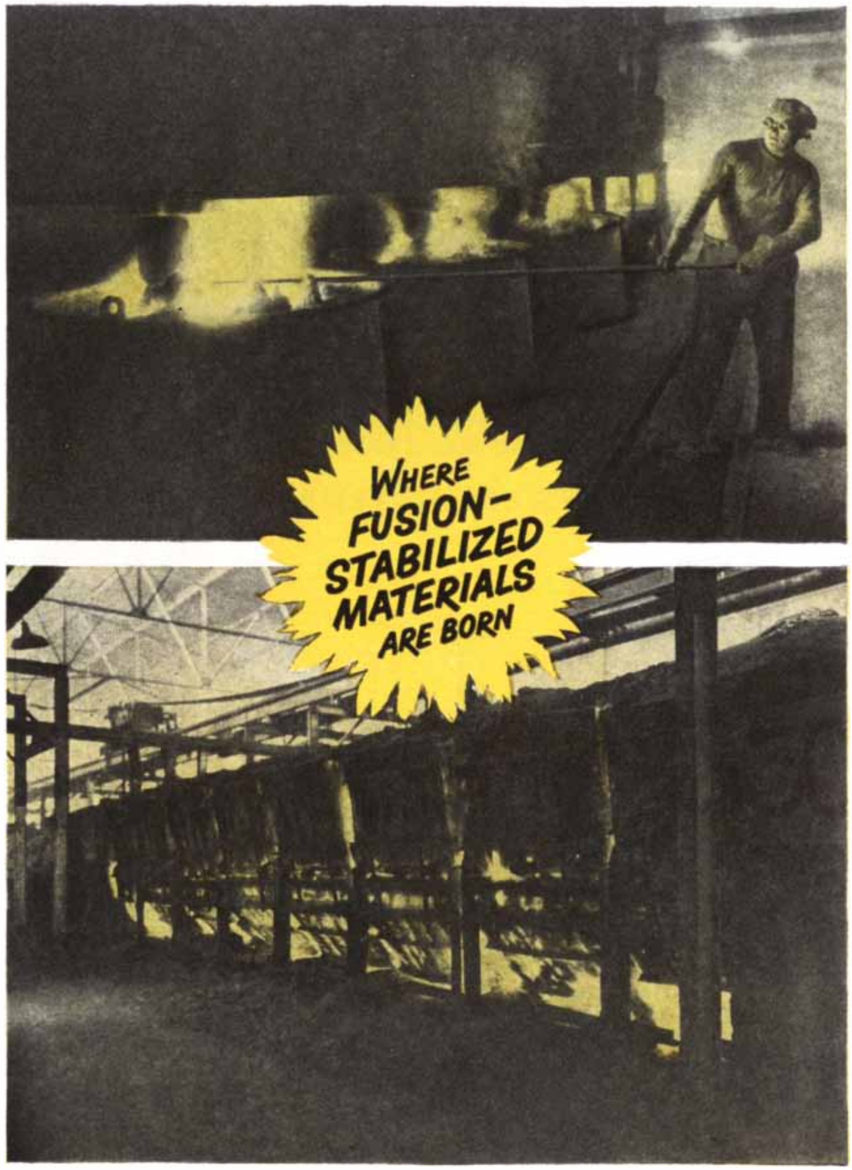

Above: Norton arc-type furnaces. *Below:* Norton resistance-type furnace.

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SCIENTIFIC AMERICAN

OCTOBER, 1955 VOL. 193, NO. 4

THE GENEVA CONFERENCE

In a setting rich in a history of men's quest for peace, international cooperation was furthered by the greatest scientific conclave of all time. Delegates of 72 nations shared their nuclear knowledge

by Robert A. Charpie

For two weeks in August Geneva was the headquarters of the scientific world. The International Conference on the Peaceful Uses of Atomic Energy was not only the largest meeting to date on nuclear energy but probably the most exciting international gathering of scientists ever held. More than 1,200 delegates from 72 nations came together after long separation and freely discussed all phases of the tremendous new field of atomic energy. The dramatic circumstances and character of the Conference were perhaps best attested by the veteran science reporter who cabled his editor: "It has become a commonplace to see American and Soviet scientists with their heads together vigorously debating the pros and cons of some highly technical point discussed during the Conference."

Many had felt beforehand that the Conference, surrounded by highly controversial issues, was doomed to fail in its objective of launching effective international cooperation in the peaceful uses of atomic energy. But as Sir Christopher Hinton of the British delegation observed, the meeting "far exceeded the wildest hopes of those who organized it." Lewis L. Strauss, chairman of the Atomic Energy Commission, who headed the U. S. delegation at Geneva, indicated that President Eisenhower was so impressed with the success of the Conference that the U. S. will introduce a resolution into the forthcoming session of the United Nations General Assembly calling for another such conference to be held in Geneva in two or three years. The suggestion was immediately endorsed by delegates of other nations, including the U.S.S.R.

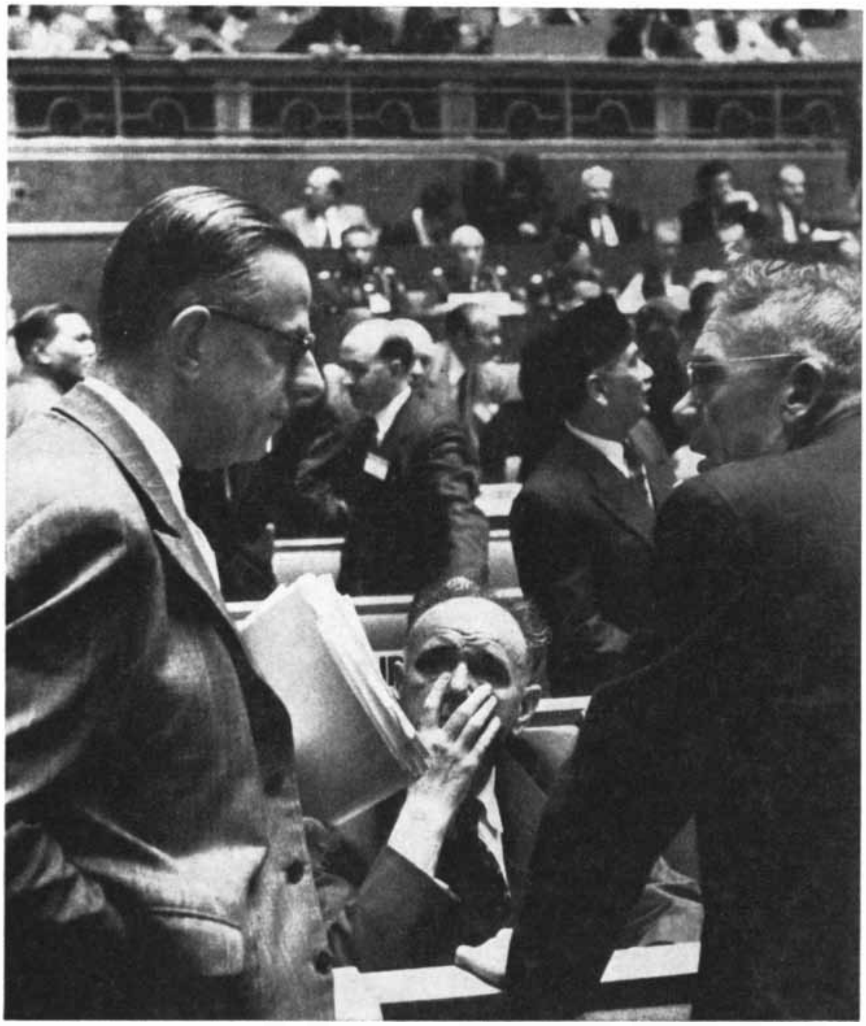
The International Conference was first proposed in April, 1954, by Mr. Strauss in a speech at San Francisco. He hoped that an exchange of information and ideas among scientists of all nations might pave the way for more substantial cooperation in atomic energy, which in turn would eventually result in the formation of the international atomic agency that had been proposed by President Eisenhower four months earlier in his famous "atoms for peace" speech before the UN.

The Conference was officially constituted on December 4, 1954, when the United Nations General Assembly unanimously approved a joint resolution, presented by Henry Cabot Lodge on behalf of Canada, the United Kingdom and the U. S., to sponsor such a conference. The UN appointed a seven-nation advisory committee to aid Secretary-General Hammarskjold in the organization of the Conference. The nations serving on the Advisory Committee were Brazil, Canada, France, India, the United Kingdom, the U.S.S.R. and the U. S.

At a meeting in January the Advisory Committee laid the groundwork for the Conference. It prepared a preliminary topical agenda and rules of procedure. The members of the Committee, all scientists, chose to follow the pattern of a scientific meeting rather than of a UN political meeting. This decision contributed greatly toward making the Conference a success, operationally as well as scientifically.

The Advisory Committee recommended as the two principal officers of the Conference Dr. Homi J. Bhabha, Indian Cabinet member and chairman of the Indian Atomic Energy Commission, and Walter G. Whitman, head of the chemical engineering department at the Massachusetts Institute of Technology and a member of the General Advisory Committee to the U. S. Atomic Energy Commission. Mr. Hammarskjold appointed Dr. Bhabha president of the Conference and Professor Whitman its secretary-general. Professor Whitman was charged with the responsibility of organizing the detailed operation of the Conference.

After the January meeting the approved topical agenda and rules of procedure were circulated to the 84 countries which are members of the UN or its specialized agencies. Each nation was invited to submit, by May 15, abstracts of the papers it proposed to offer for presentation to the Conference. Meanwhile Professor Whitman and his deputy, Viktor S. Vavilov of the U.S.S.R., with the aid of the members of the Advisory



LEADERS of medical research in three countries confer at Geneva. From left to right they are J. F. Loutit of Britain, Louis Bugnard of France and Shields Warren of the U. S.

MEDICAL SESSION in the Assembly Hall on "Safety Standards and Health Aspects of Large-Scale Use of Atomic Energy" was attended by experts from many nations.

Committee, assembled an international scientific secretariat. This group, which began work in early May in New York, was composed of 19 young scientists from 13 countries. They were chosen to represent virtually every field of research within the purview of the Conference. In the short time of three months the scientific secretariat completed the plans for the conduct of the Conference, including a detailed agenda for the presentation of papers. The work of this secretariat was itself an outstanding demonstration of effective international cooperation in the field of atomic energy.

The secretaries prepared a four-language glossary of nuclear energy terminology, consulted on translation problems, assisted in the technical training of interpreters and reporters for the Geneva meeting, and digested and disentangled the difficult technical papers for the benefit of the press. These special problems were solved by small international working parties. The esprit de corps which developed in the secretariat is one of the author's most cherished memories.

The principal business of the Conference was the presentation of the scientific papers in technical sessions. From 1,125 abstracts submitted to the Conference, 474 papers were selected for oral delivery at Geneva; all the contributions will be included in the published record.

The first three days of the Conference were devoted to discussions of topics of broad general interest. For example, there were papers on the world's requirements for energy during the next 50 years, on the economics of nuclear power, on the capital investment required to initiate and sustain a large nuclear energy enterprise and on the possible future role of nuclear energy in supplying the power needs of the world. Two high lights of the general sessions were the descriptions of the U.S.S.R. atomic power station reactor and of the U. S. boiling-water reactor—the first central station reactors in the world designed and built to deliver useful quantities of electricity. The Russian station is a 5,000-kilowatt power plant near Moscow; the U. S. power reactor is at the National Reactor Testing Station at Arco, Idaho.

One of the major surprises of the Conference was provided by President Bhabha in his opening address. In setting the stage for the discussions on the role of nuclear energy in the future Dr. Bhabha predicted that within 20 years it will be possible to derive energy from

OPENING SESSION was held in the General Assembly Hall of the United Nations in the former Palace of the League of Nations. The session was notable for the prediction by Conference President Homi Bhabha that the energy of nuclear fusion will be harnessed.

NIELS BOHR AND I. I. RABI, of Denmark and the U. S., were among the Nobel prize winners in physics who gathered at Geneva to discuss peaceful uses of atomic energy.

V. I. VEKSLER (*left*), the leader of the Soviet Union's accelerator research, and a col-

the controlled fusion of heavy hydrogen nuclei. He pointed out that since heavy water is present in ordinary water to the extent of 1 part in 5,000 such a technological break-through would guarantee mankind a source of abundant energy essentially forever. Bhabha disclosed that scientists of the Indian Atomic Energy Commission are already working on several problems connected with obtaining the controlled release of thermonuclear energy. There were no technical discussions of the subject on the agenda at Geneva, but it was a topic of informal conversation among the delegates.

Representatives of both the U. S. and England acknowledged that they are doing some work on evaluating the problems of controlling fusion reactions. In a press conference Mr. Strauss said that the difficulties which beset the achieving of a controlled thermonuclear reaction appear so great that he felt it would be a very long time before the fusion process could be tapped as an important energy source.

Another feature of the general sessions was the publication by the U. S. of a price list for some of the critical materials on which nuclear energy depends. For example, heavy water was priced at $28 per pound and uranium at $11,000 per pound of contained uranium 235 when the U-235 content is 20 per cent.

In addition to topics involving reactors, delegates at the general sessions

CYRIL SMITH (*left*), University of Chicago metallurgist, lunches with G. V. Kurdyumov of the U.S.S.R. on the Palace terrace.

PIERRE GUILLAUMAT (*left*), chief of the French delegation, with Francis Perrin, French High Commissioner of Atomic Energy.

league talk with A. Lundby (*right*), a prominent young nuclear physicist of Norway.

HOMI BHABHA of India, presiding officer of the Conference (*right*), chats with A. M. Gaudin of the Massachusetts Institute of Technology after a session in the Assembly Hall.

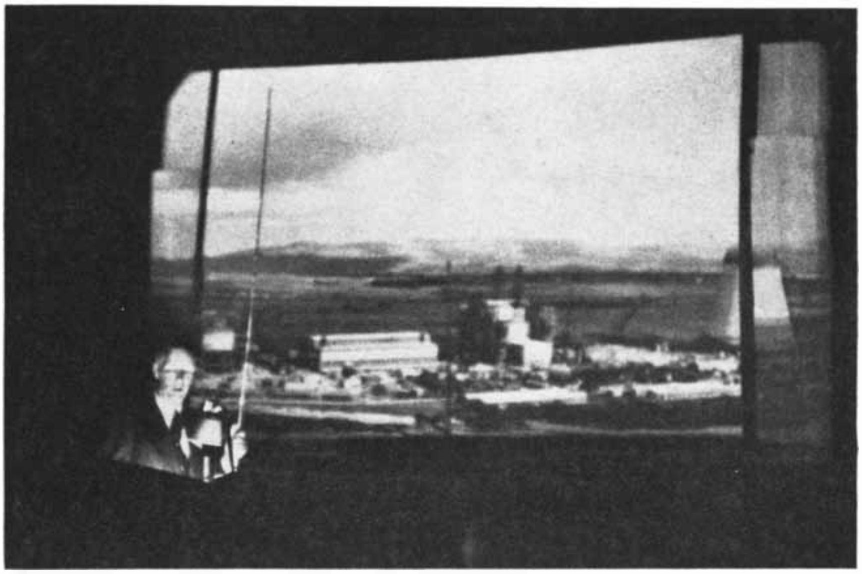
heard papers on recent developments in the uses of radioisotopes and on the biological effects of radiation. A. K. Guskova and G. D. Baisogolov of the U.S.S.R. reported on a case study of two Russian workers who accidentally received near-lethal doses of radiation while working around a reactor. They described the details of the treatment which was successful in returning these patients to normal health.

After the general sessions the Conference split into three sets of parallel technical sessions. The first was concerned with reactors and physics, the second with chemistry and technology, the third with the life sciences and the uses of radioisotopes. The central theme of the Conference—full exchange of information—was emphasized in every paper and every discussion.

In the reactor section the papers presented detailed designs for advanced power reactors as well as what has already been learned from operating experience with research reactors and experimental power reactors. There were reports on the information that has been obtained from experiments concerning the breeding of fuel—both plutonium and uranium 233. For the first time there were detailed discussions of techniques for fabricating fuel elements and for recovering unburned fuel from fission products, also of the effects of irradiation on the physical properties of reactor

VIKTOR VAVILOV (*right*), of the Soviet Union, served as Deputy Secretary-General of the staff for the Geneva Conference.

SIR JOHN COCKCROFT (*left*), chief of the British delegation, talks with a newsman during an intermission in the daily sessions.



BRITISH PLANS for the Calder Hall atomic power station are explained with slides by Sir Christopher Hinton, Managing Director of the United Kingdom Atomic Energy Authority.

U. S. AND U.S.S.R. reactor designers get together as the American (*right*) explains the blueprints and details of a U. S. research reactor to the Russians at the Geneva Conference.

materials. The physicists of the various countries compared their methods and results in the all-important task of measuring the nuclear reaction cross sections of the fuel materials, and their results, developed independently, showed remarkably close agreement [*see article on page 56*].

In the biological sessions the delegates discussed fully the effects of radiation on animals and the state of current research on treatments for radiation sickness, as well as the manifold uses of radioactive isotopes in various branches of medicine and research.

Taken as a whole it seemed to observers that a genuine effort was made by every participant in the Conference to present the most up-to-date information available on every subject on the agenda.

An important part of the Conference was the array of elaborate technical exhibits in the Palace of the Nations. There were displays by various governments on every aspect of the peaceful uses of atomic energy. France demonstrated, among other things, some special operations in the raw materials field. The United Kingdom showed some interesting fuel-element fabrication techniques. The Soviet Union's display included elaborate reactor models. The U. S. exhibit was very comprehensive, including not only the operating swimming-pool reactor but also such other large items as a technical library of documents on the whole field of nuclear energy, a section on the medical applications of radioisotopes and an operating demonstration of the separation of uranium from fission products by solvent extraction, combined with an installation for performing chemical analyses by remote control. The library drew about 1,000 fascinated visitors each day. At the end of the Conference it was presented to the UN to be maintained permanently in the Palace of the Nations.

Several technical movies had been prepared especially for the Conference. The two most dramatic were the Soviet film story of their first atomic power station and the U. S. film on reactor safety experiments conducted at Arco by the Argonne National Laboratory. The audience was intrigued by the tests named "Borax" (for "Boiling Reactor Experiments") in which a reactor of the boiling-water type was allowed to "run away" in order to help establish realistic safety criteria for water-moderated reactor systems. In addition to showing that such reactors can be made inherently safe by careful design, the Borax experiments gave scientists some evidence on the possible effects of a reactor disaster.

The U. S. swimming-pool reactor was by far the most popular exhibit at Geneva. During the two weeks of the Conference more than 60,000 people visited the reactor building.

The reactor was designed, constructed and operated by the staff of the Oak Ridge National Laboratory under the direction of C. E. Winters. It is composed of a lattice of uranium-aluminum plates immersed in a large pool of water, which serves as the moderator, coolant and radiation shield. The reactor fuel charge is 20 kilograms (44 pounds) of uranium enriched to 20 per cent in U-235. This is exactly the type of fuel that the U. S. has contributed to the fissionable material pool of the proposed international atomic agency. Thus the Geneva Conference reactor is a prototype of a research reactor which might be built by any nation out of an allotment from the pool. With the 200 kilograms of U-235 contributed to the pool by the U. S., 40 to 50 research reactors of this type could be constructed.

Many non-American scientists carefully examined the swimming-pool reactor's construction and operational details. Several of them, including D. V. Blokhintsev of the U.S.S.R., operated the reactor. A steady stream of illustrious visitors were shown how it worked. The most famous was President Eisenhower, who took time off from the four-power "summit" meeting in Geneva on July 20 to inspect and operate the already assembled reactor.

On August 20 the reactor and its building were formally turned over to the Swiss Government, which purchased them from the U. S. for $180,000, about half the construction cost. The Swiss Commission for Nuclear Research will move the reactor and building to Wurenlingen, near Zurich.

SITE OF CERN, the European center for nuclear research, was visited by many delegates interested in the international project. The excavation is for the magnets of the 600-million-electron-volt synchrocyclotron, which are scheduled to be erected at Geneva this month.

The delegates to the Conference heard a series of evening lectures delivered by distinguished scientists on topics of general interest. Niels Bohr of Denmark opened the lecture series with a discussion of the philosophical foundations of modern physics. A. L. Kursanov of the Soviet Union and Alexander Hollaender of the U. S. spoke on the use of isotopes in biology and medicine. George de Hevesy of Sweden and Willard F. Libby of the U. S. discussed isotopes in research and isotopic dating. Hans Bethe of the U. S. and Louis Leprince-Ringuet of France lectured on recent theoretical and experimental results in the study of elementary particles.

One of the most interesting moments was provided when V. I. Veksler of the Soviet Union and Ernest O. Lawrence of the U. S. spoke on accelerators. Professor Lawrence discussed a U. S. research program aimed at the evaluation of the possibilities of obtaining very large currents of energetic charged particles from an accelerator. His talk served as the focal point for many interesting discussions in Geneva. Veksler, one of the discoverers of the synchrotron principle, reported that the Soviet Union was building a 10-billion-electron-volt accelerator and planning one of 50 to 100 Bev.

The closing evening lecture was delivered by Sir John Cockcroft, director of the United Kingdom Atomic Energy Research Establishment at Harwell. His authoritative talk, in which he predicted that nuclear energy will occupy a central role in the future progress of our civilization, was for many of the delegates the high light of the entire Geneva program.

In addition to the Conference itself Geneva played host to the Atomic Trade Fair which was held at the Palais des Expositions in the central part of the city. The Trade Fair consisted of both industrial and governmental exhibits. Its most popular displays were a huge British exhibit on the Calder Hall reactor power plant, scheduled to produce useful electricity in late 1956, and a U. S. Information Agency exhibit on the "Atoms for Peace" program of this country.

The Geneva Conference represents a progress report, dated August, 1955, on all the peaceful uses of atomic energy. Any nation interested in embarking on a nuclear energy enterprise can look to the Proceedings of the Conference as a reliable guide on the prospects and methods for utilizing this new energy source in the near future. Every paper submitted will be printed in full. The U.N. expects that the published Proceedings, which will inevitably become one of the standard reference works on nuclear energy, will be available in English early in 1956.

Considerable profit has already accrued from having scientists of all countries discuss their mutual technical problems. The Conference established that, at least in a limited area, it is possible to overcome formidable language barriers and political precedents. We realize more sharply than ever before that neutrons create the same problems in every country. We hope that Geneva-1955 will become a turning point, and that by broadening the cooperation which the Conference initiated it will be possible to realize, at an early date, the full potential of nuclear energy working for the good of all mankind in a world at peace.

GENEVA: Chemistry

The exchange of ideas on reactor material problems, from prospecting to fuel element fabrication, opened the way to work on design of power plants for every nation's needs

by J. M. Fletcher and F. Hudswell

The Conference had as its short title "Atoms for Peace," but "atoms for power" is a more descriptive title for its main theme. The reports and discussions left no doubt that the rate at which a world-wide higher standard of living can be achieved will depend largely on the rate at which nuclear power can be provided. To fill their power needs countries such as India, Brazil and Australia will require substantial amounts of nuclear power by the end of the century.

The realization of abundant "atoms for power" at an economic price was shown to be dependent on four main factors: (1) the engineering of reactors so that they will be cheap to build, safe and reliable in operation and easily maintained; (2) supplies of uranium and thorium; (3) efficient extraction and fabrication of these metals; and (4) advances in chemical and metallurgical technology. The "B" sessions of the Conference, which will be reviewed in this article, covered the last three of these points.

The Conference brought forth a number of designs for reactors which are likely to be economical within a decade for large power stations (100,000 kilowatts and more). But plans for economic small reactors (about 10,000 to 20,000 kilowatts) suitable for the smaller or less industrialized countries were conspicuously absent or nebulous. There will be a very real need for such reactors if the disparity between the advanced and backward countries is to be narrowed rather than widened. And indeed the potential world demand for small reactors may well be 10 times that for the "giants." This emphasizes the importance of the Conference reports on studies of new materials, which may make the small power reactor a practicality. The production reactors so far have had to rely on established materials and simple systems: rods of uranium metal for the fuel; graphite or water (light and heavy) for the moderator; water, air or carbon dioxide for the coolant; steel for construction. With these materials alone, engineers expect to be able to design giant reactors which will produce power at an economic price. But a small reactor along these lines will not work unless it uses a heavily enriched fuel, requiring large quantities of fissile material (such as U-235). New materials—*e.g.*, liquid sodium as the coolant, beryllium as the moderator, zirconium for the "plumbing," and fuels in solution form—may open the way for reactors generating a moderate amount of power and needing only a modest investment of fissile fuel.

Three of the 18 Conference sessions on the chemical technology of reactors dealt with "special" materials. They include heavy water, graphite, zirconium and so on. All must be refined to a high level of purity. Tons of heavy water are required for a reactor. Since ordinary water contains heavy water only in tiny amounts (about one seventieth of 1 per cent), and since present separation

OTTO HAHN OF GERMANY, at right, who 17 years ago with F. Strassman discovered uranium fission, presides over session on "Facilities for Handling Radioactive Materials."

processes tend to be low in efficiency, the throughput of ordinary water required to produce each ton of heavy water is extremely large. The chief production processes are electrolysis and fractional distillation (the two forms of water having slightly different boiling points). P. Baertschi and W. Kuhn of Switzerland suggested that the best method of obtaining pure heavy water is likely to be a combination of electrolysis and distillation.

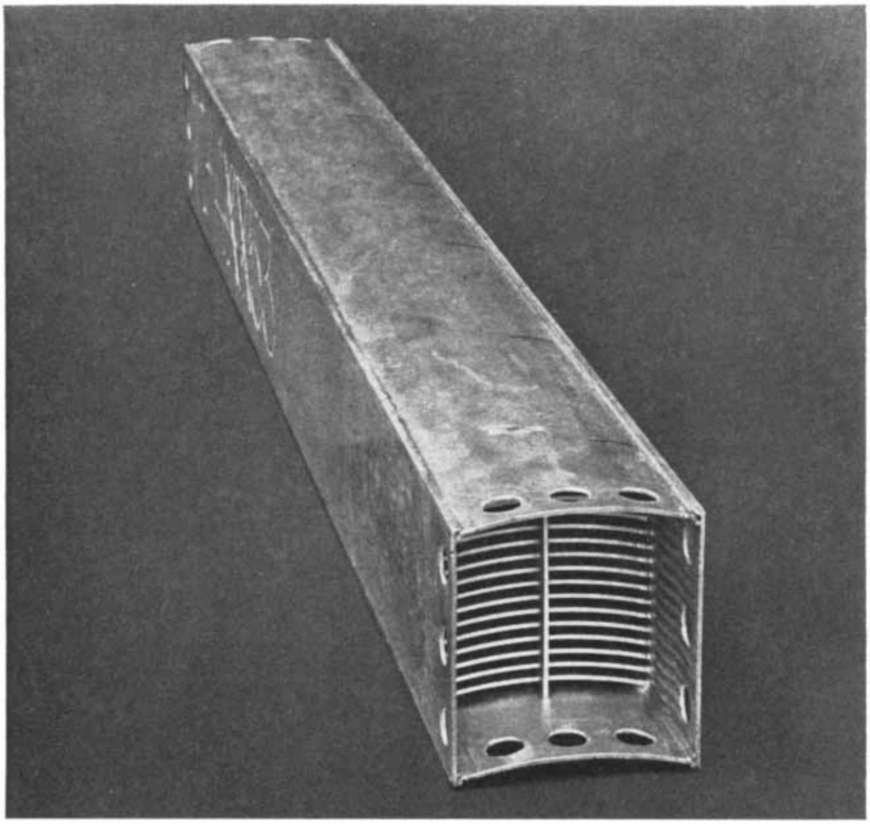
Graphite, now used extensively as a moderator, must be prepared in quantities of hundreds of tons with high chemical purity and preferably with a high density. Dense graphite might be used without a covering can in reactors cooled by liquid metals. A U. S. team explained in outline how graphite can be made from a number of organic compounds (*e.g.*, petroleum coke). One great disadvantage of graphite as a moderator is that it burns away at high temperatures in air. But there is promising research on the use of a solid coating over the graphite to shield it against oxidation.

Zirconium metal has come into prominence because it has very good resistance to corrosion and absorbs comparatively few neutrons in a reactor. This is a rare combination of properties. But there is often a snag between the fact and the ideal. In its ores zirconium is invariably accompanied by hafnium, which absorbs neutrons all too readily. Ever since the discovery of hafnium in zirconium ores, efforts have been made to develop an easily worked separation process. The first methods were extremely laborious, because the two elements are chemically almost as alike as two isotopes of the same element. But the needs of the atomic energy industry have stimulated relentless pursuit of the problem in various countries. These efforts have succeeded so well that zirconium can now be obtained with a hafnium content of less than one hundredth of 1 per cent. Several practicable methods for achieving this end were described at the Conference. The most promising appears to be a solvent extraction process: the compounds obtained from the ore are dissolved in an aqueous solution with nitric acid and sodium nitrate, and zirconium is then extracted by a solvent consisting of tributyl phosphate diluted with an inert liquid.

The Conference was marked by the declassification of a great deal of information about the fissionable fuel itself. The classical fuel element is a rod of natural uranium metal (about one foot long) encased in an aluminum or magnesium "can." The can keeps in the fission products and protects the uranium from attack (chiefly corrosion) by the coolant outside. In the production of the uranium rods, a highly purified uranium compound (uranium nitrate or oxide) is converted to the fluoride and then reduced by calcium or magnesium. One U. S. paper described a more advanced type of fuel element, now used in modern research reactors and in pressurized-water power reactors; it was exhibited in the swimming-pool reactor at the Palais des Nations in Geneva. This new fuel element is a set of curved plates of uranium and aluminum, set in a concertina arrangement [*see photograph on the next page*]. Compared to the classical rod, the elegance and finish of the new element reminds one of the difference between a jet airplane and a prewar biplane.

The crux of a successful reactor may lie in designing a fuel element which can be left in the reactor for a relatively long time without becoming distorted or disrupted. An excellent paper by J. P. Howe showed how intensively this problem is being pursued in the U. S. He mentioned such ideas as uranium bonded in zirconium, uranium oxide dispersed in an aluminum or ceramic body, uranium carbide dispersed in graphite. The fuel aspects of plutonium have been much less discussed, but it is abundantly clear that within a decade it also will be used as a fuel. Howe suggested that a dilute alloy of plutonium in uranium will be used in breeder reactors employing

TECHNICAL SESSIONS, like this one devoted to the chemistry of fission products, provided headphones so that delegates could tune in on running translations of papers into English, French, Russian or Spanish, the four official languages of the Conference.



FUEL ELEMENT of improved U. S. design encases uranium-aluminum alloy plates in aluminum box two feet long. It was exhibited in the swimming-pool reactor at Geneva.

fast neutrons. In whatever form it is used, plutonium will pose novel problems in technology. On account of its radioactivity, the metal will have to be refined, fabricated and handled in enclosed equipment. As for thorium, from which the fuel uranium 233 may be made, a process for producing it by the electrolysis of a fused salt was described in a paper by G. E. Kaplan of the U.S.S.R. This paper illustrated the attention being devoted in advanced industrialized countries to the use of electricity rather than chemicals for producing metals from their compounds.

The effects of radiation on reactor materials are sufficiently important to have occupied three sessions. Graphite, fuel elements, structural materials, water (light and heavy)—all these have to withstand the disruptive forces of the fission process and intense bombardment by neutrons, gamma rays and so on. It was evident that a large amount of experimental effort had been expended by all the nations possessing reactors on measuring the effects of radiation upon the physical, electrical and mechanical properties of materials. These papers and others indicated that scientists in the United Kingdom and in the U.S.S.R. have gone ahead of their American colleagues in making precise measurements and devising original methods for laboratory investigations, though the U. S. is ahead in the more practical aspects of materials technology. A U.S.S.R. paper described a difficult technique of photographing irradiated uranium metal under the electron microscope; because the metal is radioactive, all the operations have to be remotely controlled. Another example of good experimental work in this subject, reported in a British paper, was a picture showing, at the crystal level, how irradiated uranium rods had been warped.

In the sessions on chemical processing, the ion exchange and solvent extraction methods were the stars of the show. The wide usefulness of ion exchange resins in industry is well known. In the field of reactor fuel purification, the so-called "anion" exchange resins, which exchange negative ions, are very much in the forefront. Metals usually form positive ions in solution, but the heavy metals tend to form negative ones. In mixtures of ores in liquor form (after the ores have been treated with acid or alkalies) anion exchange resins have the uncanny facility of being able to hold on to the uranium but to none of the other metals present, such as iron, chromium or nickel. These resins can also separate U-233 from thorium and plutonium from uranium. K. A. Kraus of the U. S., who did the basic laboratory work on which the anionic processes depend, was present at the Conference, and the delegates, many of whom have read his publications for years, were delighted to meet him there. In the brief space of 20 minutes allotted to him, Kraus gave a classical summary of the research which determined the conditions under which metals form negatively charged (anionic) species.

An equally striking chapter of the Conference was the disclosure of the versatility and usefulness of solvent extraction for purifying uranium and for the efficient separation of fissile material from impurities. Many details of the operating conditions have been secrets closely guarded by the U. S. and the United Kingdom, because their processes for purifying uranium and extracting plutonium have relied a great deal on this method. Nothing was more indicative of the whole spirit of the Conference than the extensive practical information about the processes that was given in papers by American and British workers. Although French experience in this field has been limited, it was a pleasant reminder of the co-ordination of the Allied efforts during the war to hear an account by Bertrand Goldschmidt of France of the investigations in 1944 by a joint U.K.-Canadian team who were convinced that solvent extraction held out the greatest promise for the future. There were exhibits from the U. K. and from the U. S. of the process at work with uranium solutions. These dynamic models were a source of considerable interest to the numerous delegates and observers who at all times thronged the exhibitions in the Palais des Nations.

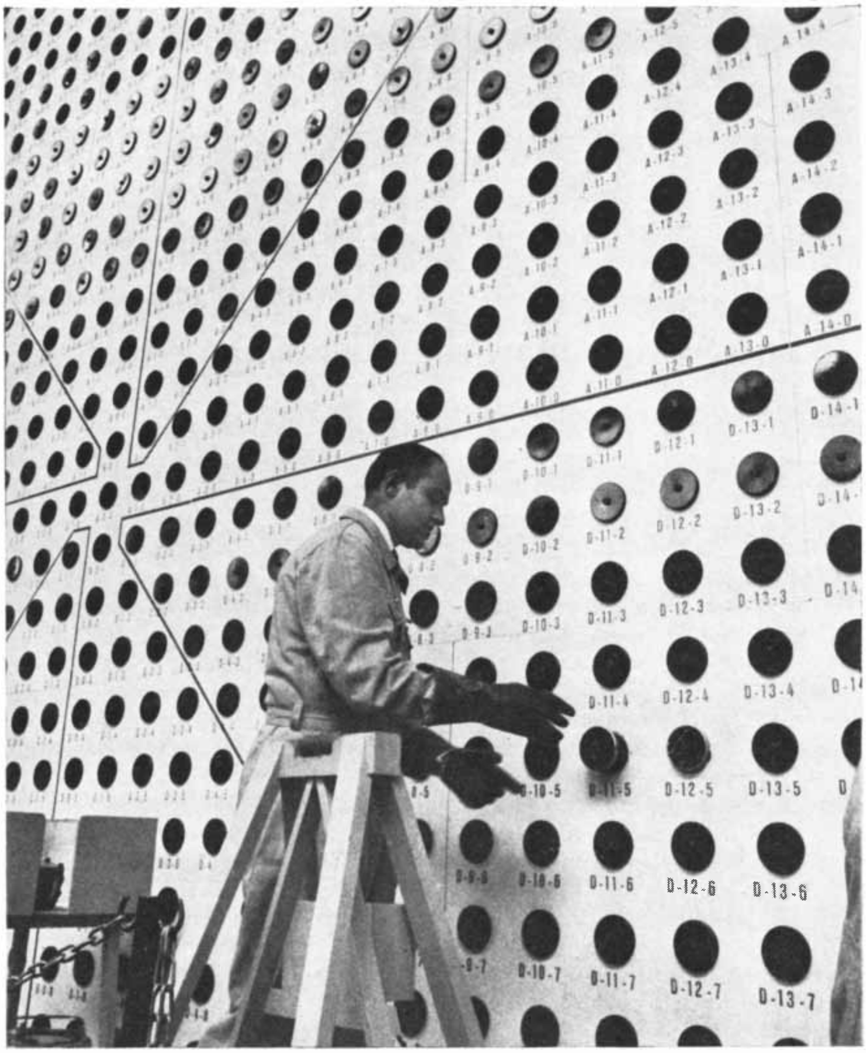
Three sessions were devoted to the fission process and the chemistry of fission products and of heavy elements. They illustrated the enormous amount of chemical research necessary to support a program on nuclear energy. The chemistry of uranium, of the transuranic elements and of the fission products enters into the processing of fuels after their use in a reactor. Unlike fossil fuels, nuclear fuels need rejuvenation, on account of the accumulation of poisons and the slow depletion of fissile material in the fuel elements.

This field of chemistry also involves, of course, the basic study of the synthetic elements, such as americium and curium, which are formed by additions of neutrons to uranium. There were contributions from the U.K., the U. S. and the U.S.S.R. on such "rarified" subjects as the chemistry of neptunium, americium, curium, ruthenium and technetium. U. S. workers suggested names for the most recently discovered synthetic elements: einsteinium for element 99, fermium for 100 and mendelevium for 101. The Soviet delegates were enthusiastically appreciative of the naming of element 101 for Mendeleyev.

The occurrence of uranium and thorium, prospecting for these metals, and treatment of their ores and ore concentrates each occupied one session. Paul F. Kerr of the U. S. gave a masterly survey of the world's sources of uranium and thorium. His paper was appropriately followed by contributions from representatives of many other countries: Argentina, Australia, Belgium, Brazil, Canada, France, India, Italy, Japan, Portugal, the U.K. The session on prospecting reflected the desire of all nations, large and small, to discover possible sources of uranium and thorium. All the current methods of prospecting, including ground and aerial surveys, were discussed.

During the last decade prospecting for uranium has proceeded on a scale unmatched in history by the search for any other metal. All over the world substantial quantities of uranium are being found. Concentrated deposits are not plentiful, but there is a vast reserve of uranium in certain gold ores, in shales and in phosphatic rocks. The uranium content in these sources ranges up to 1 per cent. Seven countries reported known uranium resources which come to a total of more than a million tons. Delegates were left with the impression that uranium prospecting and mining has developed so rapidly that it is already at a stage of "perfection" equal to that of the older established metals, such as copper and lead. The price of uranium concentrates should in future be largely determined by the well-known factors of grade of ore and its accessibility. For the distant future, Harrison Brown of the U. S. suggested that even granite contains enough "easily" extractable uranium and thorium to make the extraction worth while in terms of energy.

Sir John Cockcroft, in his concluding general talk on the "Future of Atomic Energy," summarized the situation by saying that there seems to be ample uranium and thorium available to tide us over "until we achieve our final goal and produce by fusion reactions in the *light* elements an inexhaustible power source for the world."



OAK RIDGE REACTOR model was shown at the commercial exhibit. Once the world's largest and most potent atomic pile, it has been used for research and for making isotopes.

BETWEEN SESSIONS geologist Paul F. Kerr of the U. S. discusses his survey of the world's uranium and thorium sources with U.S.S.R. delegates. Intent listener is V. V. Shcherbina.

GENEVA: Biology

Hazards of radiation have been minimized by safety standards which are strikingly similar in all countries, but geneticists still worry about the long-range effects of small, steady doses

by C. A. Mawson

The Geneva Conference discussions on biological and medical aspects of radioactivity ranged over an immense field of topics, from cancer treatment to fundamental studies of photosynthesis. Naturally considerable attention was concentrated on the hazards to life that will be introduced throughout the world by the development and operation of reactors in a nuclear power age. These hazards will have to be faced not only by workers in atomic energy plants but by the general public as well.

This article will review briefly some of the Conference papers and discussions on radiation hazards and on uses of radioactive isotopes in medicine and agriculture.

So much has been written on the effects of radiation that it is unnecessary to elaborate on the theme that excessive exposure can cause burns, nausea, falling of hair, anemia, leukemia, sterility, genetic mutations and cancer. It is not so generally recognized that man has lived in a radioactive environment throughout his history and has evolved successfully under bombardment by nearly all kinds of radiation. This was strikingly shown by a large cloud chamber in the U. S. exhibit. The chamber gave onlookers an idea of the swarm of ionizing particles that continually fills the air around us as background radiation. No radioactive material was put into the box, yet at any instant about 500 tracks could be seen. They were due to cosmic radiation and to alpha particles produced by the natural radon in the air.

We are normally exposed not only to cosmic radiation but also to radiations emitted by potassium 42 and carbon 14, which occur naturally as a small proportion of the potassium and carbon we take into our bodies. From birth we also accumulate small but detectable amounts of uranium, radium and thorium in our bones. The total radioactivity in the body of an average adult is equivalent to about five to nine thousandths of a microgram of radium.

It is against this background of natural, inevitable radiation that we must consider the risks to which the use of atomic energy will expose all living matter. There was great interest at the Conference in the controversial subject of the effects of exposure to low-level radiation upon the genetic future of the human race. It was strongly proposed that this subject be investigated by studying the relative prevalence of genetic defects in parts of the world with greatly different amounts of natural background radiation.

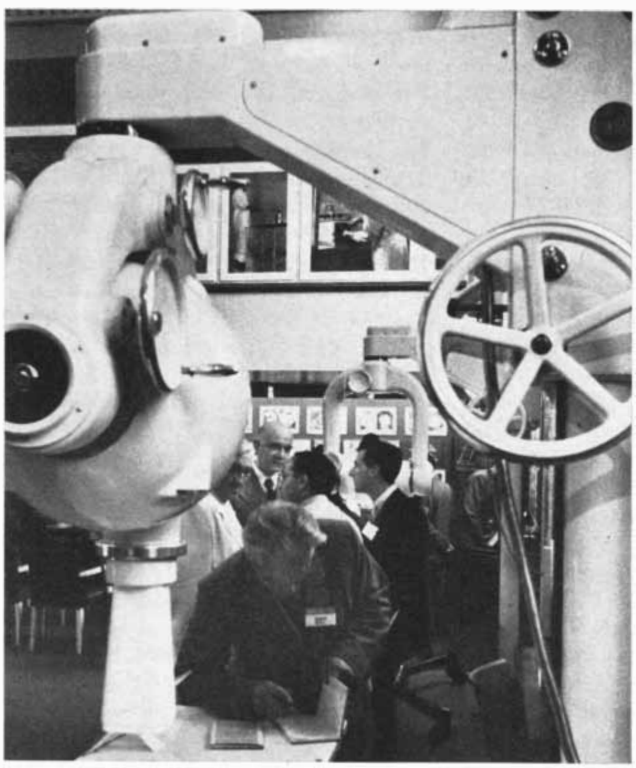
Many delegates were shocked when Sir Ernest Rock-Carling suggested that reduction of fertility and shortening of the life-span by radiation "might not altogether be deplored in a world suffering from overpopulation." Rock-Carling added that "one mutation which results in an Aristotle, a Leonardo, a Newton, a Gauss, a Pasteur, an Einstein, might well outweigh 99 that lead to mental defectives." Replying to this, Ake G. Gustafsson of Sweden protested that it takes a highly improbable combination of many mutations to produce a genius, but a single mutation may produce a mental defective. Moreover, the likelihood of transmission of genius to future generations is minute compared with that of transmission of idiocy.

Damage to living cells from radiation is rarely visible under the microscope. But it can be seen after very large doses of irradiation are applied to one-celled organisms such as yeasts or bacteria. M. N. Meissel of the U.S.S.R. described a series of experiments, mainly with yeasts, which showed profound changes in the organisms' metabolic systems, particularly those concerned with nucleic acids, carbohydrates, fats and sterols. He showed a magnificent film in color which depicted the morphological changes in the cells. The pictures were made by phase contrast, luminescent and ultraviolet microscopy. It was fascinating to watch how irradiation frustrated the cells' attempts to divide and made them grow into long, threadlike forms with giant nuclei.

So little is known of the effects of long-continued low-level irradiation on freely breeding populations of mammals that it became obvious that a large-scale investigation of this problem, preferably on an international scale, was a pressing necessity. On the genetic effects of large doses of radiation there was much more to report. W. L. Russell of the U. S. reported that a dose of 600 roentgens causes mutations in the sperm of male mice and damages the gonads, where the sperm are manufactured. The damage to these glands is permanent and leads to production of mutation-bearing sperm for the rest of the individual's reproductive life. The most significant point in Russell's work was the finding that the radiosensitivity of the mouse gonad is 15 times as great as that of the fruit fly *Drosophila*, which has hitherto been used widely as a basis for calculating the maximum permissible dose rates for man. The maximum permissible exposure may now have to be revised downward.

Aside from direct damage to bodily organs, irradiation has harmful indirect effects; among other things, it reduces the body's resistance to infection. I. A. Pigalayev of the U.S.S.R. reported experimental evidence that it causes a decline in the amount of antibodies against

ITALIAN OBSERVERS at the U. S. scientific exhibit study effects of radiation on corn. With nuclear bombardment, which multiplies mutation rates, experimenters have created new plant varieties, including some that resist disease and others suited to arid soil.



B. N. TARUSSOV of the U.S.S.R. delegation takes notes in the shelter of an X-ray machine displayed in his country's exhibit.

C. A. MAWSON of Canada, author of this article, learns how the Russians study plant nutrition by means of radioactive tracers.

bacteria in the body. Such indirect effects introduce an additional factor into the calculation of permissible exposure levels.

Everyone working with radioactivity recognizes the dangers involved, and elaborate systems of protection have been devised. Thanks to these rigid controls, very few persons in atomic energy plants have been exposed to more than the permitted dose, even in accidents; there were no overexposures, for instance, in the serious accident at the Chalk River reactor in Canada in 1952. The excellent safety record means, of course, that there has been little experience of human injury available for study, and therefore little opportunity to decide at what exposure level injury to human beings begins. To make sure of being on the safe side, very conservative limits for exposure have been established all over the world. The permissible exposure levels set up in the U.S.S.R. are similar to those in the West. A. A. Letavet of the Soviet Union gave a detailed account of the Russian safety regulations and labor hygiene. Atomic workers are limited to a six-hour working day and receive an annual vacation of 24 to 30 days, depending on the amount of exposure. Anyone who is exposed during his work to more than 10 times the natural background radiation is examined and treated at one of the "night sanatoria" maintained for these workers.

W. Binks of the United Kingdom explained the safety recommendations of the International Commission on Radiological Protection. The Commission has fixed the maximum permissible level of exposure for atomic plant workers at three tenths of one roentgen per week. If a large group of people is exposed, this figure must be reduced, for genetic reasons, to three hundredths of one roentgen per week. Even that exposure would mean that each individual would accumulate in 30 years a total dose of 47 roentgens, which is about the dose generally supposed to cause doubling of the normal mutation rate. Hence Binks suggested that if more than 10 per cent of an entire population is exposed, the permissible dose level should be reduced still further.

The greatest industrial hazard from radiation is in uranium mines. Henri Jammet of France discussed protection measures. The miners are exposed to radioactive dust and to radiation from the walls, but the most serious menace is radon, a radioactive gas emitted by radium. A concentration of less than a billionth of a curie of radon per liter of air is considered tolerable, although it may expose the lungs to 10 to 20 roentgens per working week. The radon in mines frequently exceeds this level, and after blasting the level may be 500 times as high. Radon is carried through the mines by water and percolates through fissures. Jammet suggested that unused workings should be sealed off, that water should be drained from the mines efficiently and that clean air should be provided by high-pressure ventilation. Work is progressing on protective paints and oils to coat mine walls. Such precautions have greatly reduced the radon hazard in French mines, but it is still high, and some workers must wear masks supplied with clean air.

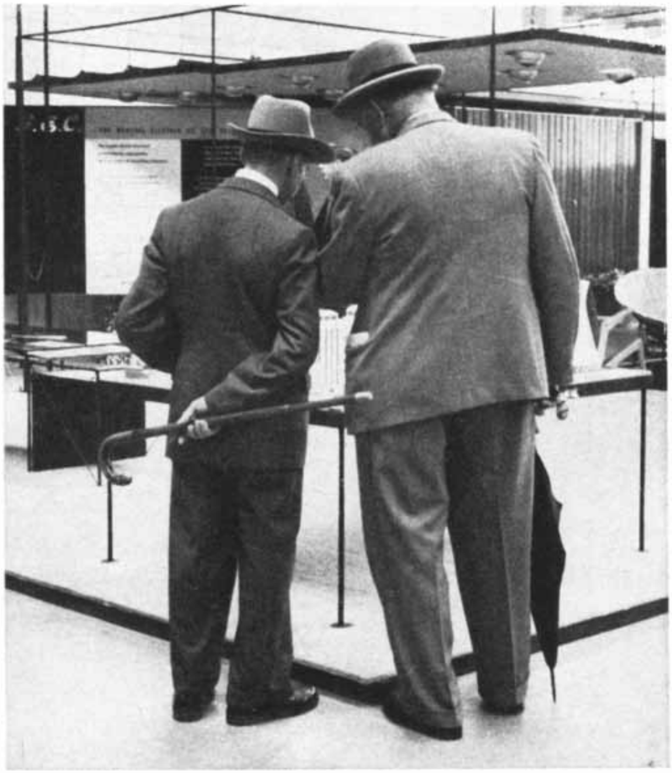
SLAVE HANDS, directed by woman on other side of wall, demonstrate their dexterity. In "hot" laboratories they enable chemists to handle radioactive material without exposure.

For the general population the chief hazard may be the radioactive wastes from atomic power plants. So far the wastes from the large reactors at Hanford in the U. S. and Harwell in England have been disposed of without hazard; there has been no dangerous accumulation of radioactive material in the wildlife or plants in the vicinity of those installations. But investigators pointed out a number of potential dangers in the future. Fish in contaminated rivers, eating organisms which have concentrated radioactive phosphorus, may become unsafe for food. Cattle grazing on pastures near atomic power plants may concentrate radioactive iodine and secrete it in substantial amounts in their milk.

A number of delegates to the Conference reported progress in devising treatments for radiation injury. Alexander Hollaender of the U. S. and D. W. Van Bekkum of the Netherlands described preventive treatments with certain chemicals which lower the sensitivity of tissues to radiation. These include cysteine, beta-mercaptoethylamine and tyramine. They may act by reducing the cells' supply of oxygen—an element that plays a key part in the process of destruction of the cells by radiation. The protective chemicals help only if they are given before the exposure; once the damage to the cells has been done, it is irreparable.

Jack Schubert of the U. S. gave a detailed report of work done at Argonne on removal of radioactive poisons from the body, particularly the heavy metals, such as plutonium, which lodge in the bones. Chelating agents injected into the veins will remove significant amounts of radioisotopes from the body. Zirconium citrate also is effective in this way, causing increased excretion of plutonium even when the metal has been in the body for several years. A combined treatment with zirconium citrate and the chelating agent EDTA looks highly

WALTER H. ZINN of the U. S. (*left*) listens to explanation of a Russian reactor by a physicist of the Soviet Union.



BRITISH EXHIBITS in the Trade Fair attracted much attention. Here visitors inspect a model of a reactor designed for export.

promising, though zirconium has disturbing side effects in man which were not apparent in animal experiments.

The medical papers at Geneva had to do not only with treatment of cancer but also ranged over various other uses of radioactive isotopes in diagnosis and therapy. M. N. Fateyeva and A. V. Kozlova of the U.S.S.R. gave encouraging accounts of progress in the alleviation of various forms of cancer with radioactive phosphorus and cobalt. The reports from all countries showed, however, that the doctors were not allowing enthusiasm to override caution. J. S. Mitchell of England was careful to point out that the use of radiophosphorus for treatment of blood diseases might expose the genital organs to dangerous doses, and that treatment of thyroid conditions in young people with radioiodine might lead to cancer in this organ in later life. Dwight E. Clark of the U. S. gave figures to show that X-ray treatment of young children for relatively benign conditions such as whooping cough and inflammation of the sinuses caused an alarming later incidence of cancer of the thyroid among these patients.

The delegates, and the general public, who visited the exhibits at Geneva showed great interest in the "teletherapy" machines. These machines contain radioactive cobalt, cesium or iridium in amounts ranging up to many thousands of curies. They emit a narrow, intense beam of high-energy radiation which is particularly suitable for treating deep-seated tumors. One of the more elaborate machines was the "cobalt bomb," or Theratron, which formed the centerpiece of the Canadian exhibit.

Several ingenious devices for locating and treating tumors in the brain were described. Brain tissues possess a "barrier" which normally prevents substances in the blood from diffusing rapidly into the tissues. Tumors, however, do not have this barrier. Lloyd E. Brownell and William H. Sweet of the U. S. told how this property can be employed to map tumors and abscesses in the brain. Radioactive arsenic, when injected into the blood, concentrates in the brain tumor or abcess. A scanner consisting of a pair of scintillation counters, aligned on opposite sides of the patient's head, then can locate the radioactive material with great precision. Radioarsenic emits positrons, or positively charged electrons. When a positron encounters a negative electron, the two particles annihilate each other, and their energy is transformed into two X-rays radiating in exactly opposite directions. Such an event, and only such an event, is recorded by simultaneous signals in the two scintillation counters. Hence the scanner excludes most of the background radiation and writes a precise map of the tumor area in the brain where the positron annihilations are occurring. The picture shows not only the shape and size of the tumor but also its depth inside the skull.

Lee E. Farr of the U. S. reported a new method of treating brain tumors with slow neutrons from a reactor. Neutrons have little therapeutic value in themselves, but when absorbed by boron atoms they give rise to high-energy alpha particles which destroy tumor cells in the immediate vicinity. The patient first receives an injection of boron; the boron concentrates in the brain tumor, and it is then irradiated with neutrons. Only the tumor cells are destroyed, because the surrounding normal tissue, by virtue of its barrier, does not collect boron. For the irradiation the patient's head is carefully positioned over a special hole in the reactor shield through which an intense beam of slow neutrons emerges. This form of treatment is in its infancy, but the results have been sufficiently encouraging to justify the design of a special reactor for further investigation.

Speakers from several countries reported good results in treating cancer with radioisotopes planted inside the body. One of the advantages of this kind of treatment is that substances in colloidal or insoluble form tend to concentrate in the lymphatic system, which so often spreads secondary cancerous growths through the body. Widespread metastases have been controlled by injection of radioactive colloidal compounds, and implants of radioactive gold and other metals in the form of beads and wires have been useful for treating inoperable cancers.

In agriculture and forestry the uses of radioisotopes are as manifold as in medicine. Speakers from Canada, the U. S., the U.S.S.R. and Great Britain reviewed a wide range of work, from studies of how plants use fertilizers to the creation of desirable varieties of plants by artificially induced mutations. The relations between plants, fertilizers and the soil are very difficult to discover by conventional means, but they can be traced with accuracy and dispatch by means of radioactive tracers.

TRADE SHOW, held in the Exhibition Palace in downtown Geneva, was distinct from official government exhibits in the Palais des Nations. The U. S. display occupies the foreground.

Plant breeders in many countries have employed radiations to alter crop plants. It is true that only one mutation in 500 is a "good" mutation from the standpoint of survival of the species, but one must remember that a mutation which is useless or even deleterious to the plant may be very favorable for the farmer. For instance, if the barley plant's habit of growth were changed so that it stood erect instead of drooping, the alteration would be of no advantage to the plant but it would allow farmers to cut barley with a combine harvester. Plant breeders in Sweden and the U. S. have produced erect varieties of barley by irradiating seeds with X-rays or slow neutrons. The X-ray mutants vary considerably in height; the height of the neutron mutant varieties, on the other hand, is remarkably uniform.

Mutations occur in nature all the time, but a plant breeder has to make countless trials and wait a long time before he finds one that is economically useful. With radiation he can greatly speed up the mutation rate and thus obtain many more experimental varieties in a short time. Mutation by irradiation has already yielded new plant varieties which resist rust and other diseases, varieties which are especially efficient in utilizing artificial fertilizers, varieties which are particularly suited to poor or arid soils.

Mutations can be induced by irradiating not only seeds but also cuttings or even whole plants in the field. Improved varieties of fruit trees have been developed by irradiation of cuttings. The U. S. exhibit at Geneva showed a white carnation plant which bore red flowers on one branch as the result of a "somatic" mutation. The mutation can be propagated: plants raised from cuttings from this branch bear only red carnations.

Among the papers on fundamental research in biology, two that stood out were those by Melvin Calvin of the U. S. and A. A. Nichiporovich of the U.S.S.R. on tracer studies of photosynthesis. Calvin, using radioactive carbon 14 as a tracer, had worked out the complete sequence of steps by which plants manufacture sugar from water and carbon dioxide with the aid of chlorophyll.

Space does not permit an account of the many other brilliant papers on radiation biology. But enough has been said to show that this Conference was a historic occasion at which the minds of men from most of the nations of the world met in friendship and found that in spite of barriers of language and tradition they had a fundamental unity of outlook and a great desire to work together for the happiness and progress of mankind.

Kodak reports to laboratories on:

what every high speed camera photographer should know . . . a cellulose ester that doubles as a mounting medium and an optical cement . . . 59 years of radiographic tricks

That new fast film

This picture is obsolete. No longer do fellows need mirrors and auxiliary incandescents to pour on the light when photographing lawn mower cutting action outdoors at 3,000 frames per second. Now they load their high speed cameras with *Cine-Kodak Tri-X C-P Reversal Film.* This is that new fast film that takes a Ph.D. to tell when it's underexposed—in a new version which permits showing the footage as a positive within an hour. (The boss hates to look at a negative.) When not cutting grass, the fellows can also now make their indoor high speed movies without sacrificing camera speed and/or depth of field to make the lighting easier.

The picture is one of the illustrations in a recent Machine Design *article, "High Speed Photography in Product Development," by W. G. Hyzer. This article is so clear and encouraging that a man who sends for a free reprint to Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y., may wind up buying a* Kodak High Speed Camera.

A push from the Navy

We have made our decision to accord *Cellulose Caprate* official status as an Eastman Organic Chemical, albeit of only Practical Grade.

Certainly we had no thought of putting on a push for this casual effluent of basic research on cellulose chemistry; we can think ot other things that would do our shareowners more good. The push, rather, came from the Navy, which had a hunch that one or the other fatty acid ester of cellulose might melt to a thin liquid below 250 F and still show little or no cold flow at 160 F. If so, and if a good many other if's could be satisfied, it might prove to be a better optical cement than polymerizing resins, which tend to go through a volume change as they set. We had the assortment of esters and the Navy chemists had the perseverance. After a while, the finger fell on *Cellulose Caprate*, painstakingly purified and properly plasticized.

It gives the Navy everything it wants in an optical cement for rugged service, except that the index of refraction can't seem to go any higher than 1.493 (which gives a little Fresnel reflection against glass) and it is not fungistatic (though vicious tropical fungi don't thrive nearly as well on it as they do on good old-fashioned Canada balsam).

As Eastman P7137 it needs to be put through a purification procedure, such as described in Naval Research Laboratory Report No. 4242. The report erroneously names a sister division of ours as suppliers of Cellulose Caprate *rather than Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company). And, we stock some 3500 other organic chemicals.*

The soft x-ray

Because so many professional opinions on periodontoses, pelves, porosities, and the like are reached from observations on our x-ray film, we find ourselves with the resources to do little things for our friends, who are legion.

For example, a bibliography on soft x-ray microscopy, microradiography, electron radiography, and geometric x-ray microscopy.* It lists every paper and article on those subjects known to us, except that unlike our bibliographies of vitamin E, this is not annotated. The arrangement is alphabetical by authors, whether they be of the industrial, medical, metallurgical, botanical, zoological, entomological, or fine arts persuasions or just plain physicists.

The earliest reference was published April 13, 1896, in *Comptes rendus hebdomadaires des séances de l'Académie des sciences* by F. Ranwez under the title, "Application de la photographie par les rayons Röntgen aux recherches analytiques des matières végétales." The most recent is dated August, 1955, and deals with electron radiography in the investigation of postage stamps. Among the 350-odd items that lie between these two, you will find "Ueber Weichstrahlaufnahmen mit der Gleichspannungsmaschine 'Trifas' der Elektrizitätsgesellschaft 'Sanitas' " (H. Chantraine, *Fortschritte auf dem Gebiete der Röntgenstrahlen vereinigt mit Röntgenpraxis, 38:* 534-541, September, 1928) and "Микрорентгенография" (С. В. Гречишкин, *Вестник рентгенологии и радиологии, 20:* 397-408, 1938).

Sending out free copies of the microradiography bibliography is easy for Eastman Kodak Company, X-ray Division, Rochester 4, N. Y. We'll go beyond that. If you'll give us the details of your problem, we'll do our best to answer questions about the use, handling, and behavior of sensitized materials in experimental radiographic work. But you wouldn't want us to do your research for you, would you?

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*For the casual reader:

Soft x-rays are those of wavelength longer than about 0.25 Å. They are so easily absorbed that exceedingly thin or low-density materials, quite transparent to the ordinary x-rays of the healing arts, cast informative shadows. If the shadows are of microscopic details, if they are caught on very fine-grain film in close contact with the specimen, and if this film image is greatly enlarged in printing, that is *microradiography.* A switch in this technique is to use hard x-rays (wavelength shorter than 0.050 Å) that can knock electrons out of a sheet of lead and let differences in absorption of the electrons by the various parts of the specimen tell the story on film. This is *electron radiography.* Still another way of doing x-ray microscopy is to use a very tiny but intense x-ray source and keep it so close to the specimen that it casts greatly enlarged sharp x-ray shadows on the film, which can then be even further enlarged in projection printing. This is *geometric x-ray microscopy.*

This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

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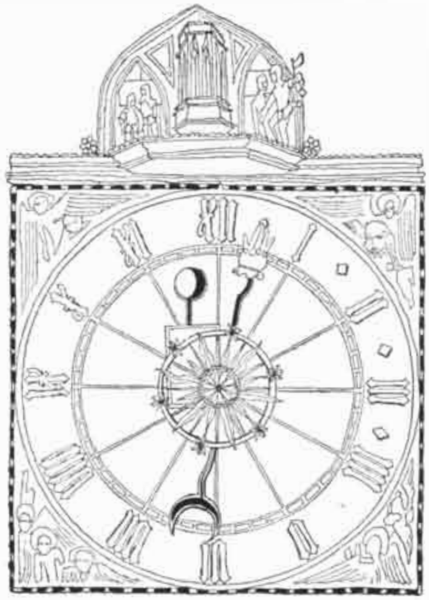

SCIENCE AND

Atoms-for-Peace Award

The international good will that prevailed at the Geneva Conference on atomic energy was highlighted by the announcement of a new $75,000 annual prize. The award, which includes a medal, will be made each year by an international jury to the individual or group of individuals in any country who have made the year's greatest contribution to peaceful uses of atomic energy.

The award was established by the Ford Motor Company Fund (a philanthropic agency in no way connected with the Ford Foundation). It set aside $1 million to provide for the prize and administrative expenses. In case the jury can find no candidate who merits the award, that year's prize money will be used for "scholarships and fellowships most likely to contribute to the advancement of the new science of peaceful application of atomic energy."

A representative of the U. S. Bureau of Internal Revenue said that in his opinion the Atoms-for-Peace Award would be exempt from U. S. income tax, as are the Nobel and Pulitzer prizes.

German Reactors

West Germany plunged into the atomic energy field with the announcement that it will purchase two experimental reactors from the U. S. One will be installed at Karlsruhe by the Bonn Government, which has allotted $1,190,000 for the project. The other, at Munich, will be financed by the Bavarian State Government.

The Bavarian project will be headed by Werner Heisenberg, Nobel prize winner and currently director of the Max Planck Institute of Physics in Göttingen. Heisenberg said he would endeavor to move the whole Max Planck Institute to Munich.

Representatives of West Germany were everywhere at Geneva, showing a great interest in nuclear power. Shortly after the Conference closed, *Farbwerke Hoechst*, a successor company to I. G. Farben, announced that it would construct a heavy water plant near the city of Frankfurt.

Soviet Physics in English

Reports in English on the work of U.S.S.R. physicists begin this month to become available in the U. S. through a new publication: an English translation of the Russian *Journal of Experimental and Theoretical Physics.* It will be published bimonthly by the American Institute of Physics at a subscription price of $30 per year in the U. S. and Canada.

This journal was selected for translation in a poll of U. S. physicists. Its U. S. editor is Robert T. Beyer of Brown University. He will assign the translation work to physicists who know Russian. Brown University also provides offices for *Mathematical Reviews*, which publishes translations of selected Russian mathematical papers.

More Speed

At the Edwards Air Force Base in California are rocket-propelled sleds which test airplane sections and the ability of the human frame to withstand extraordinary accelerations and decelerations. Skimming over rails laid across 10,000 feet of dry lake bed, they are the fastest land vehicles in the world. Last month a new land-speed record was announced: 1,100 miles per hour. The new sled that made the record attained the top speed less than five seconds from the start of the run. It weighs 4,300 pounds. The sled was first catapulted by a burst of eight rockets on a pusher sled and then accelerated further by its own seven rockets. The purpose of this sled is a military secret, but it is known that it has never carried a human being.

Other high-speed sleds at Edwards have had human passengers. Lieutenant

THE CITIZEN

Colonel John Paul Stapp, an Air Force medical officer who has ridden them many times, has just received the Cheney Award for having slid at 632 miles an hour. This is the fastest a man has ever traveled on the ground, and just a little faster than the muzzle velocity of a .45-caliber pistol bullet.

A new air-speed record is due to be set at Edwards before the end of the year. Lieutenant Colonel Frank K. Everest will pilot the Bell X-2, a plane expected to fly faster than 2,000 miles an hour. Until now the X-2 has made only unpowered glide flights. This rocket-powered craft has a stainless steel skin, because friction with the air will heat its surface to a temperature which would soften conventional aluminum alloys.

More Satellites

On the heels of the announcement that the U. S. expects to fire rocket-powered satellites beyond the earth's atmosphere in the International Geophysical Year 1957-58, the U.S.S.R. disclosed that it has plans to do the same. In a *Pravda* interview A. G. Karpenko, secretary of a Soviet Academy of Sciences committee which is coordinating research on space travel, explained that the first Soviet satellite would be designed to circle the earth at an altitude somewhere between 125 and 625 miles. Later models may rise above 1,000 miles.

Karpenko reported that radio-guided rockets in the U.S.S.R. have already attained an altitude of 300 miles and carried animals. Five years ago U. S. military authorities announced that monkeys and mice had been shot to 80 miles (and survived) in rockets at White Sands.

The U. S. Congress is keeping a close watch on satellite developments. A knotty question arose when Representative Frank M. Karsten of Missouri introduced a bill to name the first U. S. satellite "Astranaut." To which committee should the measure be referred? After anxious consultation, House parliamentarians finally turned it over to the Foreign Affairs Committee.

Looking ahead into astronautics, the Glenn L. Martin Company has announced plans for a new laboratory which will "explore, both theoretically and experimentally, the frontiers of man's knowledge." Welcome W. Bender, manager of the company's advanced scientific laboratory, specifically mentioned two frontiers: space travel and ways to circumvent gravity. He pointed out that "many scientific barriers—flight beyond the speed of sound, for example—have been breached not by annihilation but by a better understanding of them."

The Pulsing Sun

The sun is a variable star; such is the conclusion reached by Charles G. Abbot, retired secretary of the Smithsonian Institution, after a lifetime of observations. He finds that the sun has pulsations of intensity which are obscured by the perturbations of the earth's atmosphere but would be obvious to an astronomer on the moon.

According to Abbot's measurements, the sun's fluctuations range up to 2 per cent. They show some 64 cycles, the longest of which is 273 months. Abbot believes that some of the fluctuations may influence cycles on the earth. One, for example, corresponds to a 212-day cycle noted in some studies of human pulse rates. Another, strongly reflected in the weather, is a cycle of about six and a half days. At least 20 of the solar cycles, says Abbot, can be correlated with temperature and precipitation in various parts of the U. S.

Fiddler Crabs and Cosmic Rays

Twice a day, with clocklike regularity, the little fiddler crab changes color. By day pigments dispersed in its skin cells give the crab an inky blush; in the evening the pigments retire into tiny dots and the crab's skin becomes pale for the night.

Many have tried in vain to account for the fiddler crab's clocklike changes [see "Biological Clocks and the Fiddler Crab," by Frank A. Brown, Jr., SCIENTIFIC AMERICAN, April, 1954]. Sunlight is not the answer, for the crab's coloring changes regularly even under constant illumination. Looking for a subtler explanation, Brown and two co-workers at Northwestern University have recently investigated the effect of cosmic rays. After 16,000 observations over a three-month period they have decided that cosmic ray showers may indeed be the solution.

In the *Proceedings of the Society for Experimental Biology and Medicine* Brown and his colleagues told about experiments in which they observed groups of fiddler crabs kept under sheets of lead, where the crabs were exposed to

The new "miracle metals" are nickel, steel and copper

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Stokes is the leading supplier of production vacuum furnaces for industry. Any of the basic furnace designs, ranging from laboratory units to 1000-pound capacity and higher, can be modified to meet your particular requirements. If your interest lies in high-purity metals, write for your free copy of Stokes Catalog 790, "High-Vacuum Furnaces."

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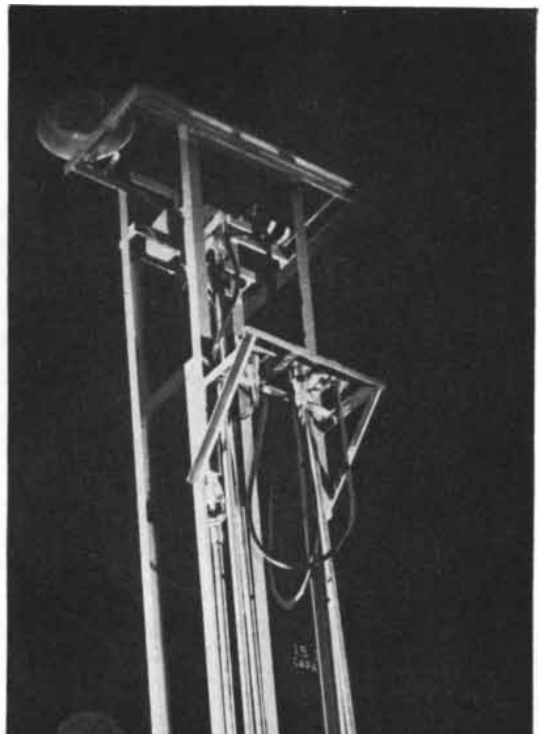
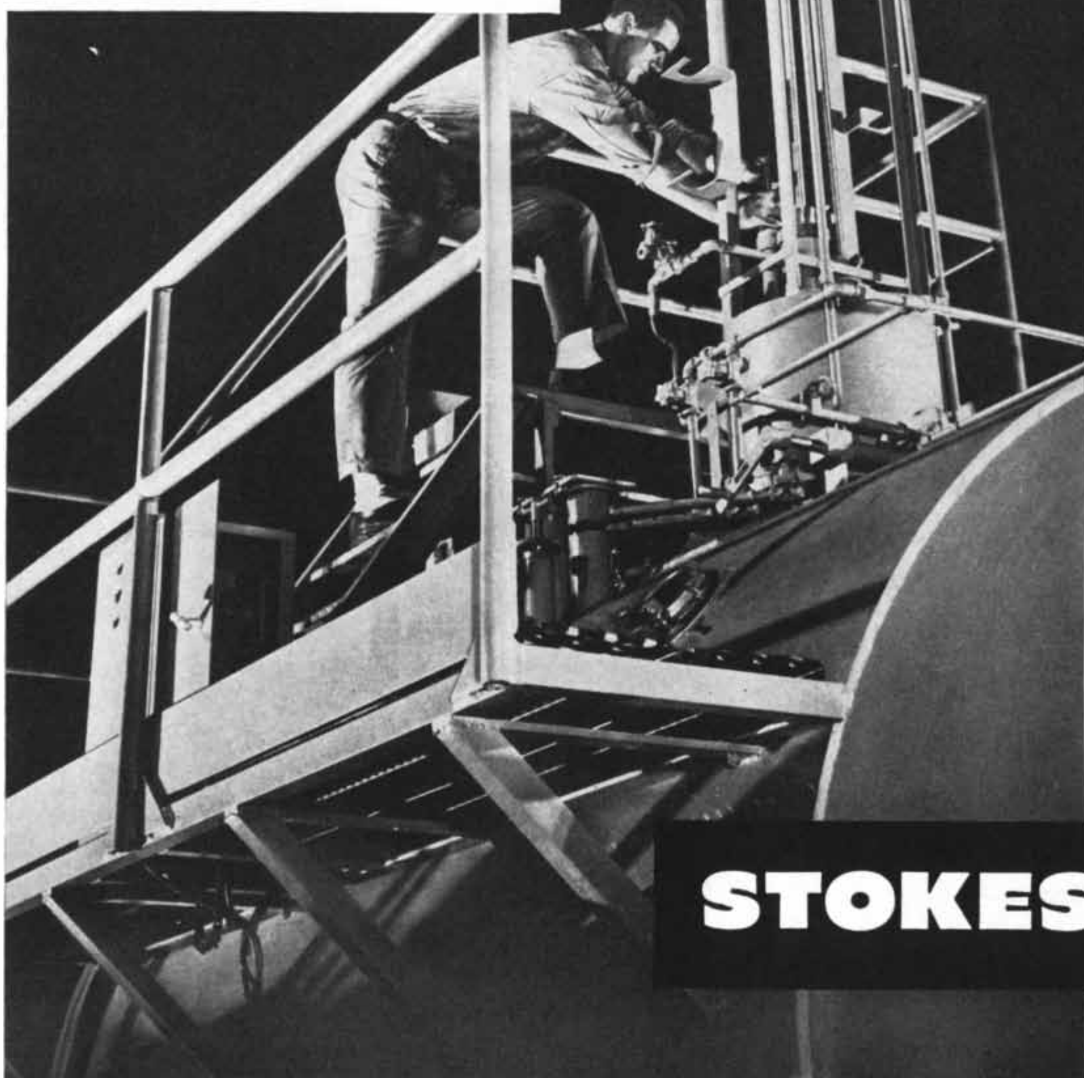



STOKES

intense showers of electrons from cosmic radiation. The results were striking. In the nighttime hours the crabs were significantly paler than usual, and in the daytime hours, abnormally dark. The increased cosmic bombardment evidently intensified the usual color changes. Cosmic radiation is known to have a regular daily rise and fall of intensity.

The experimenters suggest that cosmic rays somehow act on the endocrine glands responsible for the crab's color changes.

Discriminating Resin

The metallic wealth dissolved in the oceans far exceeds all that has been mined from the land. Mining the seas for their metals is an ancient dream which nowadays seems less and less fantastic. Fresh hopes have just been aroused by chemists at the Polytechnic Institute of Brooklyn, who have developed a new ion exchange resin, polythiolstyrene, with a peculiar affinity for heavy metals, including silver, gold and uranium.

Harry P. Gregor of Polytech explains that polythiolstyrene contains active groups of atoms which specifically bind heavy metal atoms by the process of chelation. A heavy rinse with strong acid can then wash the bound metal out of the resin. Gregor has successfully salvaged copper from dilute solutions like those encountered in copper refining and has recovered traces of silver from spent photographic solutions. Since the resin is a strong reducing agent, the silver comes out in pure metallic form.

The synthesis and properties of polythiolstyrene were reported in the *Journal of the American Chemical Society* by Charles G. Overberger and Alexander Lebovits. A group under Overberger is exploring the biological activity of similar resins. They may serve as models of enzymes and possibly as drugs for removing radioactive poisons from the body.

High-Frequency Transistors

One of the drawbacks of transistors, their inability to handle extremely high frequencies, has been overcome by scientists at the Bell Telephone Laboratories. By adding a fourth electrode to the basic junction transistor and by other refinements they have made a "junction tetrode" transistor which generates more than one billion oscillations per second.

This improvement promotes the transistor into a realm heretofore ruled by vacuum tubes: the ultra-high-frequency

range used for radar, television and some telephone communication. The Western Electric Co. will soon begin to manufacture the new transistor.

Long-Range Thermometer

The optical pyrometer, an instrument for measuring the temperature of hot objects by the color of their glow, has been useful in such industrial applications as reading temperatures inside jet engines and steel furnaces at a distance. Now *Industrial and Engineering Chemistry* reports a new version, the infrared pyrometer, which can also measure low temperatures at a distance. The editors suggest that it could even measure "the temperature of an ice cube a half mile away at the North Pole."

The instrument distinguishes temperature changes as small as four hundredths of one degree Centigrade. Its recording needle almost jumps off the scale when a human hand passes in front of it. If the pyrometer is aimed at the moon, "you get a heck of a wallop," the article reports.

The infrared pyrometer works on the principle that every object gives off infrared radiation at a rate dependent on its temperature. The heart of the instrument is a flake of metallic oxides called a thermistor, whose conduction of electric current is increased when it is heated. An amplifying and recording system translates this conductivity into a temperature reading.

Filter Houses

For the Atomic Age the U. S. Forest Products Laboratory and the Army Chemical Corps have jointly developed a new building board which is as effective as a gas mask. The material lets air and carbon dioxide through but filters out radioactive dust, poisonous gas and germs.

Work on the new "diffusion board" was headed by Alfred J. Stamm, a well-known wood chemist, and Harold Tarkow. The nature of the screening chemicals is a secret. Pilot-scale production at two plants has demonstrated that the board can be made from any kind of wood and can be pressed with much the same equipment used to make ordinary fiberboard.

Victory over Screwworms

The screwworm is a major pest of cattle in the U. S. Southeast, particularly Florida. From 1951 to 1953 U. S. Department of Agriculture en-

tomologists perpetrated an elaborate trick upon Florida's screwworm population: they sterilized male screwworm flies by radiation and released them, so that females, which mate only once, would produce no offspring. Unfortunately for the experiment, virile male flies from nearby areas prevented extermination of the Florida screwworms.

Last year the Department of Agriculture researchers tried again under more favorable conditions. In cooperation with the Netherlands Antilles Veterinary Service, they released sterilized screwworms on the isolated island of Curaçao. In late summer they released 68,000 of the fraudulent males each week over the 170-square-mile area of the island. By early October the entire screwworm population had been wiped out.

Reporting their success in *Science*, R. C. Bushland, A. W. Lindquist and E. F. Knipling of the Department of Agriculture observe: "The immediate significance of the Curaçao experiment is that it lends support to the theory that screwworms might be eradicated from Florida through the use of sterilized flies. . . . In normal winters the insects survive only in peninsular Florida. If the overwintering population could be extirpated, the Southeast might be kept free of an insect that annually does millions of dollars' worth of damage."

Primordial Moss

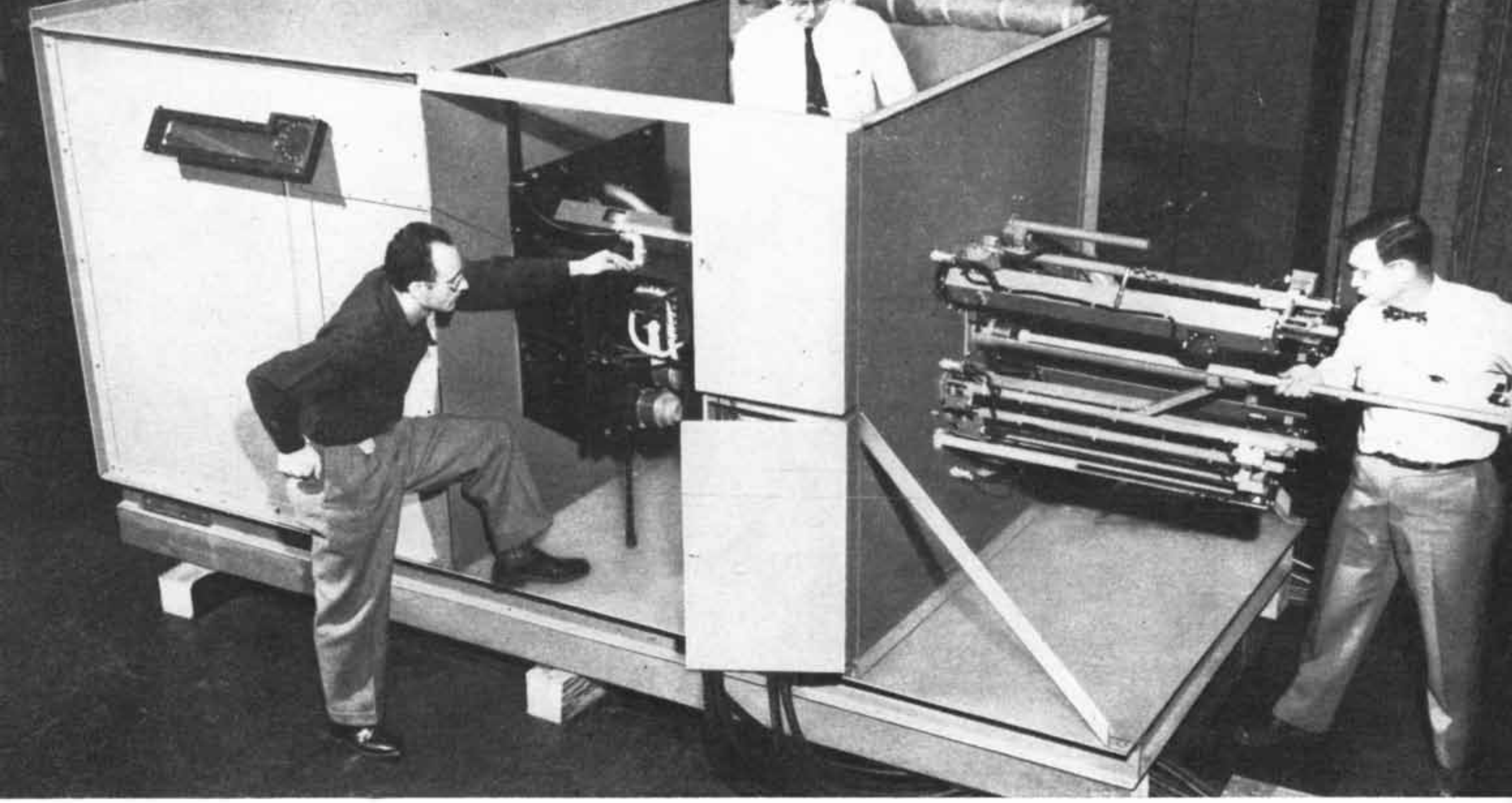
Copper is toxic to most forms of life, but the rare copper mosses actually thrive on copper ore. In fact, these primitive plants recently guided Norwegian prospectors to the discovery of a rich copper deposit.

Some botanists have assumed that these mosses somehow require copper in their growth cycle. Others have thought that the mosses seek an acid environment such as that found around copper ores.

Albert Schatz, of the National Agricultural College in Pennsylvania, offers another explanation in the current issue of *The Bryologist*, the botanical journal devoted to mosses. He says that copper mosses use sulfur from copper sulfides for photosynthesis.

Sulfur photosynthesis is rare; heretofore it has been observed only in some green and purple bacteria. But it was probably common in the distant geologic past before the earth's atmosphere acquired oxygen. Schatz suspects that copper mosses are survivors of that era.

Schatz was formerly at Rutgers University and assisted Selman Waksman in his work on streptomycin.



G-E Nuclear Test Reactor

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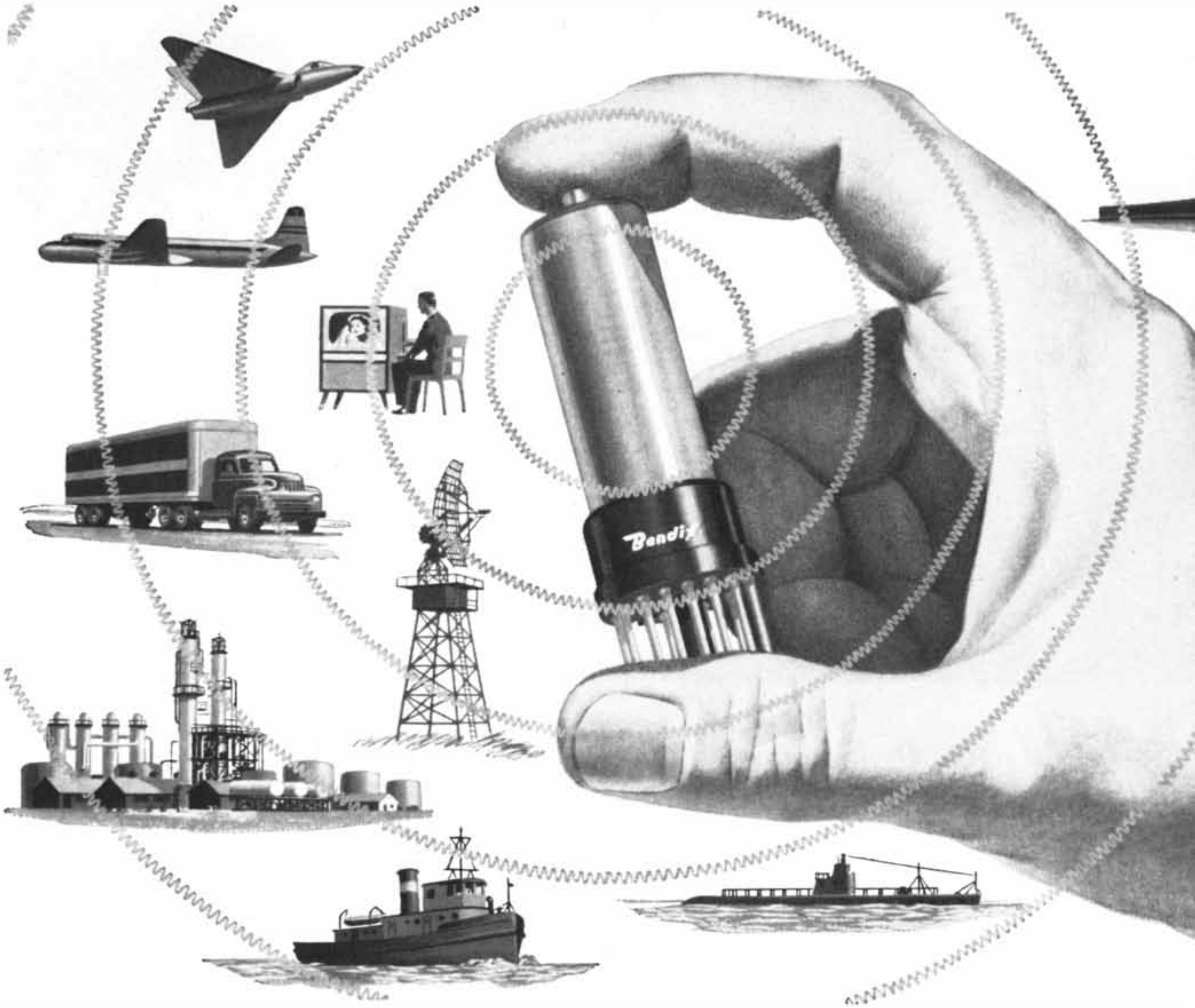


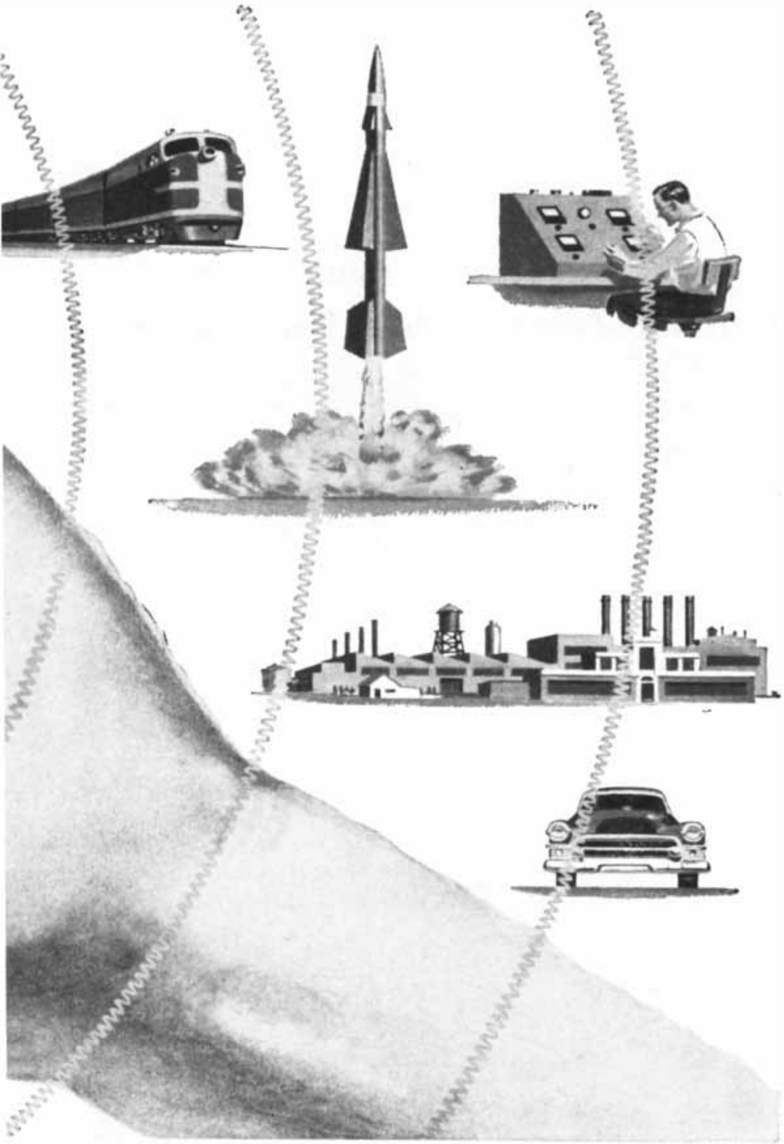
Bendix Electronic Devices of vital tasks for every

Necessity was surely the mother of electronics. Broadly speaking, man's progress in science and mechanics was rapidly outstripping his physical and mental ability to employ his developments efficiently, and so he harnessed the electron and made it do thousands of both menial and extremely vital tasks for him—ranging from calling foul-line errors on bowlers to reporting what goes on in a guided missile in flight.

In the latter case, for example, within the span of a two-minute flight period at speeds of thousands of miles per hour, Bendix electronic telemetering equipment transmits simultaneously over one hundred different categories of information back to the ground. This information would be valueless, of course, if Bendix had not also developed high-speed electronic receiving and recording equipment, as well as digital and analogue computers to quickly catalog this fund of knowledge which otherwise might involve months of labor by expert mathematicians.

Relatively speaking, electronics is in its infancy. Yet every hour every day it performs new jobs more efficiently. And the future looks particularly bright because of its broad, almost universal, application.

We cannot possibly describe in this small space the great variety of Bendix electronic devices. Listed at the right are some of the electronic products we have developed and manufacture for the aviation, automotive, railroad, marine, communications, television and other



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Radio control transmitters
Radio—navigation, communications
R. F. amplifiers
Radio noise filters
Radio receivers for homes
Radiosondes
- Airborne
- Ground station

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Reactance oscillators
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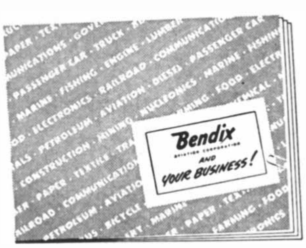

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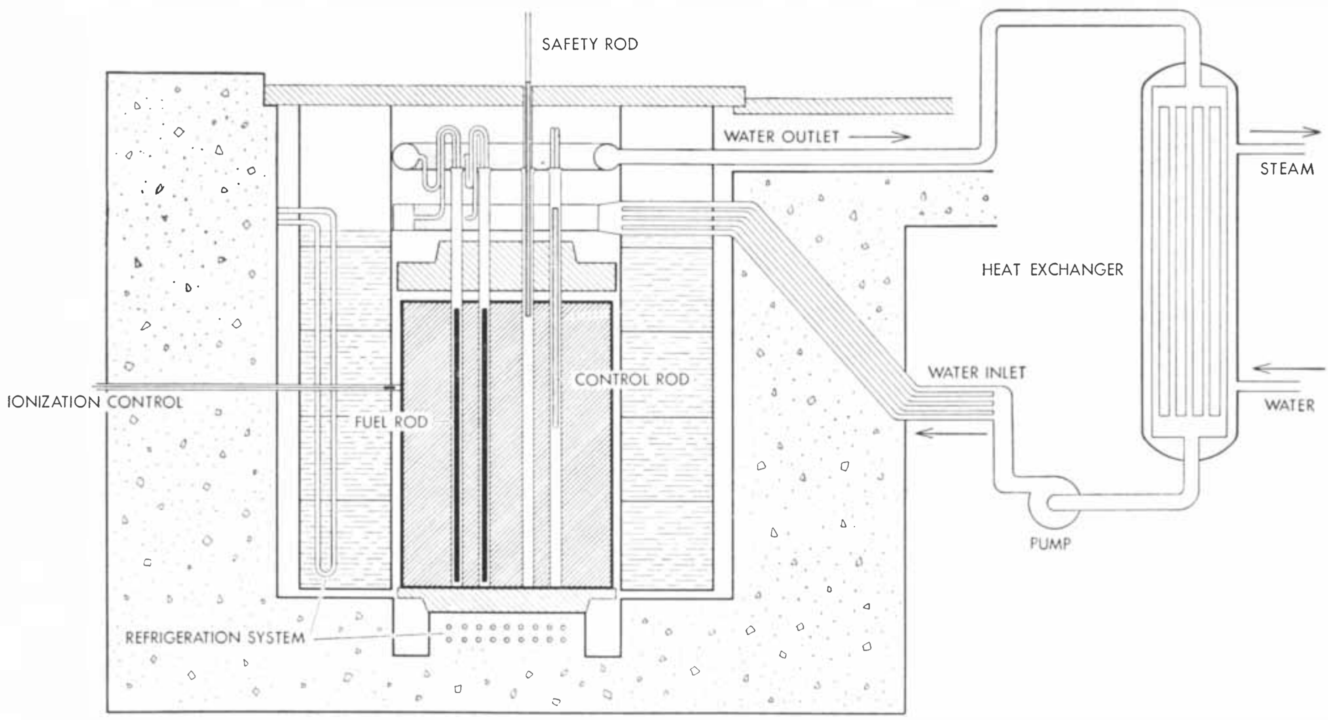
GENEVA: Reactors

Hopes for harnessing atomic power were brightened by the reports of scientists from many nations. It was demonstrated again that no country holds a monopoly on nuclear knowledge

by Robert A. Charpie

History will record the Geneva Conference of 1955 as the event which opened the door, for all the peoples of the earth, to the age of nuclear power. In this meeting of nuclear scientists from many countries the promise of atomic power began to take form and substance.

For uninitiated listeners the outpouring of information on power reactors at Geneva had two chief points of interest: they were interested first to hear whether nuclear power could live up to its advance press notices, and secondly to know how different countries compared in progress in this field. On the first point, they were soon satisfied that nuclear power had a very big future indeed. On the second, the listeners came away convinced that although the U. S. is still the leader in the development of advanced power reactors, other nations are rapidly closing the gap. The U.S.S.R. already has a 5,000-kilowatt electrical power plant in operation and is now building at least one larger version of the same reactor type which will generate 100,000 kilowatts of electricity. Great Britain will have the first large-scale reactor plant operating at Calder Hall by the end of 1956. It will supply power to the British Electric Authority grid. The first large U. S. power station—the 60,000-kilowatt plant being built by Westinghouse near Pittsburgh—will not begin operating until 1958, but the Geneva reports on the broad, diverse program being pursued in the U. S. left no doubt that the nuclear power effort of



PRESSURIZED WATER reactor furnishes energy for the 5,000-kilowatt atomic power station of the U.S.S.R. Academy of Sciences. Heat of fission in its lattice of uranium rods and graphite is absorbed by circulating distilled water, which is kept under a pressure of 1,500 pounds per square inch. Pressure raises the boiling point of water and enables it to absorb more heat. The heat exchanger reduces the temperature of the water from about 270 to 190 degrees centigrade, thereby extracting the energy for generating electric power. The Soviet Union announced that it plans to construct a 100,000-kilowatt version of this type of reactor.

this nation is the most advanced in the world.

The scientists representing nations not yet committed to nuclear energy found the Conference a revelation. For the first time all the pertinent technical facts were publicly available. Even cynical observers had to agree that the Conference had furnished enough information to permit any nation to decide whether it wished to go into the nuclear power business and how best to begin.

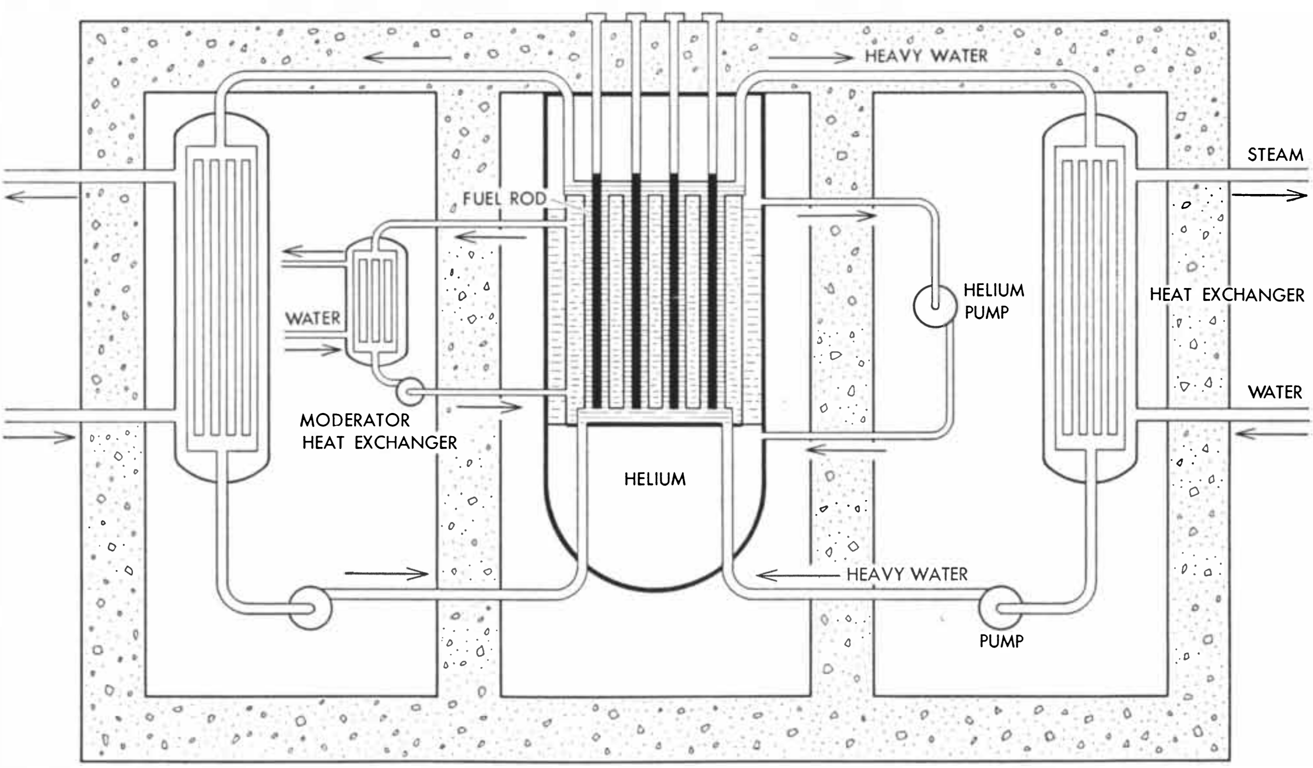
Some of the most significant facts that might influence these decisions were presented in the reactor physics sessions dealing with the fundamental properties of fissionable materials. The main focus of interest was the "breeding" question: What are the prospects for realizing practicable power reactors which will breed more fuel than they consume?

The only naturally occurring fissionable material that can serve as fuel for a reactor is uranium 235. Unfortunately U-235 makes up only 71 hundredths of 1 per cent of natural uranium. But the idea that the more plentiful U-238 could be burned by converting it into fissionable plutonium in a "breeder reactor" has been in the minds of reactor physicists ever since plutonium was discovered more than 12 years ago. In theory the possibilities are perfectly simple. All one needs is a supply of neutrons sufficient to continue the chain reaction in the reactor and also to manufacture plutonium from U-238. Plutonium itself is the best source of neutrons, for when a plutonium atom captures a high-energy neutron and fissions, its fission yields, on the average, about 2.9 neutrons—a better yield than from the fission of U-235. In a reactor utilizing plutonium fuel (which of course must first be made from U-238 with neutrons from an initial charge of fissioning U-235), one of the neutrons from each plutonium fission would sustain the chain reaction and most of the remainder (1.9 on the average) presumably could be captured by U-238 to produce new plutonium atoms. Since the number of plutonium atoms manufactured is greater than the number destroyed, as time goes on the amount of fuel in a breeder reactor will increase.

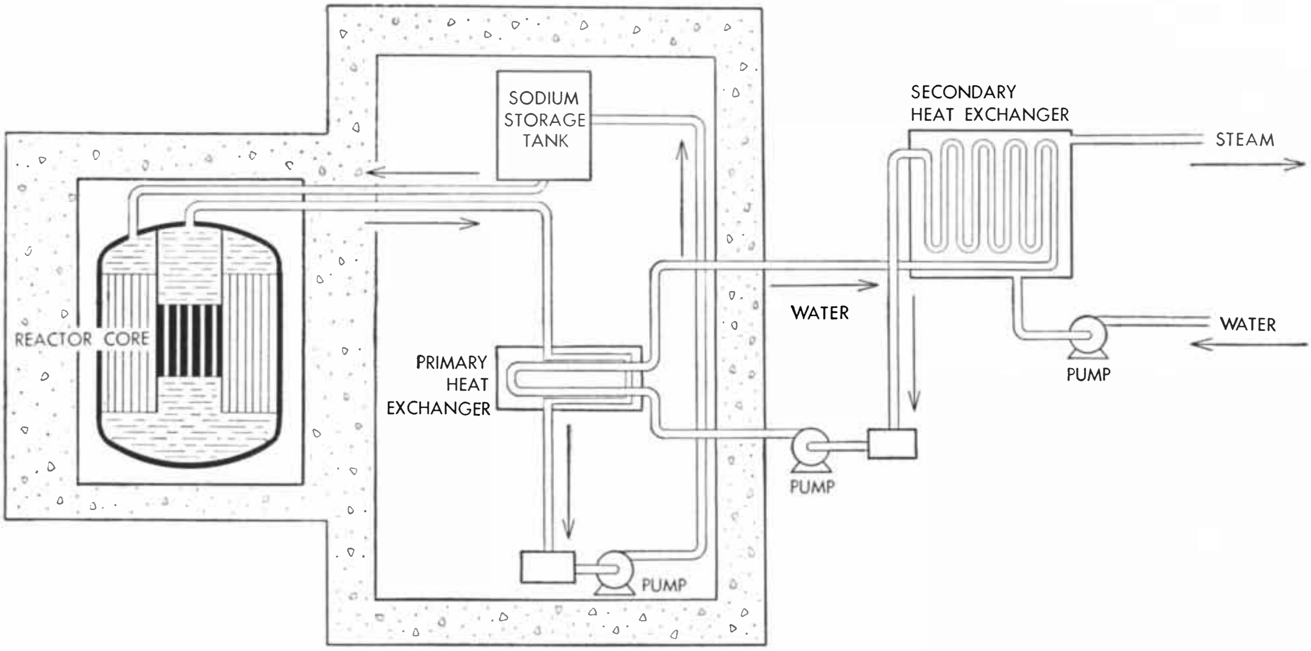
Likewise thorium could be the basis of a similar breeding cycle. When a thorium atom captures a neutron, the reaction results in formation of an atom of the fissionable isotope uranium 233, just as U-238 is converted by neutron capture into fissionable plutonium. The conversion of thorium to U-233 does not require fast neutrons, as the manufacture of plutonium does. It can be carried out with low-energy (thermal) neutrons. This considerably simplifies the problems in designing the reactor. However, there is also a debit side: in the U-233 cycle the neutron economy is tighter, for U-233 releases only 2.3 neutrons instead of 2.9.

In these breeding schemes it is a long step from theory to practice, because there are so many elements in a reactor which tend to rob the cycle of its neutron supply. Until Geneva every country's experiments in breeding were classified, so that the practical feasibility of the idea was wrapped in mystery. But when the delegates brought their data out from under wraps and compared notes at Geneva, it became plain that enough has been learned to assure that both the uranium and the thorium breeding cycles will work.

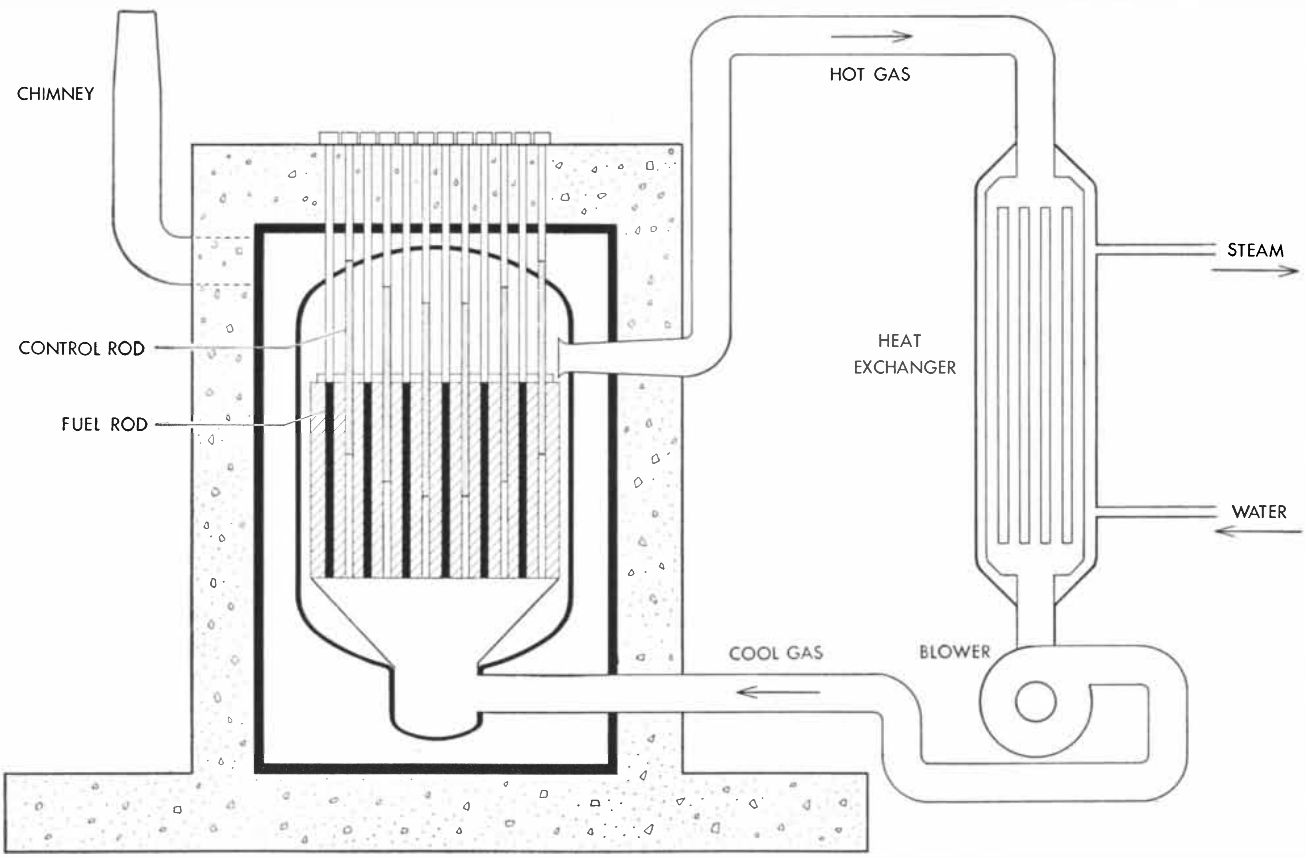
The British reported the results of breeding experiments with their Zero Energy Fast Reactor (ZEPHYR). This is a laboratory reactor operating at low temperature without cooling. ZEPHYR is uncomplicated by the structural materials and coolant that a power reactor would require; nonetheless it achieves breeding by a large enough margin



PRESSURIZED HEAVY WATER reactor will be Canada's first atomic power plant. When completed in 1958 at Des Joachims, Ontario, it will generate 10,000 to 20,000 kilowatts of electricity. Heavy water is chosen because it absorbs almost no neutrons. In this reactor it plays two roles: coolant and neutron moderator. Small circuit at left of core keeps temperature of moderator within bounds. Larger circuits transfer energy from heated heavy water to light water, which turns to steam and drives turbines. Helium circuit is a novel safety feature. When the gas pressure is shut off, the moderator drains into bulge beneath core and fission ceases.



LIQUID METAL COOLED reactor is being developed in the U. S. at Argonne National Laboratory. It is as much a breeder of plutonium as a power plant, although it will generate at least 15,000 kilowatts of electricity. The plutonium core will convert the surrounding uranium blanket into additional plutonium. Heat from the core will be absorbed in circulating liquid sodium. Because sodium becomes highly radioactive, it is necessary to transfer this heat through another stage before finally using it to generate steam.



GAS COOLED reactor being built by British at Calder Hall is described as "the slow-speed reciprocating engine of the reactor world." It is bulky but reliable and relatively simple to construct. Helium, which is chemically inert and does not absorb neutrons, would be the ideal coolant, but it is too expensive in Britain. Carbon dioxide is the initial coolant; a better one may be found. The core is a lattice of graphite and uranium, possibly enriched. A chimney vents air pumped through to cool the reactor shielding.

(about two for one) to demonstrate that a reactor with the additional structure needed for generating power would still be a breeder.

The U. S. described its successful experiments in breeding with a reactor which is an actual prototype of a power unit. The Experimental Breeder Reactor (EBR) at the Idaho Testing Station, whose achievement of breeding was first announced in December, 1953, has a liquid metal coolant (sodium) and a uranium breeding blanket.

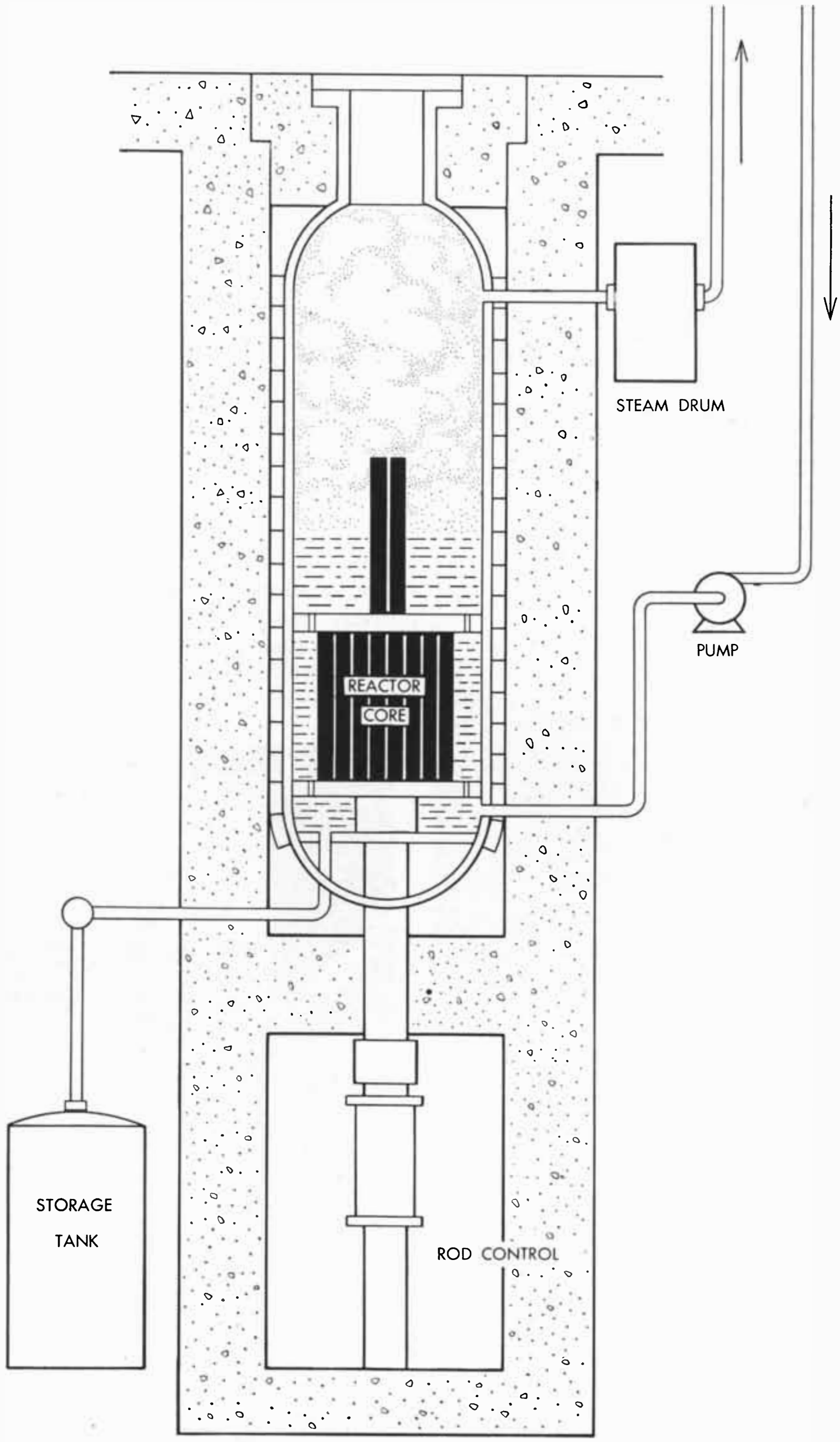
In the case of thorium, elaborate experiments to demonstrate the feasibility of breeding are less necessary. The fundamental nuclear constants are now known sufficiently to calculate the neutron economy of this cycle quite accurately. France, the U.S.S.R., Great Britain and the U. S. all contributed information on the pertinent reactions, and the Oak Ridge National Laboratory reported some direct experimental measurements of the critical mass required for a U-233 chain reaction. The critical mass is about 20 kilograms of U-233 for a slow-neutron reactor. Taking all the data together, it is possible to predict reliably that a power reactor can be built which will operate as a U-233 breeder.

One of the most interesting developments of the Conference was the comparison of critical cross-section measurements by groups of scientists in various countries. These measurements have been closely guarded secrets. It was therefore something of a surprise to discover at Geneva that the measurements in all countries, carried out independently, agreed almost exactly! Rarely has there been such a classic demonstration of the principle that "truth will out," despite all attempts to hide it.

In nuclear physics "cross section" is the measure of the statistical probability that a specified nuclear event will occur. For instance, when a physicist speaks of the absorption, or capture, cross section of U-238 for slow neutrons, he means the likelihood of capture under the given conditions; the fission cross section similarly is the probability for occurrence of fission. The cross section is expressed as an area, and the unit area (10^{-24} square centimeters) was almost immediately named a "barn"—by analogy with the proverbial barn door, though an area like 10^{-24} square centimeters is of course an extremely small unit.

At Geneva representatives of the leading countries in nuclear research adopted a set of average values for cross sections of the three fissionable materials for thermal neutrons, defined as having a speed of 2,200 meters per second. These standards, taking account of the margins of error and the spread of the different measurements, are as follows: The capture cross section of U-235 is 698 ± 10 barns and its fission cross section is 590 ± 15 barns; for plutonium the respective figures are 1,032 ± 15 and 729 ± 15 barns; for U-233 they are 593 ± 8 and 524 ± 8 barns.

There are still significant gaps in our knowledge of the nuclear constants important to reactor design. Any country entering the field of nuclear energy will therefore have to make certain funda-



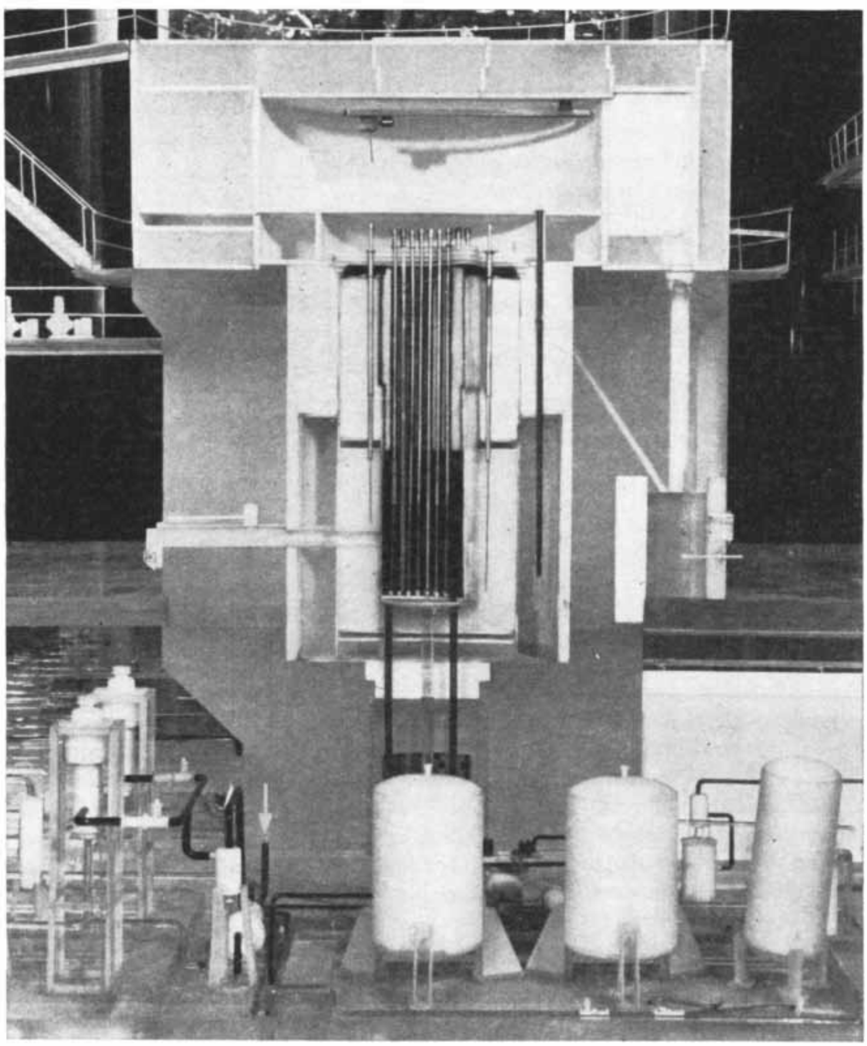
WATER BOILER, being built by Argonne, generates steam directly from the heat of its core immersed in water. It needs no heat exchanger or pressure system. With thorium fuel and heavy water as moderator and coolant, it might breed more U-233 than it consumes.

mental measurements to design the types of reactor its scientists may decide upon. The most powerful tool for neutron research of this kind is, of course, a research reactor. Since a research reactor can be used simultaneously for the production of radioisotopes and for the testing of materials and reactor components, it is only natural that there was keen interest exhibited on all sides in the sessions dealing with research reactors.

A very noticeable change has taken place in the entire research reactor business during the past year. Reactors using enriched fuel and providing a high neutron flux have replaced natural-uranium reactors for research. The reason is that they greatly speed up the measurements and other studies. The British have several enriched-fuel research reactors under construction, and one of the surprises of the Conference was the discovery that the Russians have several already operating. Such reactors will become available to any country through the international pool and the bilateral agreements whereby the U. S. has agreed to supply uranium enriched to 20 per cent.

Geneva provided information on two other factors important in power reactor technology: safety and power-cost estimates.

The bogeyman of the infant industry is the specter of what might happen if a power reactor should get out of control and spread radioactive fission products over a large area. Although reactors are designed so that there is a built-in tendency to overcome runaways automatically, accidents are always possible. To see what might happen in such an accident, the U. S. performed experiments in which water-cooled reactors were deliberately allowed to run away—the so-called Borax experiments. The tests established that it is much more difficult to arrange a destructive blowup than had previously been imagined. And the runaway reactor spread its radioactive fuel and fission products only over



EXPERIMENTAL REACTOR of U.S.S.R. uses enriched uranium immersed in heavy water. Radiation turns part of the water into explosive gas, which is burned and returned as water.

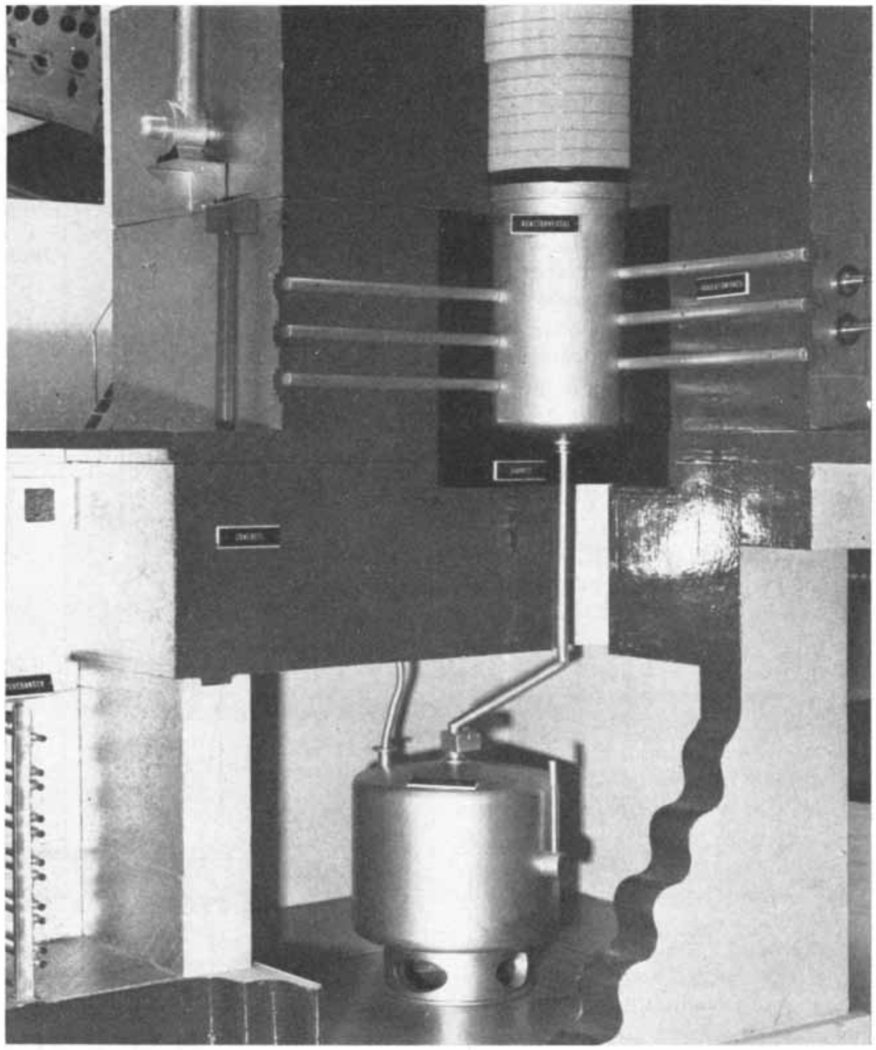
a small area around the site. A system utilizing heavy water would be even safer than the ordinary-water reactors destroyed in the Borax experiments. Consequently it appears that it would be safe to build power reactors near large centers of population.

In the realm of reactor economics there is a growing optimism springing from the fact that improvements in the technology have made it possible to construct reactors which were formerly only figments of engineering imagination. Predictions on capital costs nowadays are based on actual bids, not on guesses. And operating costs can be predicted from experience with experimental reactors already in being.

To summarize the state of the technology it is convenient to classify the reactor systems according to the coolant employed: gas, water or liquid metal.

The primary exponents of gas-cooled power reactors are the British. Their first power station at Calder Hall will use as the coolant carbon dioxide, which has relatively good heat-transfer properties and possesses the advantage of being chemically inert. Sir Christopher Hinton described this type of reactor as "the slow-speed reciprocating engine of the reactor world." It is necessarily large; it is reliable, and its design and operating characteristics permit the use of conventional materials and techniques of construction. While the first plant will produce electricity at the exorbitant cost of nine mills per kilowatt hour (against seven mills from coal in England), it seems certain that operating experience will lower the cost in later versions. But gas-cooled reactors, even in a high-power-cost country like Great Britain, do not seem to have an unlimited future.

The British propose at least two more gas-cooled reactors in their plan for the next 10 years. Research is continuing along three major directions in an effort to make significant improvements over the Calder Hall design. In the first place, consideration is being given to replacing the carbon dioxide coolant. Helium is an ideal cooling gas, because it has a high specific heat and does not capture neutrons, but it is very expensive and is not available in large quantities in Great Britain. Another possibility is hydrogen, which has remarkable heat-transfer and moderating properties, but at high temperatures it would affect the mechanical properties of the fuel and reactor materials. A second improvement being considered by the British is the use of slightly enriched uranium as fuel in the



RESEARCH REACTOR at Kjeller, Norway, is a joint Dutch-Norwegian project. It is moderated with heavy water. This reactor has been used for research purposes since 1952.

periphery of the reactor. This would have the effect of making the neutron flux and the generation of heat more nearly uniform across the whole reactor and thus increase the electrical output of the reactor. Finally, the British expect to improve the design, fabrication and performance of individual components such as blowers and heat exchangers.

Realizing that the gas-cooled reactor has limitations as a competitor in the power field, the British are also working on other types, such as the fast breeder and the homogeneous thermal breeder. Nevertheless Hinton stated quite unequivocally that the Calder Hall reactors will continue to occupy an important place in the field of reactor power for many years to come.

The water-cooled reactors form a large family. Pressurized water reactors, cooled and moderated by either ordinary or heavy water, are under development in virtually every country now involved in atomic energy. The range of concepts runs the gamut from the natural uranium—heavy water type under development in Canada to a homogeneous thorium breeder being developed at the Oak Ridge National Laboratory. Between these two extremes in water-cooled design fall the Pittsburgh pressurized water reactor, using slightly enriched uranium fuel and light water as the moderator; the Russian version of the same type now in operation, and the boiling water reactor being constructed by the Argonne National Laboratory.

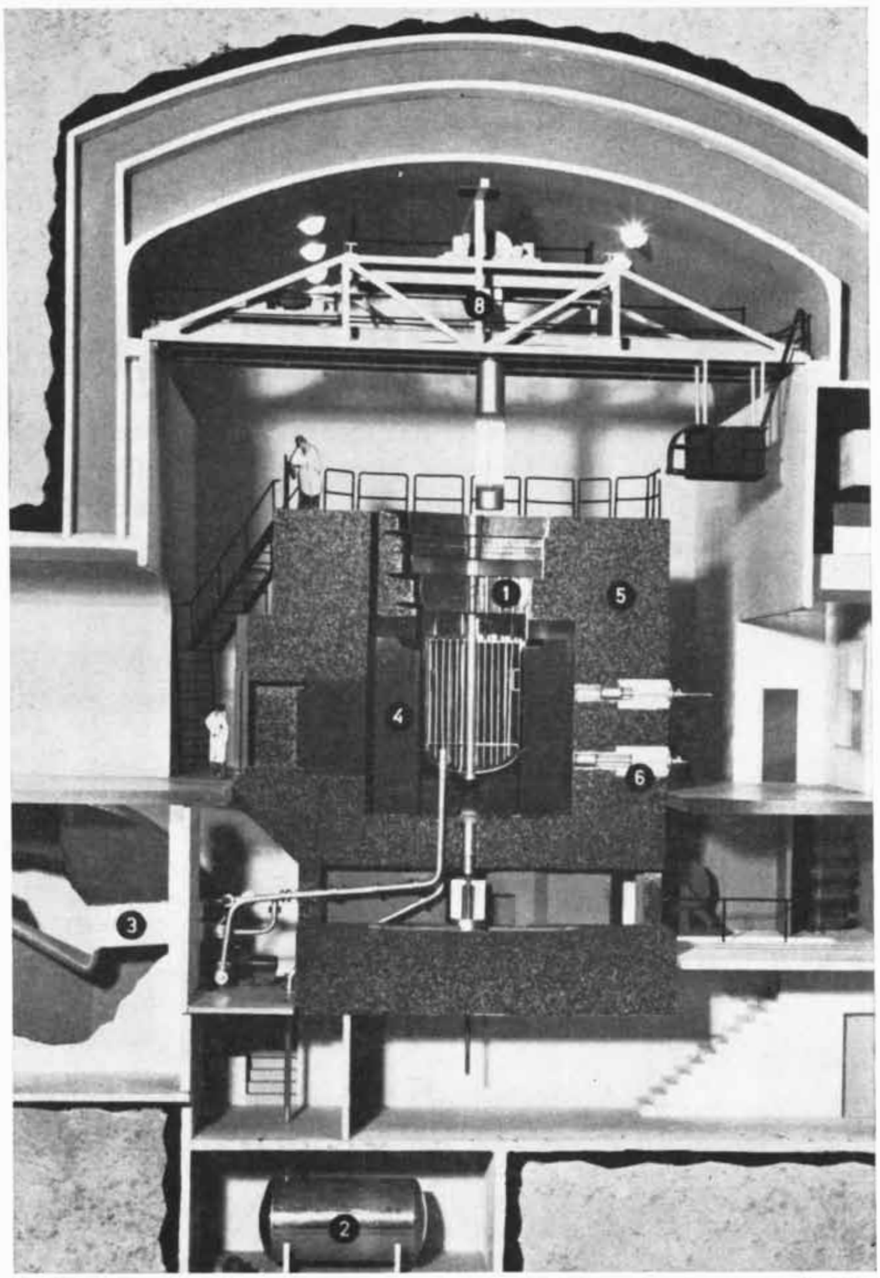
Water is attractive because of its low cost, its excellent moderating properties, its well-known chemistry and the large amount of engineering experience in using water under extremes of temperature and pressure that has been acquired in conventional power plants.

The Soviet power station is a pressurized water reactor moderated with graphite. In order to obtain operation at

sufficiently high temperatures to procure power the fuel elements are canned in stainless steel instead of aluminum. The steel absorbs so many neutrons that it is necessary to use enriched uranium (10 per cent U-235) as the fuel. Soviet engineers stated that the reactor produces electricity at a cost which compares favorably with coal-fueled plants of the same rating. The Soviet Union is now going ahead with the design and construction of at least one larger version of this station.

Research and development on the two most advanced water-cooled designs—the boiling water and aqueous homogeneous reactors—are proceeding very satisfactorily indeed in the U. S. Powerplant prototypes of both reactor systems are now under construction. It appears that either of these reactors can produce power at costs competitive with coal or oil stations in the U. S. The long-range prospects of the homogeneous type reactor seem slightly better, but the technology is less advanced at this time. (The Russians presented a paper on the design of a boiling version of the homogeneous reactor.)

R. B. Briggs and J. A. Swartout of Oak Ridge reported the discovery of a simple and effective processing scheme for removing both the manufactured fissionable fuel and a large fraction of the



RESEARCH REACTOR in Stockholm is Swedish government's first venture into atomic energy. Sweden is now building a 20,000-kilowatt experimental reactor near Stockholm.

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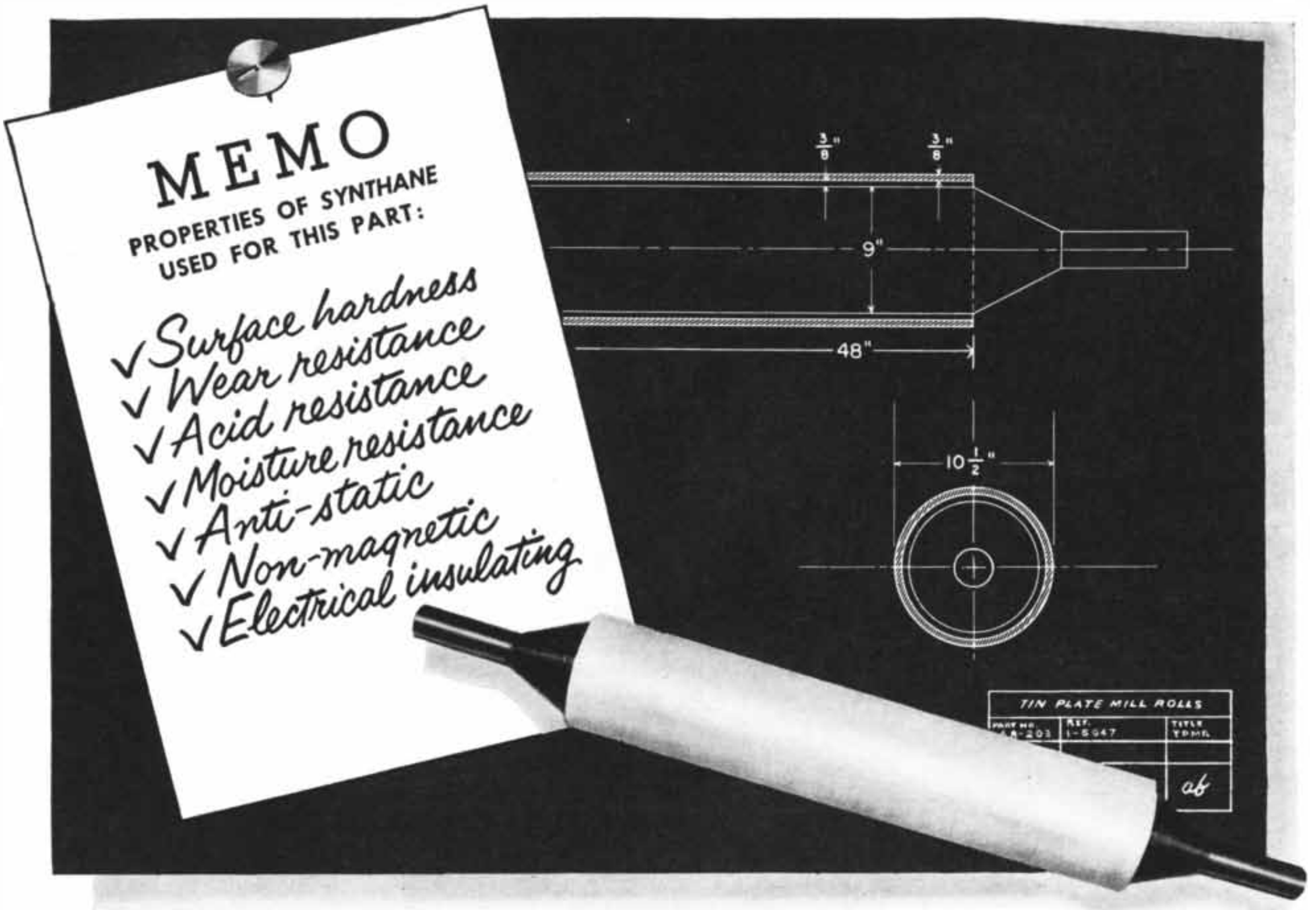

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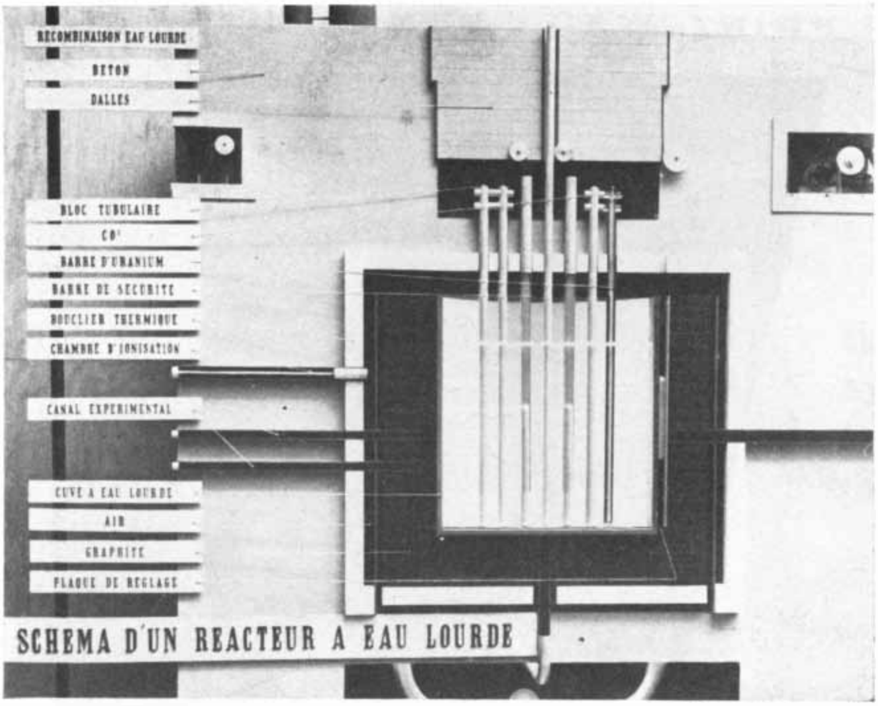
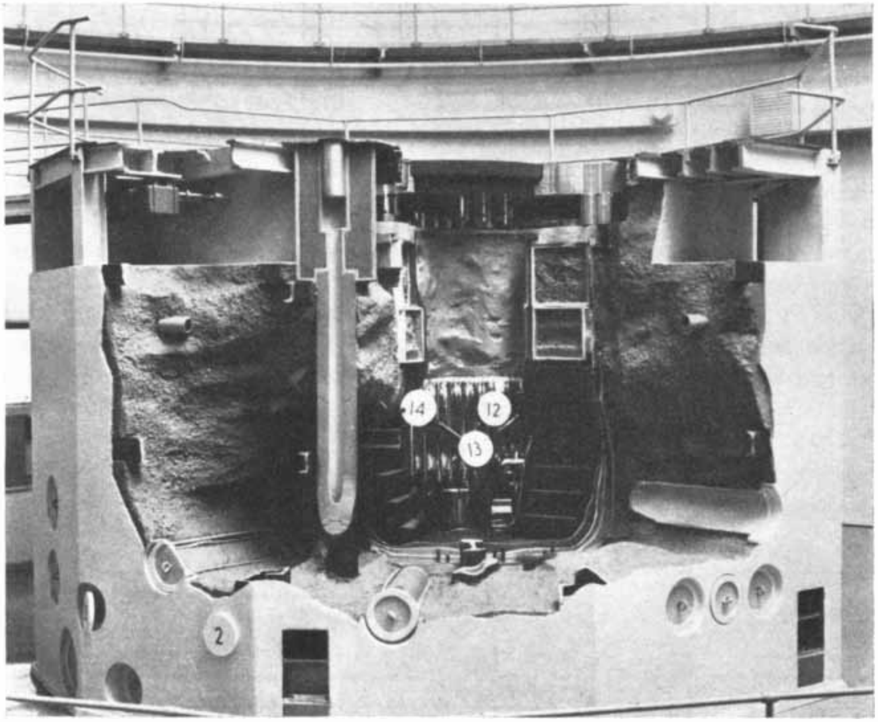


FRENCH DESIGN favors heavy water as moderator and carbon dioxide for cooling. Several of these reactors are being constructed. They are intended for plutonium production.

long-lived fission products from a homogeneous thermal breeder. This would not only be a great step forward in efficiency but would also offer for the first time the prospect of a reactor which would not dangerously contaminate the environs in the event of an accident. The Oak Ridge workers also pointed out that the aqueous homogeneous reactor is the most strongly self-stabilizing design known.

Among the reactors of the class cooled with liquid metal two interesting systems were presented in detail for the first time at Geneva. One was the North American Aviation design, which employs graphite as the moderator and liquid sodium as the coolant. A molten metal not only has much better capacities for heat transfer than water but also by-passes problems which grow out of



BRITISH EXHIBIT showed cutaway model of "Dido," a heavy-water moderated research reactor. Among the features are fuel elements (12), control rods (13) and water tank (14).

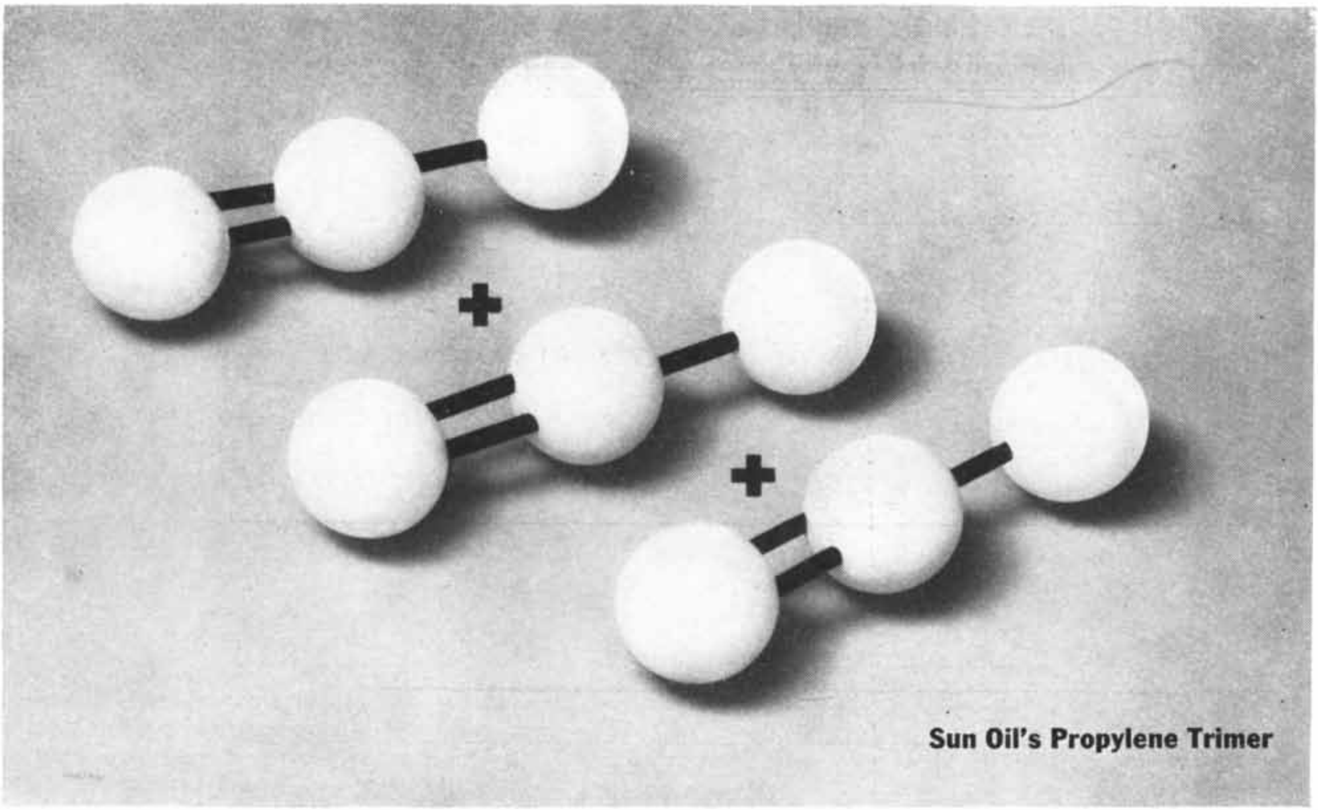
the requirement for very high pressures in a water-cooled reactor. The sodium-cooled graphite system has the advantage of high flexibility. That such a reactor can be built is now assured. As proposed by its designers, the North American Aviation reactor can operate as a converter to make power and either plutonium or U-233.

The other liquid-metal reactor described at Geneva was the fast breeder. This is the most advanced design of all. The U. S. and Great Britain have embarked on the development of fast breeder reactors, but to date only the U. S. has built and operated an engineering experiment which actually made both fissionable material and power.

Many design and operating problems must be solved, however, before the fast breeder can seriously be considered as a reasonable commercial enterprise on which to risk capital. In the first place, the fast reactor is not strongly self-regulating. This fact, coupled with the very rapid generation of neutrons, makes it necessary to take more precautions with the control and safety system. Secondly, there is the abiding paradox that in order to maximize the power potential it is desirable to have as high a proportion of "fertile" material (U-238) as possible, while on the other hand too much dilution of the fissionable fuel (plutonium) reduces the breeding performance of the system. Thirdly, irradiation damages the fuel, changing its mechanical and heat-transfer properties. Since fuel preparation is an expensive business, there is considerable incentive to keep the fuel in the reactor for as long a period as possible. Thus a difficult operational compromise must be reached: fission products must be removed from the fuel as often as practicable but not so often that it becomes too expensive.

Walter Zinn of Argonne, who is in charge of the project, indicated that despite the difficulties a large-scale fast reactor will be built in the not too distant future.

The upshot of the Geneva Conference was a great strengthening of the incentive for nuclear power development throughout the world. The Conference made clear that while nuclear energy is surely not a panacea for all of the troubles of the world, it can help to solve the problems of the power-starved and underdeveloped countries. The diligent search for the best methods of harnessing nuclear power on a large scale will go on at an ever-increasing pace in every country, and the age of nuclear power should certainly arrive within the next 10 years.



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$\begin{matrix}R_1\\H\end{matrix}{>}C{=}C{<}\begin{matrix}R_2\\H\end{matrix}$	(cis)	5
$\begin{matrix}R_1\\R_2\end{matrix}{>}C{=}C{<}\begin{matrix}R_3\\H\end{matrix}$		46

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Information Transfer in the Living Cell

Comparing components of genetic material to playing card suits, the author suggests how cells store their identities in the form of chemical codes which they use to build replicas of themselves

by George Gamow

The nucleus of a living cell is a storehouse of information. It is also something more remarkable: a self-activating transmitter which passes on very precise messages that direct the construction of identical new cells. The continuity of all life on our planet depends on this information system contained in the tiny cell nucleus. Let us examine what is known about the language of the cells.

According to modern genetics, the hereditary information of living organisms is carried by the long, threadlike bodies, known as chromosomes, which constitute the nucleus of the cell. In fact, it is possible to construct "chromosome maps" showing how distinct areas of information (genes), which are responsible for various inheritable properties, are strung together in a chromosome. When a cell is about to divide, each chromosome is replicated, so that each of the two daughter cells will receive an identical set of chromosomes exactly like the original. Thus each gets all the information originally contained in the nucleus of the mother cell.

Sometimes, because of a mistake in some step of the replication process, a daughter cell gets a gene carrying a garbled message; that is, it does not bear precisely the same information as its original counterpart. Such occasional mistakes in the copying of genes are known as mutations. They are analogous to mistakes by a draftsman or typist in copying plans and specifications for a product to be manufactured. If the modified information carried by a mutant gene is harmful to the organism in its fight for existence, as it usually is, the mutation will eventually be eliminated from the species by the Darwinian process of natural selection. If the change is helpful, the new blueprint will supersede the old and be carried on through future generations.

Comparing a living cell with a factory, we can consider its nucleus as the manager's office and the chromosomes as the filing cabinets where all the production plans and blueprints are stored. The main body of the cell, its cytoplasm, corresponds to the factory area where workers are manufacturing the specified product from incoming raw materials. The workers in a living cell are known as enzymes. They extract energy from the incoming food, break down the food molecules and assemble the separated units into various complex compounds needed for the growth and well-being of the organism.

There are thousands of different enzymes, every one a specialist. Some enzymes (*e.g.*, amylase and lipase) work in the digestive system, breaking up the crude food material into simpler parts which can be transported by the bloodstream. Some respiratory enzymes (*e.g.*, dehydrogenase and hydroperoxidase) burn incoming food fuel within the cells, using oxygen supplied through the lungs, and store the liberated energy in the form of intermediate compounds which are only moderately stable and readily give up the energy on demand. There are enzymes which are responsible for the production of purple pigment for the retina of the eye, others for the pigments coloring a person's hair, others for supplying young mothers with nourishing fluid, and so on and on. But every enzyme, whatever its task, acts strictly under orders from the manager's office—the chromosomes in the nucleus of the cell. From the chromosomes the cell factory gets precise information which determines whether the product is to be an oak tree, a herring or a human being—and whether it will be male or female, light or dark, color-blind or normal.

The problem of explaining cell communication has two parts: (1) How is information stored in the chromosomes? (2) How is it transmitted from the chromosomes in the nucleus to the enzymes in the cytoplasm?

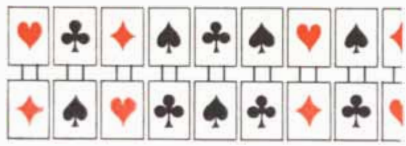
Now the first of these questions has already been at least partly answered, thanks to the work of a number of investigators, notably the team of F. H. C. Crick and J. D. Watson [see "The Structure of the Hereditary Material," by F. H. C. Crick; SCIENTIFIC AMERICAN, October, 1954]. The chromosomes are made largely of DNA (desoxyribonucleic acid). DNA can exist in a great multitude of forms, all built of the same building blocks but with the units arranged in different sequences. The hereditary information carried by a DNA molecule is contained in the order of arrangement of these units. DNA is a long-chain molecule constructed from four comparatively simple chemical units: adenine, thymine, guanine and cytosine. For convenience let us substitute four more familiar terms: spades, clubs, diamonds and hearts. Then a sequence of a few thousand cards which begins

may represent a male fox terrier, while a sequence beginning

may be a red rose.

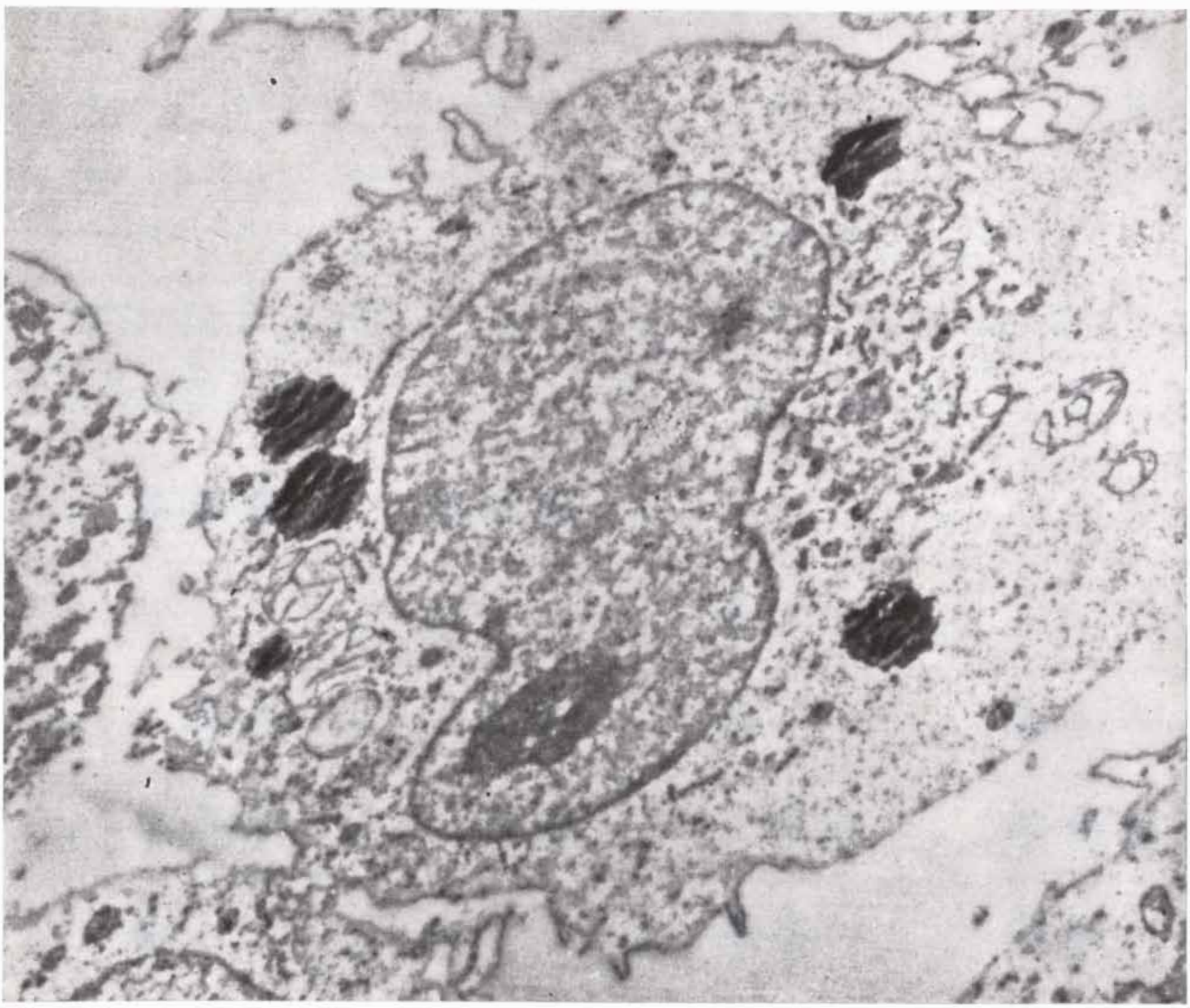
Since each position in the long chain may be occupied by any one of four possible building blocks, the variety of information that can be contained in DNA molecules is very large indeed. A chain only 100 units long, for example, could be arranged in 4^{100} different ways. This number is a thousand times larger than the number of atoms in the entire solar system! And the DNA chain is not 100 but several thousand units long. Nature chooses from a tremendous number of possibilities in formulating the blueprints for a living organism.

Actually the DNA molecule is a double chain rather than a single one. This does not add to its information content because one chain completely determines the other: that is, ordinarily adenine in one chain can be coupled only to thymine in the other, and guanine only to cytosine—or a spade only to a club and a diamond only to a heart:

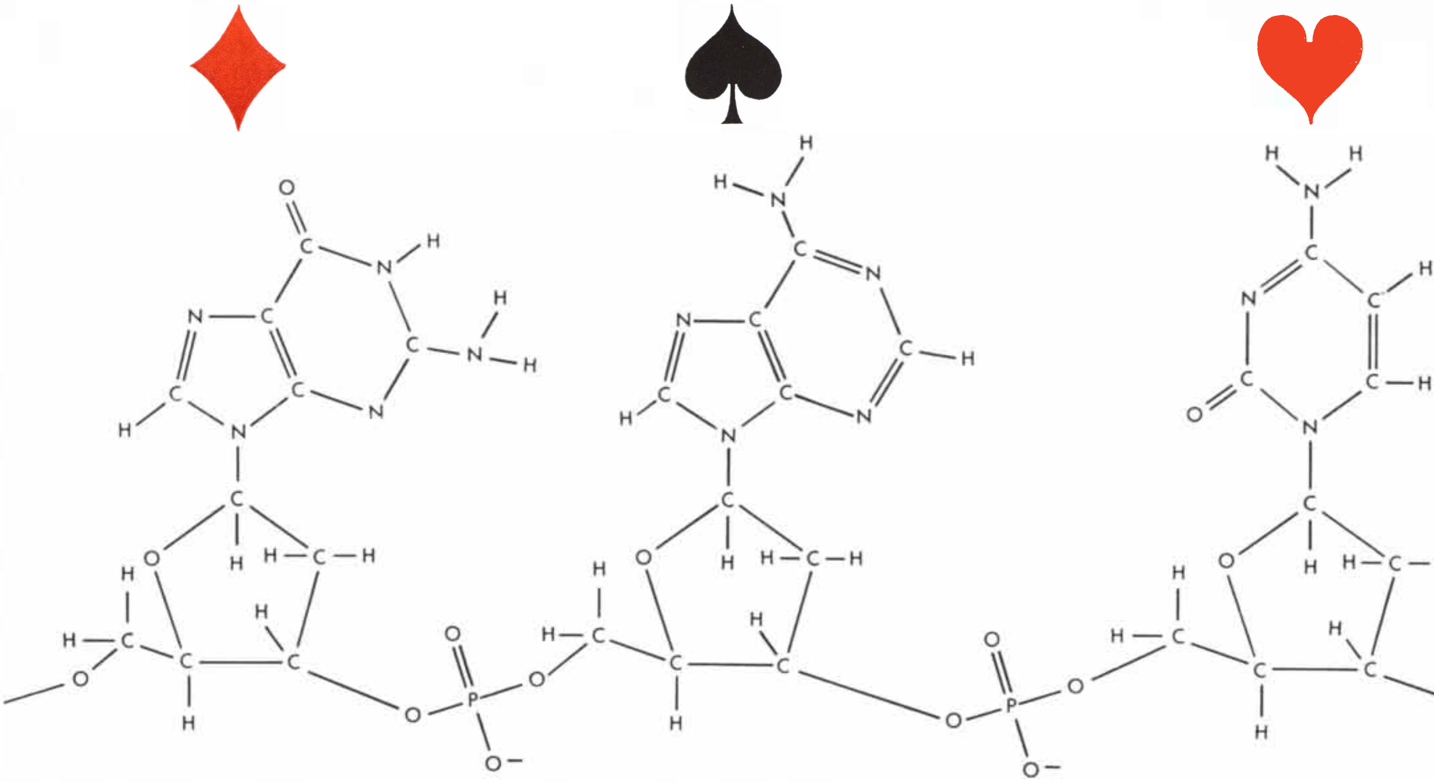


According to Crick and Watson this restriction must play an important role in the process of replication of the DNA molecule, for each single chain, when split from the other, will determine the sequence of units in a new partner chain that builds onto it. A mutation may be a mistake in coupling: for example, a "heart" may sometimes accidentally capture a "club" instead of a "diamond" at some point in generating a new chain.

Leaving the manager's office in the cell nucleus and entering the production plant, we encounter the workers, or enzymes. These molecules are built in a rather different manner from DNA. They are long-chain structures (proteins), but they are composed of some 20 different units instead of only four. The units are amino acids: arginine, cystine, proline, glutamic acid and so on. The enzymes are composed in a dif-



MOUSE TUMOR CELL, magnified 6,600 times by electron microscope, shows nucleus and various particles in the surrounding cytoplasm. The tiny dark particles probably are RNA granules. RNA in normal cell may receive reproduction code from chromosomes.



SECTION OF DNA CHAIN shows four basic chemical units, called nucleotides, which form a backbone chain of sugar molecules. In Gamow's analogy the nucleotide containing adenine is represented by the spade suit, cytosine by hearts, guanine by diamonds and

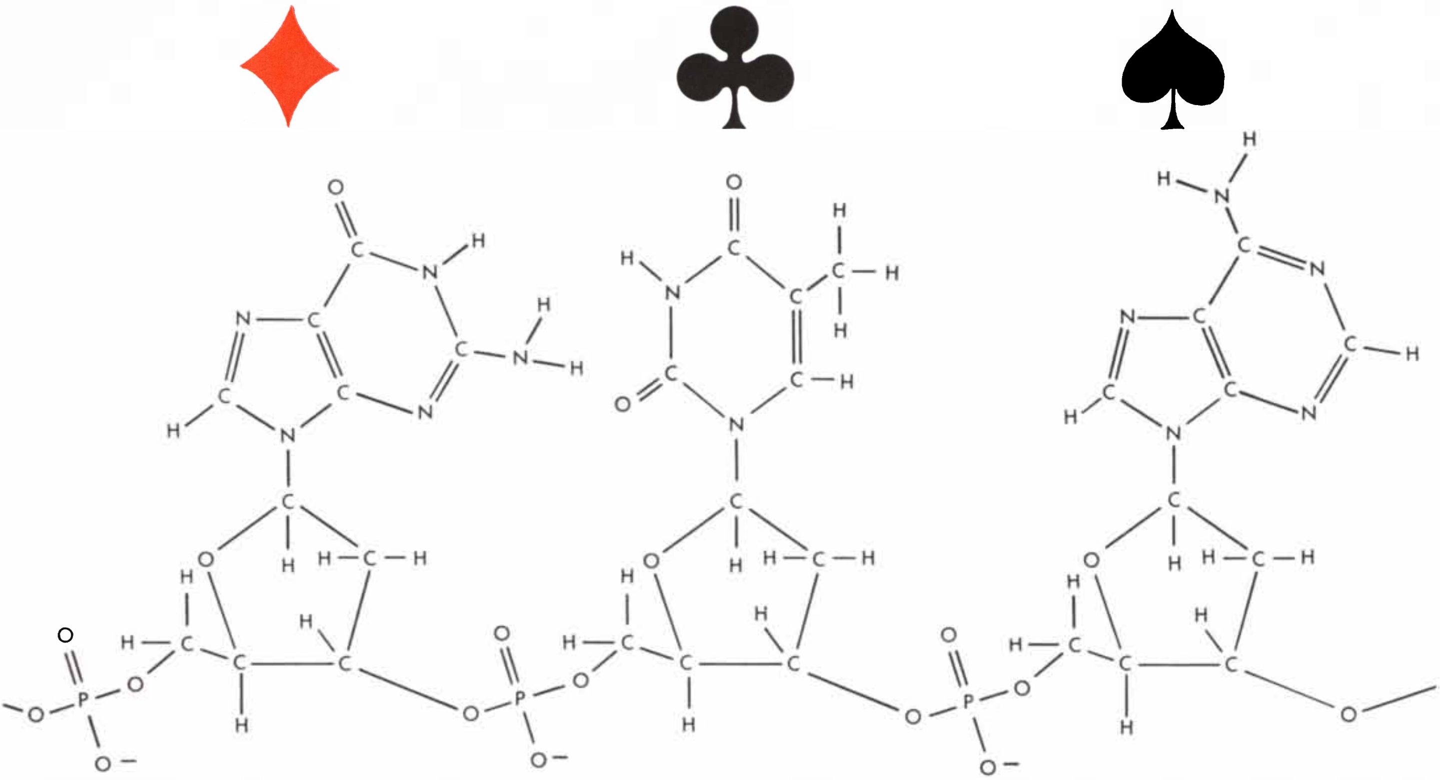
ferent language, so to speak, from the language of DNA.

Just as in human language, where the meaning of a word or sentence may be altered by changing the sequence of a few letters, so the switch of a few amino acids in a protein molecule may considerably alter its biological function. For example, consider two rather simple proteins which are very similar in structure. One is oxytocin, made of nine amino acids in this order: cystine-tyrosine-isoleucine-glutamine-asparagine-cystine-proline-leucine-glycine. The other is vasopressin: cystine-tyrosine-phenylalanine-glutamine-asparagine-cystine-proline-lysine-glycine. Although the two substances differ in only two places out of nine (the third and eighth), their functions are rather different. Oxytocin contracts a cow's uterus, helping her deliver her calf, while vasopressin contracts a bull's blood vessels, raising his blood pressure.

The information in the chromosome blueprints must be communicated to the working enzymes. How is the DNA language of the chromosomes translated into the protein language of the enzymes? What mathematical trick makes

♥ ♥ ♥	A	♦ ♦ ♦	B	♠ ♠ ♠	C	♣ ♣ ♣	D
♥ ♥ ♦	E	♥ ♥ ♠	F	♥ ♥ ♣	G	♦ ♦ ♥	H
♦ ♦ ♠	I	♦ ♦ ♣	K	♠ ♠ ♥	L	♠ ♠ ♦	M
♠ ♠ ♣	N	♣ ♣ ♥	O	♣ ♣ ♦	P	♣ ♣ ♠	R
♦ ♠ ♣	S	♥ ♠ ♣	T	♥ ♦ ♣	U	♥ ♦ ♠	–

NUCLEOTIDE TRIPLETS form a code which translates the chemical language of DNA into that of proteins. Each combination of three nucleotides can be related to a letter in an abbreviated alphabet. These letters correspond to the amino acids of proteins.

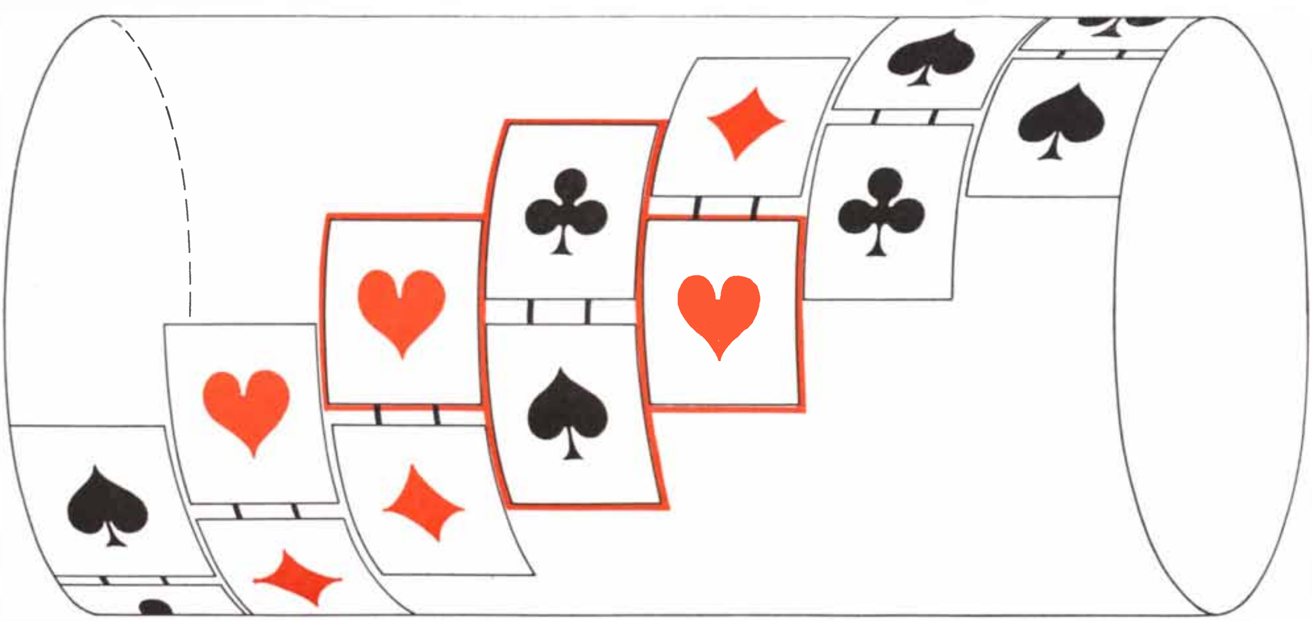


thymine by clubs. The DNA chain may extend to several thousand units in length. Since each arrangement of nucleotides may possess a different genetic property, variations in the DNA sequence determine the differences between a herring and a human being.

it possible to transform a message represented by a sequence using four symbols into one using 20 symbols?

About two years ago the writer tried a simple mathematical relation as a starting point for a possible solution of this problem. If you have four different elements and take three at a time, the total number of possible combinations of three (disregarding the order) is 20. We can think of it as a reduced poker game in which each player gets only three cards, and only the suit counts. In such a game there will be three different types of hands: (1) all three cards of the same suit (a "flush"); (2) two cards of one suit and the third of another (a "pair"); and (3) all three cards of different suits (a "bust"). The total number of possible hands will be 20. All the possible combinations are listed in the table at the bottom of the opposite page.

Now we associate with these hands 20 arbitrarily chosen symbols from the English alphabet (19 letters and a dash for a space). Each of the letters represents an amino acid, one of the 20 different units in a protein. Each suit, as we have seen, stands for one of the four DNA units, sometimes called nucleo-



NUCLEOTIDE CROSSES, such as the one outlined in red, determine the order of amino acids in a protein, according to Gamow's theory. Each cross is a triplet of three independent elements, indicated by the three red boxes. It attracts a specific amino acid.

	ALANINE	SERINE	VALINE	CYSTINE	GLUTAMIC ACID	LYSINE
ALANINE			•			
SERINE	••			•		•
VALINE			•			
CYSTINE				•••		••
GLUTAMIC ACID		••••				•
LYSINE				•		••

AMINO ACID SEQUENCES were surveyed statistically. Each dot represents a protein sequence in which an acid in the vertical listing follows one in the horizontal list. Thus serine follows glutamic acid in four cases; but glutamic acid never follows serine. Double cystines are found in three sequences. This chart is only a part of the complete table.

tides. Suppose that each amino acid possesses a special chemical affinity for a certain triplet of nucleotides; that is, a given letter always tends to associate itself with a certain hand—*a* with three hearts, *b* with three diamonds and so on. Then the order of the nucleotides in a DNA molecule will uniquely determine the order of amino acids in the protein built according to its blueprint. The DNA molecule will serve as a "template" for the construction of the protein.

The Crick-Watson model pictures the DNA molecule as a double chain of nucleotides wound in helical fashion around a cylinder. The scheme is illustrated on page 73, with playing cards representing the nucleotides. Consider the cluster of four cards outlined in red in the diagram. The cards in separate columns do not determine each other, but the presence of a club at the top of column 3 demands a spade below it. Thus in this cross-shaped cluster al-

FREQUENCY OF OCCURRENCE	POISSON DISTRIBUTION	AMINO ACID PAIRS	LETTER PAIRS IN PARADISE LOST
0	264.2	264	305
1	116	103	55
2	25.6	27	23
3	3.77	4	7
4	.42	2	3
5	.037	0	3
6	.0027	0	2
7	.00017	0	0
8	.0000095	0	2

ANALYSIS OF CHART ABOVE shows that amino acid pairing follows Poisson distribution, an indication that pairing is random. This signifies that in RNA, nature uses a non-overlapping code. Because some combinations of letters are common in English, while others are rare, pairing of letters in Milton's poem departs from Poisson distribution.

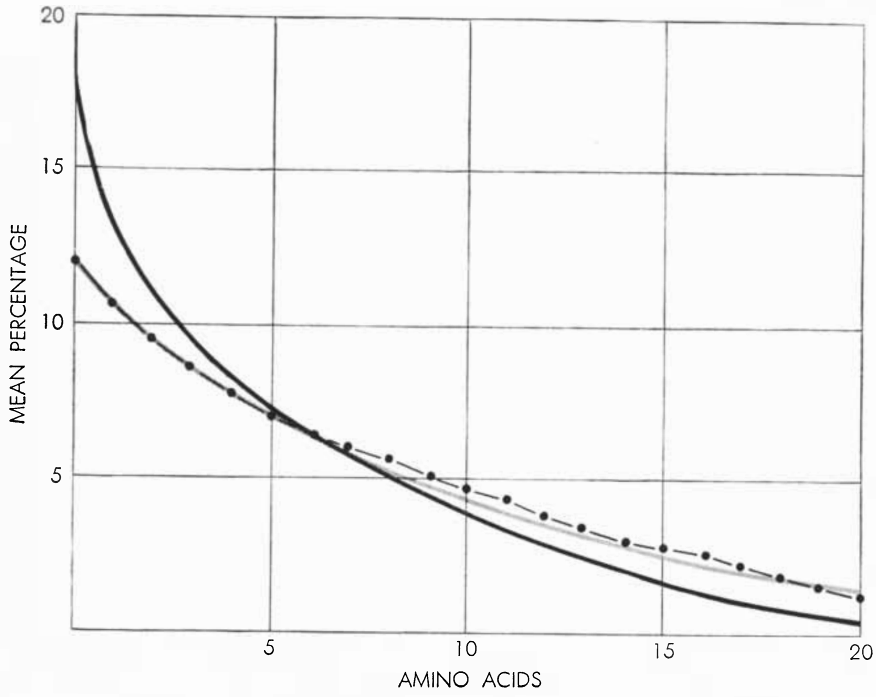
though we have four cards we have only three independent elements: the red-bordered card in column 2, the pair in column 3 and the red-bordered card in column 4. Now, as we have noted, the total number of three-element combinations that can be formed from four cards is 20. Thus we could have 20 different four-card patterns in the cross-shaped clusters that make up the DNA double chain.

We might suppose that these nucleotide "crosses," each capturing a specific amino acid from the surrounding solution, could build a protein chain in which the order of the amino acids would be determined by the order of nucleotides in the DNA molecule. If this is so, what are the capturing units—adjacent crosses or overlapping crosses? The known distance between one amino acid and the next in a protein chain indicates that the capturing crosses overlap. This gives us a means of testing the nucleotide template hypothesis. We know, for instance, that a cross of four red cards cannot overlap one of four black cards. Therefore, if our hypothesis is correct, in a protein chain an amino acid determined by four red cards will never stand next to one determined by four black cards.

Unhappily, when such a test was applied to certain selected protein sequences (a direct test of all the possibilities was out of the question), it turned out that the hypothetical DNA communication system would not work!

A way out of this blind alley was found, however. The living cell contains another agent, very similar to DNA, which seems to play an important role in the synthesis of proteins. It is ribonucleic acid (RNA). RNA appears to be a close chemical relative of DNA, though one of its nucleotides is different and it seems to be made of a single chain instead of a double one. There are indications in recent biological studies that RNA may be an intermediary which carries messages from the DNA of the chromosomes to the enzymes in the cytoplasm—like factory foremen taking instructions from the manager's office and passing them on to the workers in the factory in simplified language. The DNA molecules apparently give rise somehow to RNA molecules, and the latter get busy producing proteins from various centers (microsomes) in the factory (cytoplasm).

If the RNA clue extricates us from a blind alley, it also makes the problem of discovering and decoding the language of living cells more difficult. The structure of the RNA molecule is



CLUE TO RNA STRUCTURE is the proportions of amino acids in protein. If the selection of amino acids were determined purely by chance, relative abundances should match relative lengths of pieces of a broken stick (*solid black line*). However, observed abundances (*dotted line*) agree much more closely with the abundances to be expected if each amino acid is assumed to be determined by a randomly placed triplet of nucleotides (*gray line*).

still largely a mystery. It may be helpful, however, to speculate about it.

Suppose we again represent the four nucleotides in RNA chains by playing cards, except that one card is turned on its side to show that one of the RNA units differs from its DNA counterpart (it is called uracil instead of thymine). Do the nucleotide triplets in the RNA chain overlap, as in DNA? If they do, there should be a certain correlation between neighboring amino acids in protein sequences. To find out whether such a correlation can be found in known protein sequences, the author and his colleague Alexander Rich employed a statistical analysis based on the Poisson distribution formula, a convenient probability measure. We constructed a grid listing the 20 amino acids in arbitrary order across the top and down the side [*see upper table on page 74*]. A dot was placed in each box for each time a given amino acid follows another given one in known protein sequences. For example, alanine is known to be followed by valine in one case; this is indicated by a dot in the appropriate box. No case of alanine following valine is known; the box is therefore left blank. There are four known cases in which serine follows glutamic acid, indicated by four dots.

Now if there is no pairing correlation (*i.e.*, if specific pairings occur only with chance frequency), the number of empty squares and the numbers with one, two, three and more dots must coincide with the Poisson distribution, which describes the overlap of random events. The test shows, in fact, that amino acid pairs do follow the Poisson distribution very closely, which means that they occur almost completely at random. This absence of correlation strongly suggests that nature uses a nonoverlapping code in the translation of the RNA language into protein sequences. In contrast, the sequences of English letters in a literary passage (the beginning of Milton's *Paradise Lost*) show strong deviations from randomness [*see table at bottom of page 74*].

In another approach to the problem the writer and his colleague Martinas Yčas recently considered the relative amounts of different amino acids found in proteins. If nature selects amino acids for proteins in a random way, the most abundant amino acid, the second most abundant, etc., should occur in much the same proportions as would different lengths of pieces of a stick if it were broken at random into 20 pieces. The problem of breaking a stick at random into 20 pieces was solved for the author by his friend John von Neumann. He proved that on the average the longest piece should be 18 per cent of the origi-

CORNING GLASS BULLETIN FOR PEOPLE WHO MAKE THINGS

CORNING GLASS WORKS, 30-10 Crystal Street, Corning, New York
Please send me the material checked below:
☐ B-83: "Properties of Selected Commercial Glassware." ☐ B-84: "Manufacture and Design of Commercial Glassware." ☐ Booklet: "Glass and You."
Name__________
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Company__________
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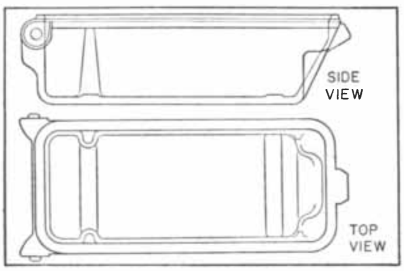
City__________ Zone_____ State_____

Bold mold

It has come to our attention that often simplicity embraces complexity.

A good case in point: the dental tray you see pictured. It's a relatively simple outfit for sterilizing small instruments by immersion. A product of the Bard-Parker Co., it's made of a PYREX brand glass, metal, and rubber.



Our contribution to the working simplicity of this sterilizer is the glass body. Actually, this main component is a quite complex, one-piece object, *molded* of one of our most versatile glasses, PYREX brand No. 7740.

A close look at the illustration will give you some idea of the many angles, radii, ridges and such to be calculated in making the molds in which this tray is pressed. Yet, its precise tolerances allow the metal and rubber cover to fit and hinge on the glass lugs, and the inside metal tray rests evenly on the built-in glass supports for draining.

At the risk of repetition, we mention again that all this is *molded* in one piece of glass.

Which brings us to the point that under Corning's scrutiny, glass can be readily made in shapes and for purposes that may never have occurred to you as possible with so hard, durable, and seemingly inflexible a material.

(And the fact that this item is made of a PYREX brand glass and stands up to the chemical action of the antiseptic solution should not be overlooked.)

From this bold mold you can induce that glass, economically mass produced by any one of a variety of processes, may hold the answer to some ticklish design and/or production problem of yours.

For nothing more than postage you might start finding out with a booklet called: "B-84—Manufacture and Design of Commercial Glassware." It tells about blowing, pressing, multiforming, sealing, assembling glass to metal, and other factors of interest to men of practical turn. Check the coupon for your copy.

Making light of it

Campers, world travelers and those deprived of electrical illumination have long turned to portable Coleman lanterns for light.

Pressurized gasoline is burned in a thorium mantle. These light sources give off with some 300 candle power, about what you get from a 300-watt bulb.

To achieve such an output, the mantle reaches and holds at about 3,000° F.

Problem: What kind of glass chimney will stand up near this internal heat, the differential ambient temperatures, and the rugged handling such a portable light is bound to get?

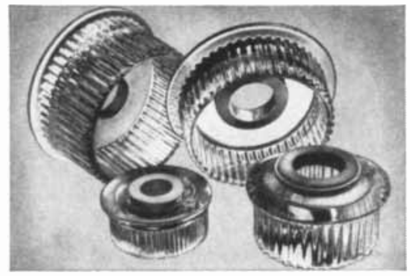
Answer: This is another example of where a PYREX brand glass solved a critical design problem, this time because of its low coefficient of expansion and high resistance to abrasion and physical shock.

For a brief rundown on the physical properties of PYREX brand glasses and other glasses, ask for our Bulletin B-83.

Godet (or how to spin a yarn)

Godet is the name given to a highly talented wheel used for spinning rayon yarn.

This intelligence by itself is neither startling nor revealing. And this picture tells you little other than that godet wheels are made of glass in dimensionally accurate intricate shapes.



Why we discourse on godet wheels (aside from the fact that we make them) lies in the somewhat unusual circumstances under which they operate.

First, viscose (cellulose solution in a mixture of carbon disulphide and sodium hydroxide) is extruded through a spinnerette into a solution of sulphuric acid. The coagulated yarn, comprised of as many as 800 delicate filaments, must then be pulled out of the acid, washed, and stretched.

Here's where the godet wheels take over. One, with a stream of hot wash solution running over it, pulls the yarn and snubs it. The other puts in the stretch.

And why glass for this chemical yarn spinning? First, there's the very important consideration of *dimensional stability*. This glass has it. Good thing, too, since any change in wheel size or shape, due to the affects of the acid, would change the wheel's peripheral velocity, and adversely affect the yarn stretch.

Moreover, the smooth finish of the glass wheels insures against fraying the fine filaments.

These wheels are also impervious to the corrosive action of both the acid and hot wash water.

And, glass is easily shaped to the complex fluted form required—in quantities, at reasonable prices.

Here's a spinning example of Corning custom engineering in glass—the right balance of the right characteristics—to do a very special type of job.

More examples are spelled out in "Glass and You." "It's a good primer for learning a great deal about today's *engineered* glasses. Use the coupon. Free.

CORNING GLASS WORKS, CORNING, N. Y.

Corning means research in Glass

nal stick's length, the second longest 13 per cent, and so on.

The curve of observed abundances of amino acids does not follow this curve of stick lengths [*see chart on page 76*]. The situation can be repaired, however, if we assume that the sequence of amino acids in a protein molecule, though not random itself, results from application of a certain code to a random sequence of nucleotides in the corresponding nucleic acid molecule. We apply the triplet code of RNA to nucleotides at random to see which combinations of nucleotides (and therefore which amino acids) will be selected most frequently. It is easy to see that the most probable three-card hand (nucleotide triplet) is a "bust." The bust can occur in six different ways (heart-diamond-club, diamond-heart-club and so on), while a suit pair has only three possible sequences and a flush only one possible sequence in a three-card hand. We say that these three hands have the relative statistical "weights" 6, 3 and 1.

When the "weighted" triplet rule is applied to the four different types of nucleotides, assumed to be randomly distributed in the RNA chain, the curve of nucleotide combinations occurring agrees perfectly with the observed abundances of amino acids in proteins [*see chart*]. This fact is a strong argument in favor of the assumption that each amino acid in a protein sequence is defined by a triplet of the nucleotides, located at random in the RNA chain.

Yet at the end we must ask ourselves a serious question. What right have we to assume randomness in the hereditary material, the product of a natural selection process which has operated for millions of years? In answer we can cite the fact that the sequence of digits in the number π (3.14158265. . .) is also random: there is no discernible system or pattern in the sequence. We may imagine a mad mathematician who, searching for "useful numbers," writes down one random sequence after another until, after rejecting millions of numbers as useless, he finally stumbles on the random number π and finds by test that it is very helpful indeed in the geometrical problem of squaring a circle.

Similarly in a living organism over eons of time the random mutations may once in a great while produce a sequence of nucleotides which blueprints a new and helpful enzyme. A lizard living in the age of reptiles may thus have acquired an enzyme which catalyzed the production of milk—and so taken the first step toward the age of mammals.

THE NEW PSYCHIATRIC DRUGS

How a trio of "tranquilizing" substances—chlorpromazine, reserpine and Frenquel—have opened up a new approach to investigation of the biochemistry of mental illness

by Harold E. Himwich

We seem to be entering a new era in the study and treatment of mental illness—a biochemical era. Research on the chemistry of mental disease has recently brought forth several exciting new discoveries. One is the new information on the emotional effects of adrenalin and nor-adrenalin [see "The Physiology of Fear and Anger," by Daniel H. Funkenstein; SCIENTIFIC AMERICAN, May]. Another is the finding that a psychotic state can be induced artificially by injections of lysergic acid ["Experimental Psychoses," by Six Staff Members of Boston Psychopathic Hospital; June]. This article will review a third major development: the so-called "tranquilizing" drugs which psychiatrists are using with remarkable effect in treating psychotic patients. These drugs are chlorpromazine (trade name: Thorazine), reserpine (Serpasil) and azacyclonol (Frenquel).

It is well known that in dealing with a psychotic individual the psychiatrist's greatest problem is to make some kind of effective contact with the patient. This is particularly true of schizophrenia. The patient may be aloof and apathetic; he may be living in a world of hallucinations and grandiose delusions; he may fancy that the radio on the ward is directing insults to him personally. Some schizophrenics are so out of touch with their surroundings that even their speech is completely incomprehensible to others (doctors call it "word salad"). Naturally it is of no avail to attempt to argue or reason with such a patient. When he becomes violent, the hospital physicians usually have no recourse but to apply a drastic treatment such as electroshock or to quiet the patient temporarily with barbiturates.

The new tranquilizing drugs have introduced a new regime in the management of patients in mental hospitals. The drugs calm the patients without putting them to sleep. Their effects last longer than sedatives. They make it possible to keep severely disturbed patients in an open ward instead of locking them up. And most important, they make even "hopeless" patients accessible to psychotherapy by reducing their anxiety and removing some of the barriers between the patient and the psychiatrist.

The new drugs promise to reduce the cost of caring for the nation's mentally ill, to decrease the number who must be kept in hospitals and to make mental hospitals more attractive places to work. Moreover, the drugs are becoming popular outside of hospitals. Physicians are prescribing them for mildly psychotic patients whom they now treat in their offices, for neurotic patients and even for entirely normal individuals who become tense under some temporary stress or crisis. A dose of one of these drugs relaxes an anxious person and enables him to deal with a trying situation more objectively.

How do the drugs produce their effects? Before we review the research on their mode of action in the body, let us look at the psychological effects in more detail.

At the Galesburg State Research Hospital in Illinois we have found that the drugs produce the most dramatic results in the most disturbed patients. They are particularly effective in quieting elderly psychotics who are apprehensive, irritable and aggressive. Most surprisingly, they show good results on many chronic psychotics who have been ill and hospitalized for a long time.

The three drugs differ in activity. Chlorpromazine seems to be most effective in suppressing the delusions of paranoid patients and in quieting patients who are restless, hyperactive and over-elated. Reserpine is most successful in helping hebephrenic patients (those whose speech is unintelligible) and catatonic ones (*e.g.*, patients who keep a peculiar posture for long periods or turn only at right angles when they walk). Frenquel moderates various kinds of schizophrenic behavior, but its effect is less marked than those of chlorpromazine and reserpine. However, no one drug is uniformly successful against a given type of disorder, and it may be desirable to try another drug or a combination of the drugs in some cases.

There are drawbacks, unfortunately, to the use of some of the drugs. Substantial doses of chlorpromazine or reserpine may produce large reductions of blood pressure, tremors, gastric disturbances, skin eruptions and jaundice. These drugs therefore have to be administered with care. Frenquel has not shown any such undesirable side reactions so far.

The tranquilizing drugs temporarily banish symptoms of mental illness, relieve anxiety and make a psychotic patient more nearly normal. Thus they are a great boon to psychiatric medicine. And in addition the drugs afford a new instrument for exploring how the machinery of the body breaks down when a person has mental or emotional aberrations.

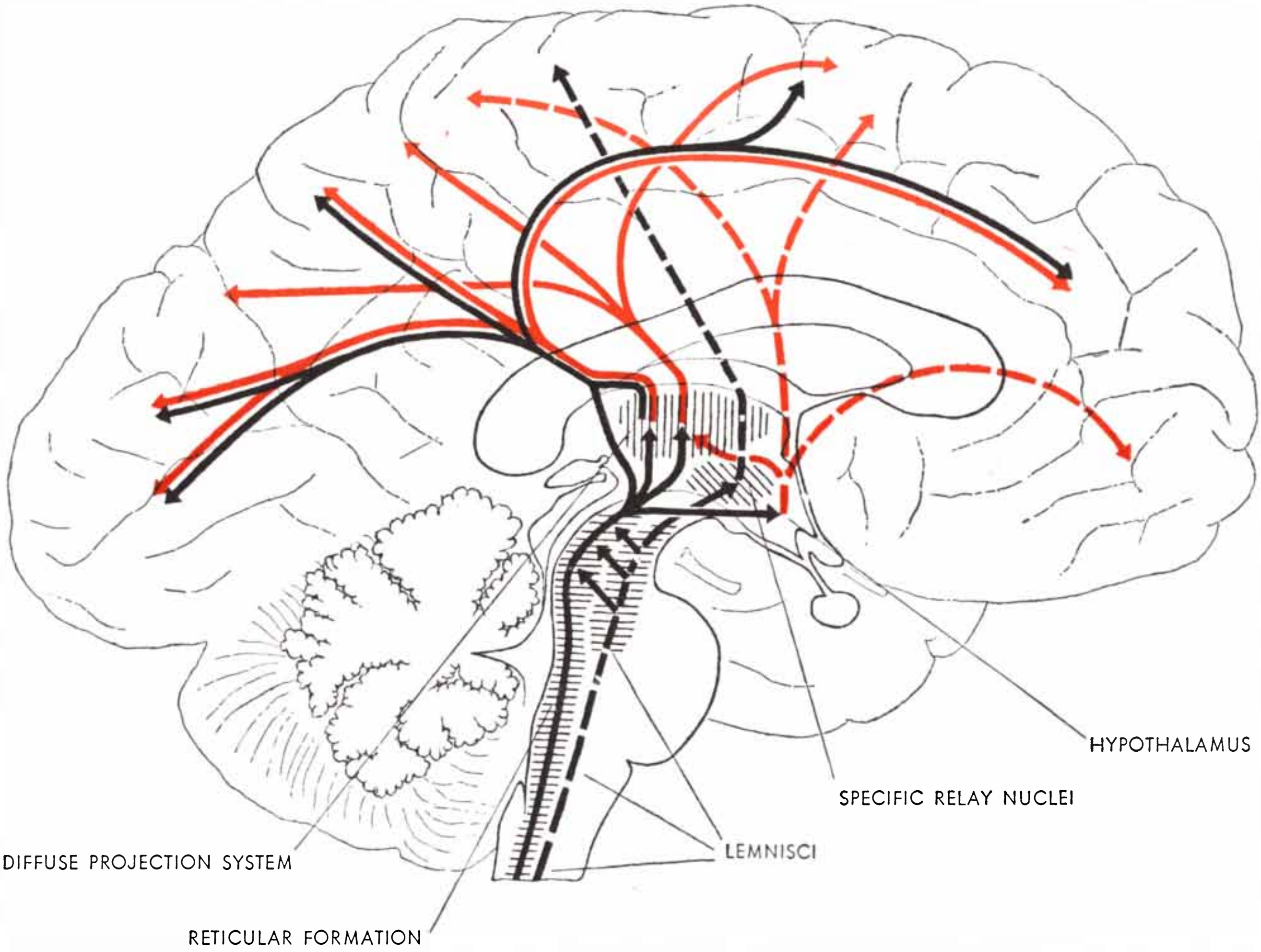
One obviously important site to investigate is the hypothalamus, a structure at the base of the brain which, as Walter B. Cannon showed, plays a key part in mobilizing reactions to an emergency. When an animal is threatened or under stress, it responds with a number of physiological changes which are triggered by mechanisms in the hypothalamus, particularly in its posterior part. In this portion of the brain are centers which correlate breathing and the heart rate with the individual's emotional state, raise the blood pressure, control basal metabolism and the body temperature, rouse the body and put it to sleep.

Now experiments on animals indicate that chlorpromazine and reserpine inhibit the activities of the hypothalamus. Reserpine is an alkaloid extract from the snakeroot plant (named Rauwolfia for a 16th-century German physician), which has been used in India for centuries as a sedative and a treatment for epilepsy, snake bite and various other ailments. Chlorpromazine is a synthetic. Both of the drugs act on the hypothalamus to lower the rate of basal metabolism and the body temperature, reduce blood pressure and quiet agitated emotions. Chlorpromazine also seems to affect the nerve system outside the brain, causing the nerves to relax and dilate the small blood vessels.

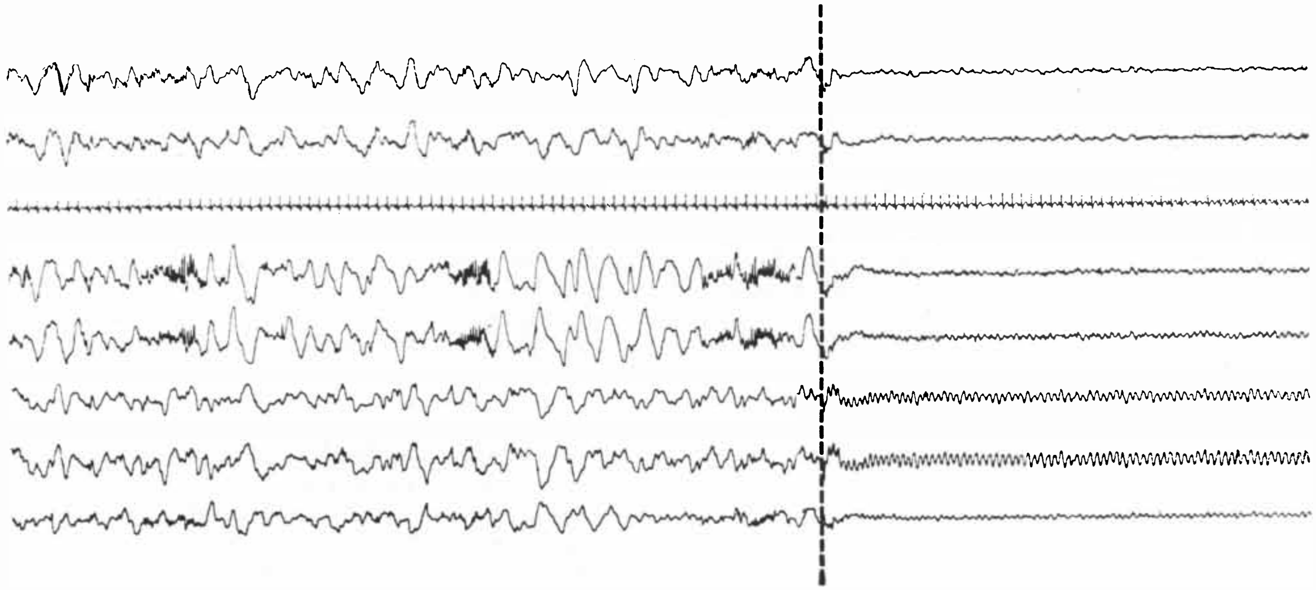
The hypothalamus is not the only part of the brain influenced by the two drugs. My colleague F. Rinaldi and I have detected effects of the drugs on other brain centers. Our method of research was to analyze electroencephalograms of brain waves.

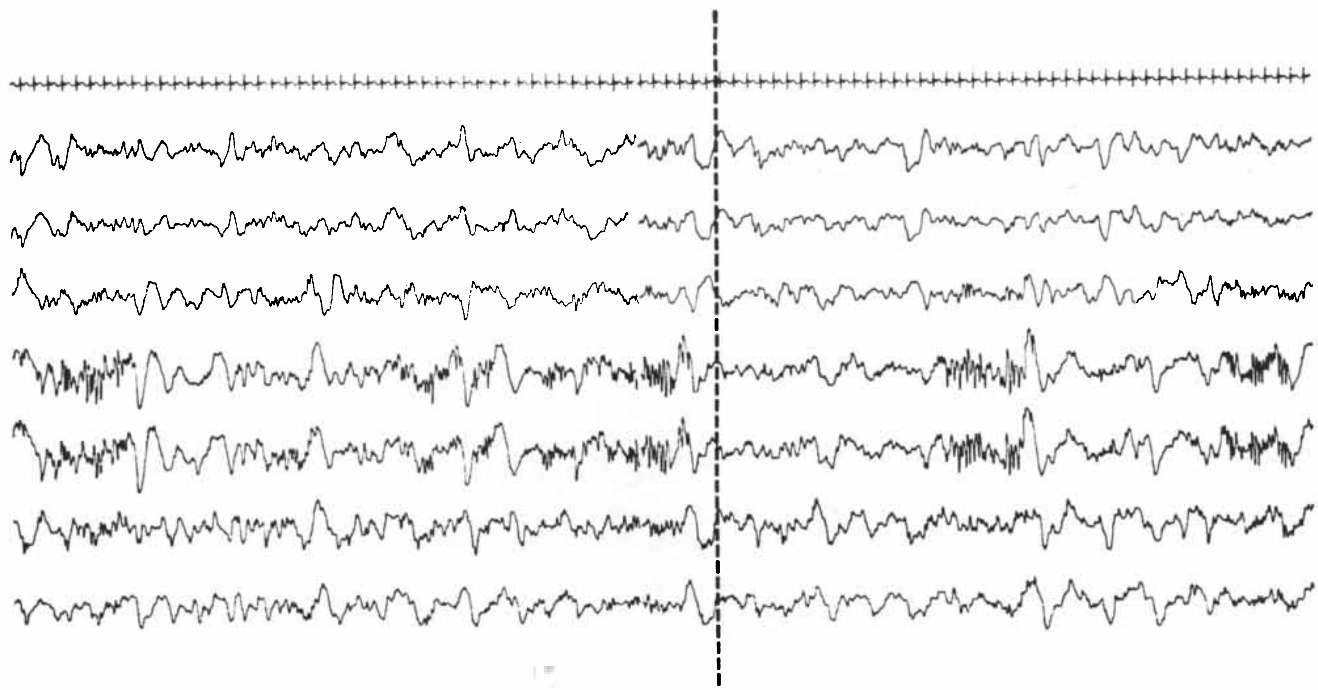
When the body is touched or stimulated in some way, nerve impulses go from the site of stimulation by pathways called the lemnisci to the thalamus in the center of the brain [*see drawing below*]. From there the impulses are relayed to parts of the cerebral cortex which interpret the sensation—touch, pain, heat, cold or the like. But there is also a parallel mental system, so to speak, which is affected by the stimulus. In the central core of the brain is a structure known as the activating system; it is located in the "reticular formation." When stimulated, the activating system produces an arousal reaction. This reaction is clearly shown in an electroencephalogram by a sharp change in the brain-wave pattern [*see upper illustration on next page*].

Chlorpromazine in small doses blocks the arousal reaction. If it is given in advance to an experimental animal, even a painful stimulus will not produce the brain-wave change indicating arousal [*see lower illustration on next page*].



TWO PATHWAYS of stimulation in the human brain are shown in this diagram. Sensory impulses pass through the lemnisci to the specific relay nuclei of the thalamus in the center of the brain. From there they are relayed to the parts of the cerebral cortex concerned with the analysis of specific sensations. This system is shown by the dashed black arrows. The other set of pathways, called the activating system, begins with branches from the lemnisci. They carry impulses to the midbrain reticular formation, which in turn relays these impulses to the thalamus. From there the activating impulses are carried to the cerebral cortex by way of the diffuse projection system. These paths are indicated by black lines. The reticular formation also sends impulses to the hypothalamus. Secondary impulses from the hypothalamus are suggested by dashed red lines, from the thalamus, by solid red lines, paralleling the black.





ELECTROENCEPHALOGRAMS are used to show the effect of a drug on the brain's activity. In the two patterns shown here each wavy line represents the electrical impulses recorded from distinct areas of a rabbit's brain. In the upper record the wave pattern at the left is the resting pattern. When a painful stimulus is applied, it changes the brain-wave pattern to that on the right side of the dashed line. The lower record shows the effect of chlorpromazine: the pattern remains essentially unchanged after the stimulus.

From this we deduce that in a human patient chlorpromazine inhibits the activating system, preventing some stimuli from rising to the level of the cerebral cortex. It thereby places a block between the environment and its influence on the mind. The individual is rendered more aloof from his surroundings. A psychotic is insulated against the terrifying creations of his imagination. A normal person is made less sensitive to troublesome situations which would ordinarily arouse a strongly emotional response, and he can be more objective in evaluating the situation.

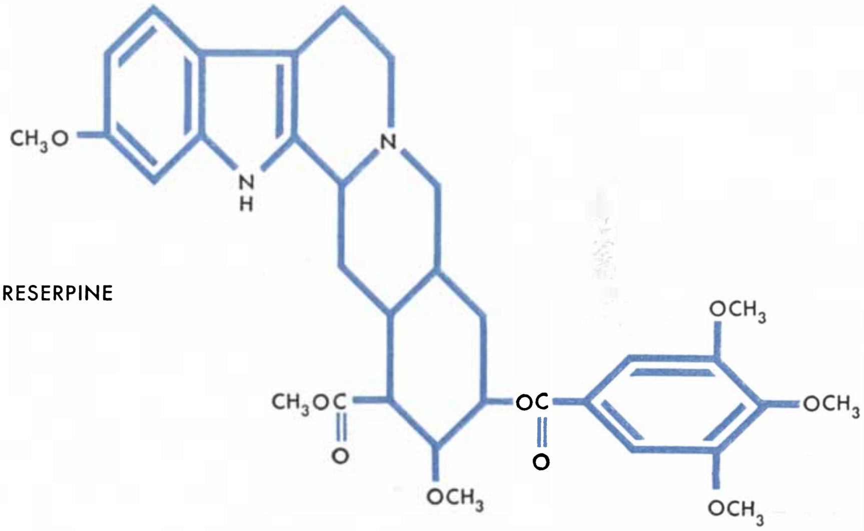
On the other hand, small doses of reserpine (or large doses of chlorpromazine) stimulate the activating system. The drug still has a calming effect upon a patient, because it depresses the hypothalamus, but it does not make him sleepy. Unlike a barbiturate, reserpine keeps the sedated patient wide-awake and at full efficiency.

It is clear that the action of the tranquilizing drugs is far from simple. The mystery of their action is deepened when we come to the third of the drugs. Frenquel does not depress the hypothalamus nor interfere with the usual functions of the activating system. How, then, does it calm a psychotic patient? A hint came from some observations by Howard D. J. Fabing of Cincinnati. Dr. Fabing demonstrated that Frenquel could prevent the psychotic symptoms,

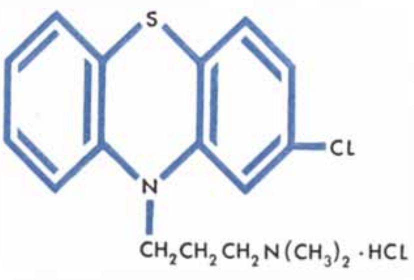
including hallucinations, which are usually produced by the drugs lysergic acid and mescaline. We returned to our animal experiments to investigate this finding further. Experiments showed that lysergic acid and mescaline would induce the arousal reaction in animals, and that Frenquel would quench this experimentally induced reaction. In other words, Frenquel has an antagonistic effect against these drugs. But just how does it act on a psychotic patient?

The problem has been approached from another angle: the chemistry of the brain. Chlorpromazine and reserpine cause fundamental changes in the brain's chemistry; this has been es-

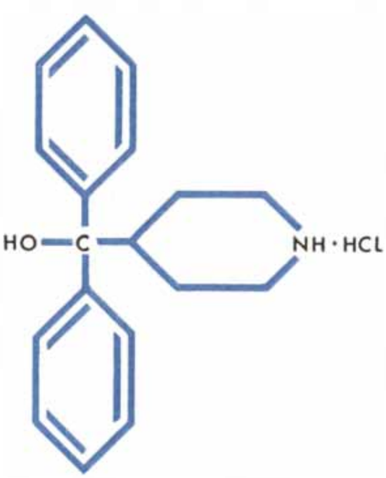
RESERPINE



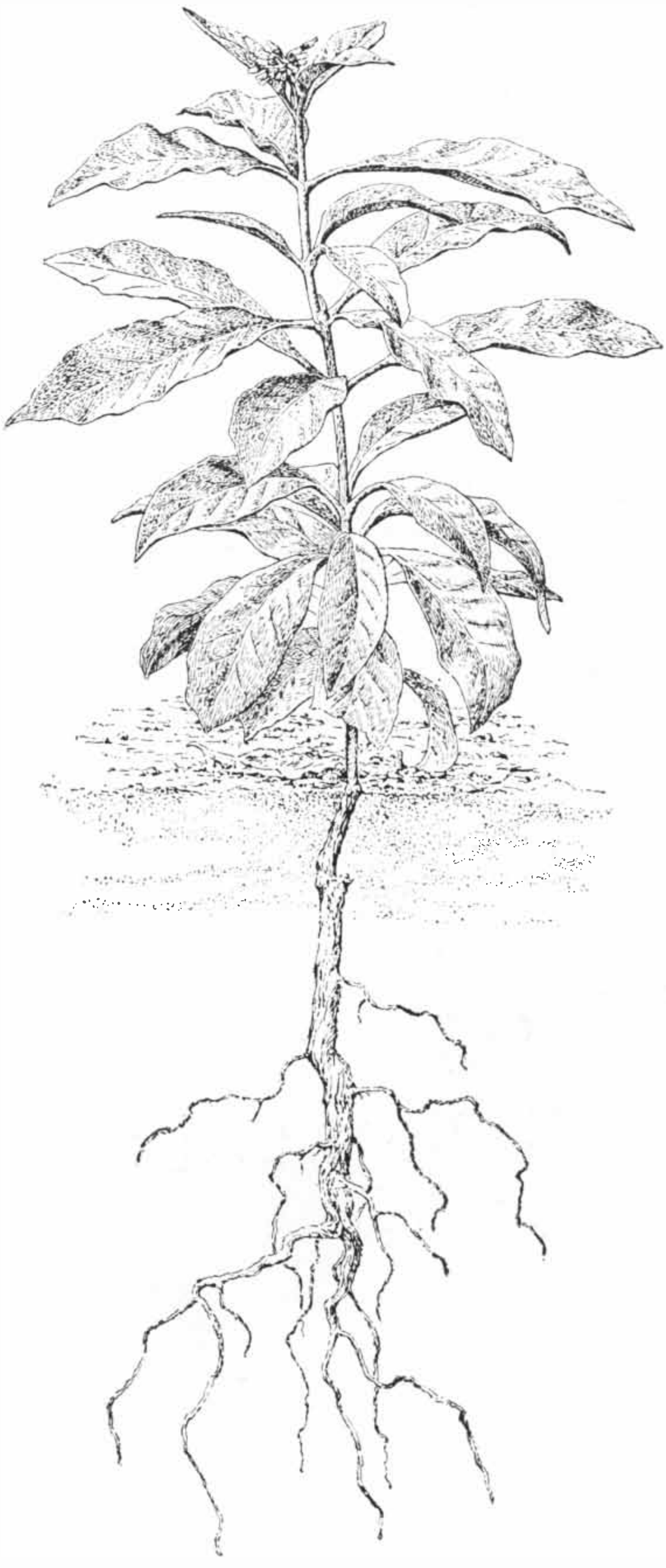
CHLORPROMAZINE



AZACYCLONOL HYDROCHLORIDE



STRUCTURAL FORMULAS of three tranquilizing drugs are represented here. The chemical name of Frenquel is alpha-4-piperidyl benzhydrol hydrochloride. Both it and chlorpromazine (Thorazine) are synthetics. Reserpine (Serpasil) is extracted from Rauwolfia.



RAUWOLFIA SERPENTINA is the species of the snakeroot plant from which the pure alkaloid, reserpine, is extracted. For centuries the root has been used in India for many ills.

tablished by experiments of Robert G. Grenell and his co-workers at the University of Maryland and by my wife Williamina A. Himwich, in our laboratory. And it now appears that an important role is played in these changes by a brain hormone called serotonin.

Serotonin, a neurohormone, acts as a sedative when given in large doses. Bernard B. Brodie and his co-workers at the National Institutes of Health in Bethesda showed in experiments on animals that the hormone's depressant action is blocked by chlorpromazine and Frenquel, and it is blocked still more strongly by lysergic acid. In our own laboratory Erminio Costa studied the action of serotonin in the uterus of the rat (the hormone is found in certain internal muscles). Serotonin causes the uterus to contract. Costa found that the tranquilizing drugs could prevent this contracting action of the hormone. On the other hand, lysergic acid and mescaline increased the contraction, intensifying the effect of serotonin. If these effects on muscle turn out to apply to the brain as well, we may be able to say that lysergic acid evokes abnormal mental states because it increases the effects of serotonin, while the tranquilizing drugs help mental patients because they diminish the effects of the hormone. An exciting investigation is being conducted into this question.

Physicians who have tested the tranquilizing drugs are convinced that they are a great step forward. Their effects have been corroborated widely in the U. S. and in Europe. Psychiatrists at last have at their command drugs which stop symptoms of psychosis just as insulin stops symptoms of diabetes. Moreover, the drugs may be used generally as sedatives in place of the barbiturates now commonly prescribed.

But chlorpromazine, reserpine and Frenquel are only a beginning. The first two produce undesirable side reactions which must somehow be avoided. None of the three drugs is effective in relieving melancholia (a profound, passive depression) or certain long-standing neuroses and psychosomatic troubles. Nor do the drugs help all schizophrenics. Yet they represent a beachhead which should be steadily extended during the coming years. We have a valuable basic clue in the fact that the drugs seem to influence the action of the hormone serotonin. Future progress seems to lie in the direction of finding other drugs which can act on the neurohormones of the brain to counteract disturbances and suppress mental illness.

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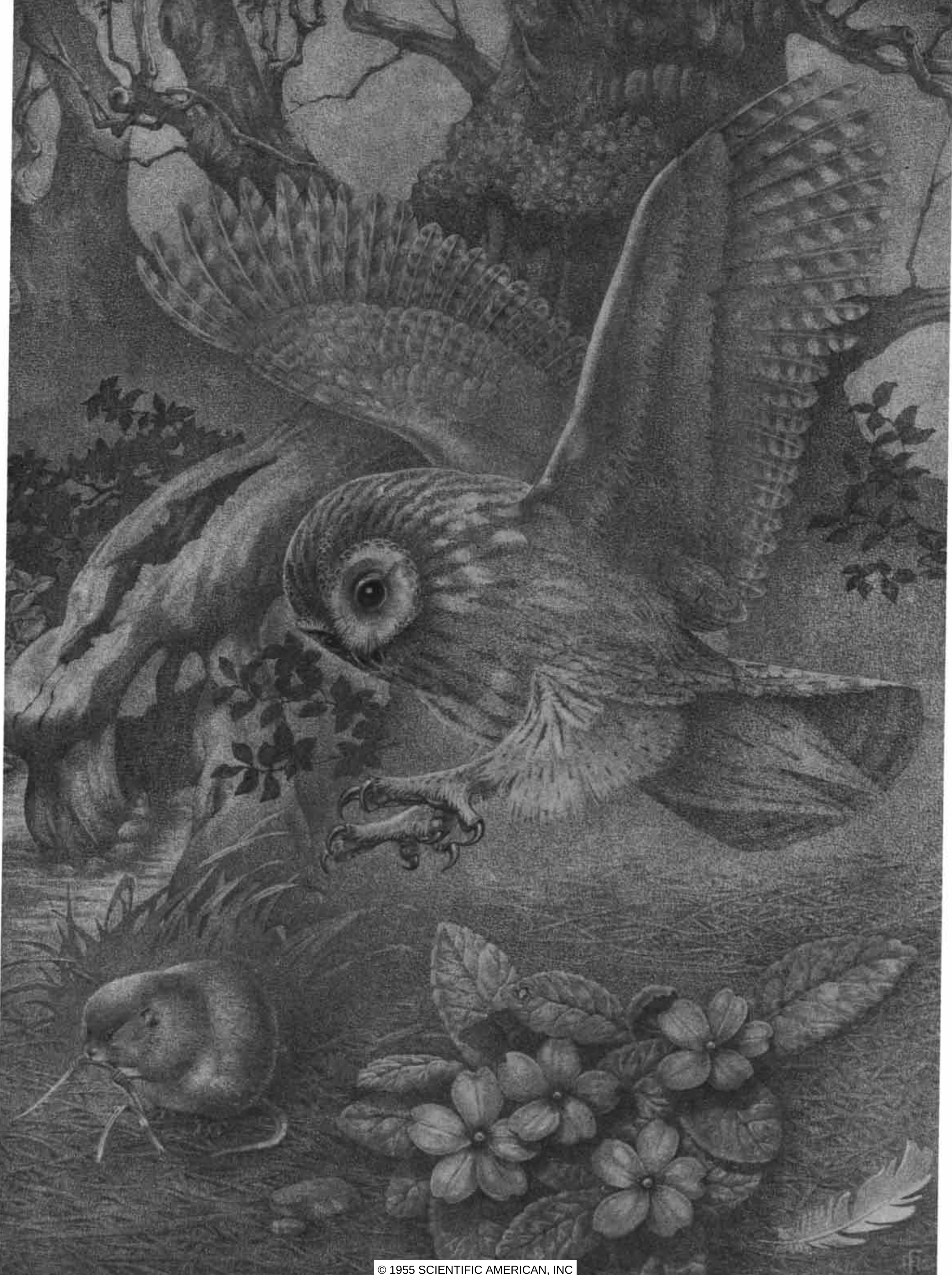


NOCTURNAL ANIMALS

Both predator and prey know their woodlands as intimately as an expert pianist knows the piano keyboard. The animals' blindness to red light makes it possible to observe them

by H. N. Southern

Animals avoid competing with one another by evolving more or less specialized ways of life. Such specialization may take the form of being bigger or smaller than other animals, of eating different foods, of living in different habitats or different niches of the same habitat, of foraging at different times of day. It is not surprising, therefore, that many animals concentrate their vital activity in the nighttime.

The study of night animals has always been a challenging one for the naturalist. Their dark world is as unknown and difficult to probe as life in the depths of the sea. Its investigation demands unusual methods, much labor and patience and a carefully governed imagination.

My own interest in nocturnal animals arose in a severely logical way. I wished to make a quantitative study of the predator-prey relationships among birds and mammals. Because both the predator and the prey populations would have to be laboriously censused, it was necessary to select a predator which did not range over too large a territory or prey on too many different kinds of animals. After considering various possibilities, I decided that the most promising was the tawny owl (*Strix aluco*). This species, slightly larger than the barn owl, feeds primarily upon small mice and voles. Although I was led to the choice of an owl by logic, it would be idle to pretend that the fascination of night work counted for nothing. I was soon absorbed in the problem of finding ways to learn the natural history of animals hidden by darkness.

First of all I had to examine closely the night animals' sensory equipment, both to determine how they get about and to discover methods of observing them without detection. Obviously some nocturnal animals must have unusually acute vision and hearing. The wood mouse (*Apodemus sylvaticus*), a night-worker which is one of the chief foods of the tawny owl, has ultrasensitive eyes and greatly enlarged ear lobes. It responds quickly to the faintest sound, especially in the higher registers. But it is not itself a silent creature. On a still night about an hour after dark, the woodland floor can be heard rustling all over with the excursions of mice. It is the predator rather than the prey which must move in silence. The owl, flying softly on wings with frayed edges, is the most soundless of all night animals. One of the most unnerving hazards of field work in the woodland at night is the sudden, silent onslaught of the tawny owl, which may fiercely attack anyone approaching its chicks. The tawny owl apparently hunts both by sight and by ear, watching and pouncing from a perch. Most owls hunt mainly by ear, locating their prey with asymmetrical ears.

TAWNY OWL SWOOPS down on a wood mouse. The owl's flight is quite silent.

Many animals active by night have no obvious adaptations of sight or hearing to help them move in the darkness. We have learned in recent years that there is another sense which guides animals, including man, in moving about in a familiar territory. For want of a better term we call it the "kinesthetic" sense. It boils down to a conditioned, and therefore swift, repetition of set sequences of muscular movements. The trained muscles of a pianist's fingers produce almost miraculous sequences of movements. A person in his own home can walk down a flight of stairs in the dark and grasp a doorknob with uncanny precision. In night animals the kinesthetic sense is all-important as a guide to movement and territory.

Let me cite two illustrations. If we put a house mouse into an unfamiliar cage, it will quickly explore its new home, traversing and retraversing it in every possible way. For ease of handling wild mice, I usually keep a refuge box in each cage, into which one can drive the mouse or mice to free the cage for cleaning and so forth. If a mouse is disturbed before it has made its preliminary explorations, it will panic and perhaps leap out of the cage. But if it has first had an opportunity to explore the cage, it will react to a disturbance by darting, swift as lightning, into the refuge box. It has achieved in a short time a familiarity with the environment which enables it to take the right path without "thinking," indeed almost without looking.

The second illustration is furnished by young owls. The chicks of the tawny owl are dependent upon their parents for an extremely long time—up to three months. This extended adolescence is devoted not to lessons in hunting but to learning the territory. A fortnight after learning to fly, the young owls have thoroughly explored a limited area. If one chases them with a flashing torch, they will fly only as far as the boundary of that area and then fly back to the middle of the territory. A week later this boundary has rippled outwards for 100 yards or so. Thus the young birds gradually extend their territory to the final range, which for an adult pair of tawny owls is some 25 to 80 acres of woodland. A territory is a thing which has to be known with an almost indecent intimacy. This appears to me the reason why animals find so little difficulty in maintaining their territorial rights.

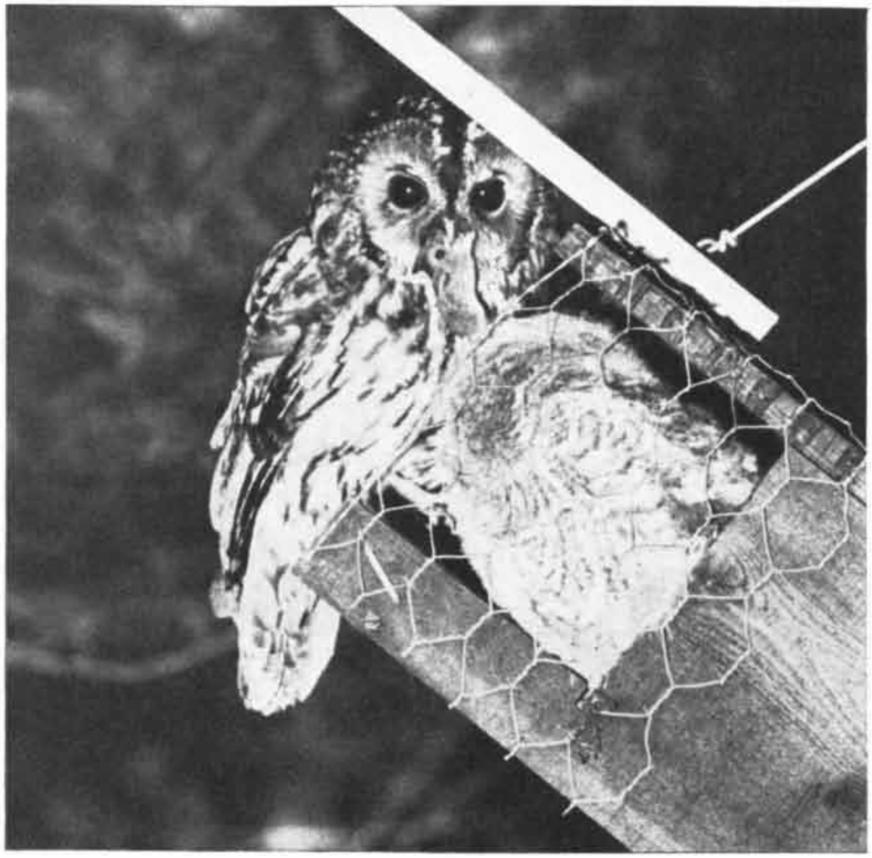
Whether or not an animal is equipped with acute sight or hearing, it is likely to rely largely upon the kinesthetic sense in moving about its territory. We need only watch a wood mouse running through a dense tangle of undergrowth with truly fantastic speed and certitude to realize that it is not "seeing" its way. Kinesthetic sense is clearly the answer. As for shrews and moles, animals which have to forage both by day and by night because their appetites need perpetual appeasement, their journeyings are governed so completely by kinesthetic sense that they are equally efficient in the light and the dark. They have little need of eyes, and their eyes can hardly function at all. Indeed, it appears that certain animals have developed nocturnal vision almost, as it were, by chance. They are a sort of random sample of night creatures—a small percentage that has taken this line of specialization as an "extra." Among rodents the wood mouse is an outstanding example of adaptation to the faintest illumination; another, less outstanding, is the rabbit. Among predators, of course, the owls are pre-eminent.

All of these animals have eyes with similar characteristics: *viz.*, the eye is greatly enlarged and has many rods, which respond to dim light. Some owls can be trained to find even dead, motionless prey in the dark. But the owl's eye is especially fitted to detect movement across the field of view, because rods are sensitive principally to changes of light intensity; cones, which perceive patterns and colors, are absent, or nearly so, from the owl's retina. Less than a millionth of one candle power, about the amount of light that falls on the forest floor on a cloudy summer night, is suffi-

HIDDEN IN BLIND in Wytham woods, the author spent many nights watching tawny owls. At first he tried to use an infrared Sniperscope, with indifferent success. Later he found cient to reveal a mouse to the tawny owl. The bird, whose eyes are immobile, has a peculiar way of moving its head constantly up and down and from side to side when it concentrates on some object, presumably to make the object move across its field of view, even if it is motionless.

Having learned something about our subjects' adaptations to darkness, we could proceed to consider ways of outwitting them. To begin with, owls are noisy in communicating over their large territories. Their rather melancholy hooting, so characteristic of English woodlands at night, is a proclamation of territory. Vocal combats between neighboring tawny owls are not infrequent and can be recognized a quarter of a mile away by the hasty and excited way

that he could flood the forest in rather strong red light without at all disturbing the birds.



OWL FEEDS WOOD MOUSE to its owlet. Owl breeding closely follows the mouse population. In seasons when mice are abundant, tawny owls may attempt to rear two broods.

in which the hooting rises to a screech or a wail. Furthermore, some males can be identified by a consistent aberration of their hooting, and thus their range of movements can be traced.

From intensive listening throughout the night, and especially in the few hours after dusk when activity is at a peak, a plan can be pieced together of the territories over quite a large area. I found it relatively easy, once I had learned the tricks, to census the tawny owls living on 1,000 acres of woodland.

This map of tawny owl territories was confirmed in an unexpected way. To take censuses of the populations of mice, I trapped large numbers of them, marked them with numbered metal leg-rings, and then released them. Simultaneously I was analyzing each month castings from the tawny owls. These contained the bones and fur of the prey they had eaten, and in the pellets I recovered many of the leg-rings with which I had marked the mice. From a single owl nest I might recover 20 to 30 rings. I knew, of course, at what points in the forest the mice marked with these rings had been released, and so I could test whether the area covered by the predations of the owls in question corresponded with the territory I had sketched in from listening. This correspondence was, in fact, almost perfect, so no room was left for doubting either the territoriality of the owls or the validity of the territory measurements.

When I turned to the task of finding a way to watch the animals directly, I first tried a wartime German invention: the infrared telescope popularly called the Sniperscope or, more flippantly, the Snooperscope. It converts an image formed from invisible, infrared rays into a visible, fluorescent image. I had beaten this sword into a plowshare by using it to watch the feeding behavior of wild Norway rats in the dark. My colleague, Dennis Chitty, had become interested in the problem of determining how it was that any alteration in the setting of bait, even so slight a change as placing it in a tin lid instead of on the bare floor, would cause rats to avoid an accustomed food. With the help of the Sniperscope we were able to watch the suspicious behavior of the rat in all its details.

Nevertheless, the Sniperscope had certain disadvantages. Among other things, the resolution of the image was coarse and the transformer supplying the current to the image-converter tube made a high-pitched whine. This last feature alone was enough to scare tawny owls. I therefore turned to another method of illumination: an automobile head lamp screened, like a darkroom lamp, to give visible red rays. At that time I had some 30 nest boxes for tawny owls distributed through the woodland, all fitted with electrical recording apparatus to show the number and frequency of visits by the parents throughout the night. It was urgent to evolve some method of overnight watching to check how many of the visits actually produced prey and what these prey were. The red light gave the perfect answer. It was invisible to the owls. Ensconced in a blind where I could watch an owl's nest through a large pair of 10 x 80 binoculars mounted on a tripod, I was able to see every detail of the owls' movements and the game brought home from their hunting, even the beetles which they occasionally brought to their young. Of some dozen families of owls that I watched intensively over two breeding seasons, no bird ever betrayed the slightest sign of nervousness of the red flood which illuminated its activities.

At one nest I managed to watch throughout eight complete nights. During this time the male brought home 20 prey, most of which were bank voles, then particularly abundant. This continuous watching was very fatiguing even though the night was divided between two observers, because it was essential never to take one's eyes away from the binoculars.

During these watches much valuable information was gained on calls and the general behavior of the owls. It was most interesting to see the chicks, as they grew stronger, climbing up to the lip of the box to be fed. I remember one which made a somewhat premature attempt. It was so unsteady that it nearly fell from the box. Thereupon it fairly bolted back into the nest and refused to reappear until several more nights had passed.

The red-light watches disclosed that during the summer tawny owls eat large numbers of earthworms. For some time I had noticed that their castings often contained no fur or bones but had a matrix of vegetable fibers. Under the direct watch it developed that some tawny owl parents organized a regular ferry service of earthworms to their chicks. When the vegetable castings were examined under the microscope, they proved to be full of earthworm chaetae (bristles). Few of the large owls eat earthworms; the tawny owl's habit of doing so may well contribute to its success as a species.

When I applied the red light to watch-

WOOD MICE NIBBLE BAIT near a live-trap. Dominant members of the mouse social hierarchy staked out a territorial claim to the trap and were caught in it repeatedly.

ing the behavior of wood mice, I was especially interested in determining the answer to a perplexing question. Live-traps set out in the woodland catch mice already marked more frequently than they do unmarked mice. Obviously this must throw all askew any attempt to estimate the total mouse population. I therefore watched a trap for several nights, pinning up the door so that it would not close when mice visited the trap for food. I discovered that of half a dozen mice which came to the trap on those nights, one pair completely dominated the scene. The others were all younger ones and only came to feed when the dominant pair had had their fill. Thus I learned that a social hierarchy existed among these wild mice, and that a trap would merely go on catching the same mouse over and over again.

I became interested to learn what other English mammals were red-blind. So far I have tested only badgers and foxes. Both of these animals appear to be quite unconscious of red illumination. Probably most carnivores that hunt at night have the same limitation. Their world is known to them more in terms of scent and kinesthetic conditioning than of vision; their nocturnal habit may be due partly to daytime persecution.

The red light can be useful not only for watching nests but also for tracking

NOISY BADGER at the entrance to its den pays no attention to red illumination. Southern crept up on the animal while it was stamping about and got close without being heard.

INDIAN
OCEAN

foraging animals at night. I have so far tried this only on the badger, which is a fairly noisy animal. By creeping up when the badger is stamping about and freezing when it is still, it is relatively easy to see closely what the badger is up to.

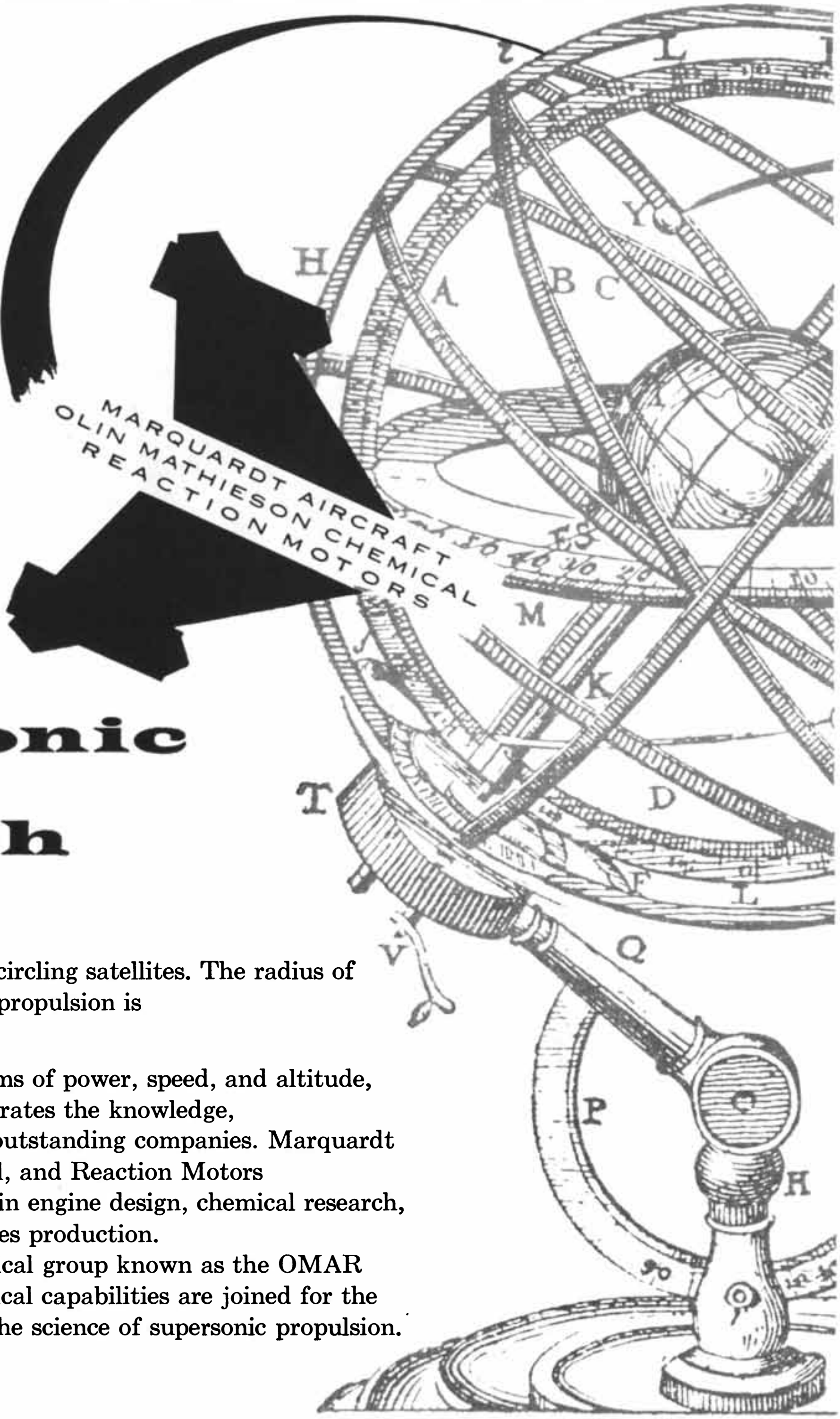
I believe that this method has great promise. If it can be used so successfully on the relatively few nocturnal animals of temperate latitudes, it should be of even greater value in exploring the richer faunas of the tropics. Its great merit is its simplicity. My apparatus has sometimes been cumbersome and costly, but a good flashlight with a concentrated spot and a red celluloid cap will serve for many purposes. To this one needs to add, however, plenty of perseverence.

The specific project which originally prompted me to test these various methods of night observation has been carried on now for eight years. The analysis and publication of the full results will take a long time. Nevertheless, we are able already to tell a number of things about the interaction between tawny owl and wood mouse populations.

In the first place, a continuous study of the contents of owl castings from all over the 1,000-acre woodland through eight years has shown very interesting seasonal variations in the diet. The owls' predations on wood mice and bank voles are greatest when ground cover is at its scantiest—from the fall of the leaves in late November until the beginning of May. During this period 70 to 80 per cent of the tawny owls' diet may consist of small mammals. Since the mouse population falls to its lowest ebb in early spring (just before the breeding season), it is clear that the preying of the owls must bear heavily on that population. During late spring, summer and early autumn, when the vegetation is thick, the owls turn to young moles and rabbits and to invertebrates such as cockchafers, ground beetles and earthworms.

The making of censuses and plotting of territories, achieved by the listening methods described earlier, revealed an astonishingly high density of owls. In 1947, after an exceptionally long and snowy winter, the breeding population on the 1,000 acres studied was 15 pairs. The following year it had increased to 20 pairs, and at the present this number has expanded further to 26 pairs, which means that each couple lives, feeds and sometimes rears young on only about 40 acres of woodland. It is unlikely that any other bird of prey which feeds principally on vertebrates can exhibit a steady density of this order.

new orbit for supersonic research



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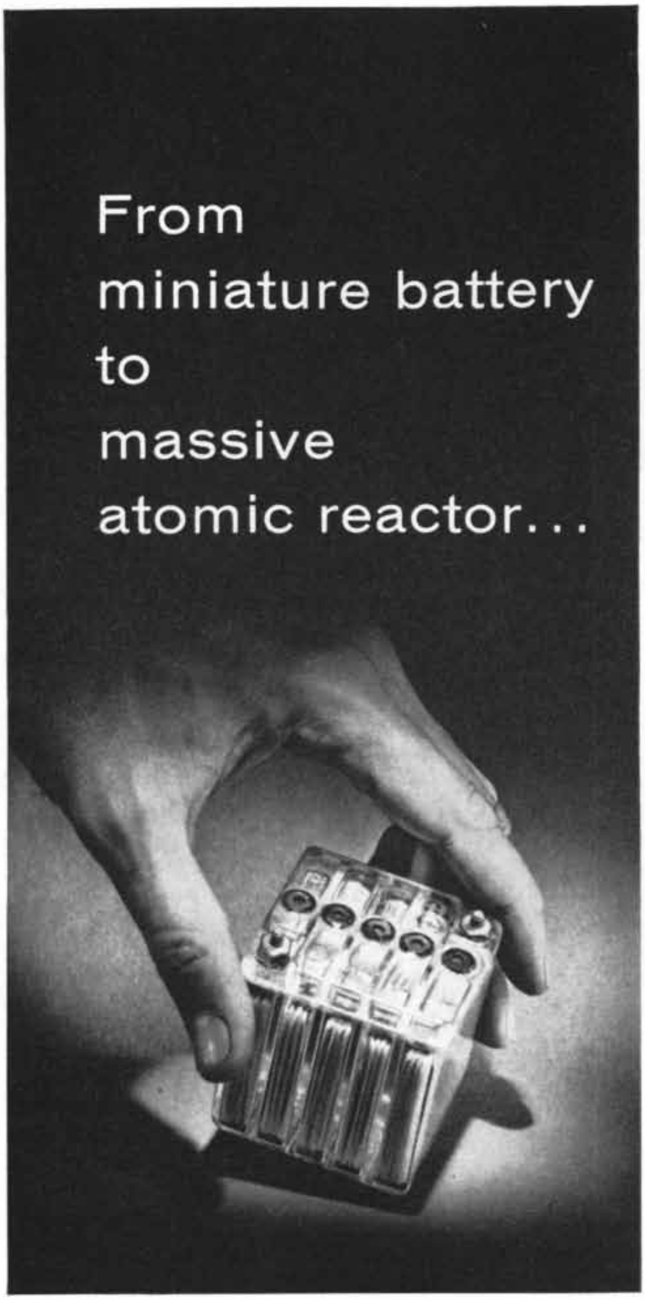
The population figures for the mice and voles are still very approximate. But the trends of the populations from year to year are quite clear. There is a very obvious link between the abundance of mice and the success of the owls in rearing young. In some years a tawny owl pair may raise two or three chicks; in others they make no attempt to breed at all. When the mice are neither abundant nor very scarce, the owls may lay eggs and allow them to chill (presumably because the hen must leave the nest to feed herself, if the male cannot bring her enough prey) or may lose chicks through starvation. If a clutch of eggs is lost, it is unusual for a second clutch to be laid. Second clutches were found on a widespread scale during only one of the years of the investigation—a year in which the populations of mice and voles reached the highest recorded peak.

The tawny owl's reluctance to replace lost clutches, as well as its early start in breeding (usually between March 18 and April 1), probably is due to the long period of the chicks' dependence on their parents. It is curious that, although the young hatchling in the nest is in great hazard of its life, once it has begun to fly it is extremely unlikely to be lost during the remainder of the dependence period.

August in woodland is a month of silence and inscrutability as far as tawny owls are concerned. The young have begun to fend for themselves, and their loud food cries cease. I have yet to evolve a method of studying the owls directly at that time. This is unfortunate, because an important part of the annual mortality falls just then. Indirect evidence suggests that the newly independent chicks suffer very high losses. For one thing, when the owls become territorially vociferous—in late September and October—their numbers have declined sharply. Returns from banded chicks show that the young owls rarely go outside the estate to establish new territories. The most important evidence, finally, is that a number of chicks have been found in a semistarved state during the latter part of August and early September.

With the exception of this period the life cycle of the tawny owl has been pieced together fairly coherently by now, and the history of this particular population is in a fair way to being depicted in quantitative terms. With certain reservations the same is true of the prey populations. In the time available very little information would have been obtainable without the methods of observation described above.



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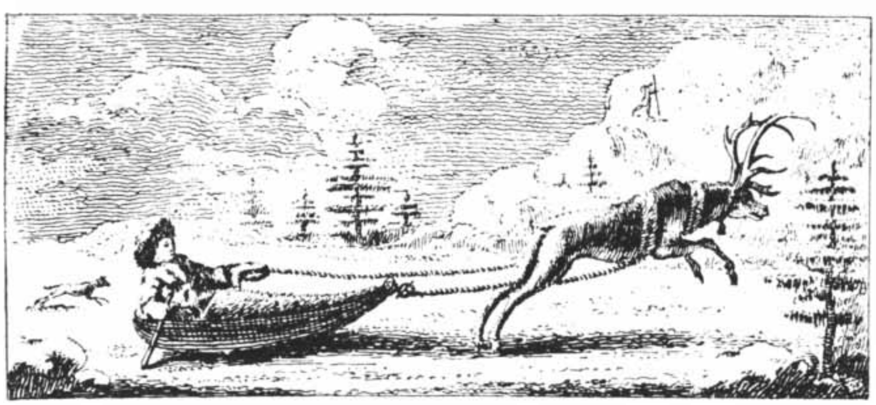
Maupertuis, a Forgotten Genius

Interpreter of Newton, forerunner of Mendel and Darwin, he earned the admiration of great men in a vital time. But he ran afoul of Voltaire, who mocked him into virtual oblivion

by H. Bentley Glass

The mid-18th century was a period almost unexampled for the vigor and advancement of science. Newton's physics had finished remaking the heavens and the earth. In biology the new classification of plants and animals introduced by Carolus Linnaeus gave a vast stimulus to the discovery and description of new species. Louis Leclerc, Comte de Buffon, was beginning his tremendous *Natural History*, which was to run to 36 volumes yet was to be a best-seller found in the library of every European with any pretension to culture. René Ferchault de Réaumur was engaged in fascinating studies of the life of insects. Charles Bonnet in Switzerland had discovered parthenogenesis in plant lice, and his young relative Abraham Trembley had described the little hydra and its powers of budding and regeneration, which awakened the greatest amazement. Was this supposed plant-animal not a living witness to the fact that, as Leibnitz had asserted, "all advances by degrees in Nature, and nothing by leaps"? It helped to inspire the concept of a "great chain of being," which was as much a key to the thinking of the 18th century as the word evolution was to become in the 19th.

Pre-eminent among the scientists of the mid-18th century was a man whose name one must hunt assiduously today to find more than mentioned in histories of science. He was Pierre-Louis Moreau de Maupertuis, a Frenchman who became president of Frederick the Great's Academy of Sciences in Berlin. Born in St. Malo in 1698, he spent his youth as a soldier in Louis XV's army and used his leisure to study mathematics. As a young man, Maupertuis was the first person on the Continent to understand and appreciate Newton's laws of gravitation. He became a defender and expounder of the new scientific doctrines, just as T. H. Huxley more than a century later was the champion of Darwinism. At the age of 38 Maupertuis headed an expedition to Lapland which, in conjunction with another expedition to the equator, confirmed the flattening of the earth toward the poles (by measuring a degree of longitude in each place), and thus provided the first convincing proof to the world that Newton's gravitational theory was correct, just as expeditions to measure the sun's gravitational deflection of light rays during an eclipse were in a later day to confirm the relativity theory of Einstein. There was no Nobel prize in those days, or surely Maupertuis would have earned one.



IN LAPLAND Maupertuis headed an expedition which confirmed the flattening of the earth near the poles, thus demonstrating Newton's recently proposed theory of gravitation. The expedition was as important as those that later measured the deflection of starlight by the gravitational field of the sun and thus confirmed Einstein's General Theory of Relativity.

Maupertuis himself believed that his greatest achievement was his discovery of the "principle of least action." This principle, all too commonly credited to Leonhard Euler, Joseph Louis Lagrange or William Rowan Hamilton (who developed Maupertuis's conception), is indeed one of the greatest generalizations in all physical science.

Maupertuis arrived at the principle from a feeling that the perfection of the universe demands a certain economy in nature and is opposed to any needless expenditure of energy. Natural motions must be such as to make some quantity a minimum. It was only necessary to find that quantity, and this he proceeded to do. It was obtained by multiplying the duration (time) of a movement within a system by the "vis viva," or twice the total of what we now call the kinetic energy of the system. This product was the "action."

Having found the quantity that tends to a minimum, Maupertuis regarded the principle as all-inclusive: the laws of movement and of rest derived from it would apply to all natural phenomena. "The movement of animals, the vegetative growth of plants," he observed, "are only its consequences; and the spectacle of the universe becomes so much the grander, so much the more beautiful, the worthier of its Author, when one knows that a small number of laws, most wisely established, suffice for all movements."

This sort of talk aroused vigorous opposition at the time. Translated into modern biological terminology, however, Maupertuis's principle is none other than Claude Bernard's principle of the maintenance of the internal environment, Walter B. Cannon's principle of homeostasis, or Le Chatelier's law of chemical equilibrium: "In a system in equilibrium, when one of the factors which determine the equilibrium is made to vary, the system reacts in such a way as to oppose the variation of the factor, and partially to annul it." In these days when homeostasis has spread from physiology into embryology and genetics, and when social scientists, emulating ecologists who talk about the balance of nature, themselves talk about the balance of economic forces or social equilibria, the confidence of Maupertuis in the universality of his principle seems justified.

In any event, it seems unfair to say, as Sir James Jeans did, that Maupertuis arrived at his principle from reasons "theological and metaphysical rather than scientific." That is to decry the theoretical approach which has proved so fruitful in modern science, and which, to cite only one example, led Einstein first to the General Theory of Relativity and in after years to a search for a single unified field theory.

The magnificent irony is that it was through his greatest discovery, the principle of least action, that Maupertuis, so eminent and so highly respected in his own day, became a forgotten scientist. The villain of his historical assassination was none other than Voltaire.

For many years Voltaire had been a close friend of Maupertuis and had addressed to him the most flattering remarks. It was indeed from Maupertuis that Voltaire first learned about the Newtonian theory and as a consequence undertook to write his own account of it—a work which was his most serious scientific production. Voltaire's attack on Maupertuis came about in the following way. A friend and former fellow student of Maupertuis named Samuel Koenig turned against him for some unknown reason and charged that Maupertuis's principle of least action was in the first place erroneous, and in the second had been proposed by Leibnitz in a letter known to Maupertuis. Koenig produced a copy of the alleged letter, but no original could be found. After considering the charges, the Berlin Academy of Sciences declared Koenig's letter to be a fabrication and expelled him from the Academy. Voltaire reacted to the expulsion with characteristic fire. Whether he took up Koenig's cause because he considered the young man a victim of tyranny in high places, or because, as some said, Maupertuis had refused him a favor, Voltaire poured upon Maupertuis some of his finest invective. And as the historian Thomas Macaulay observes: "Of all the intellectual weapons which have ever been wielded by man, the most terrible was the mockery of Voltaire."

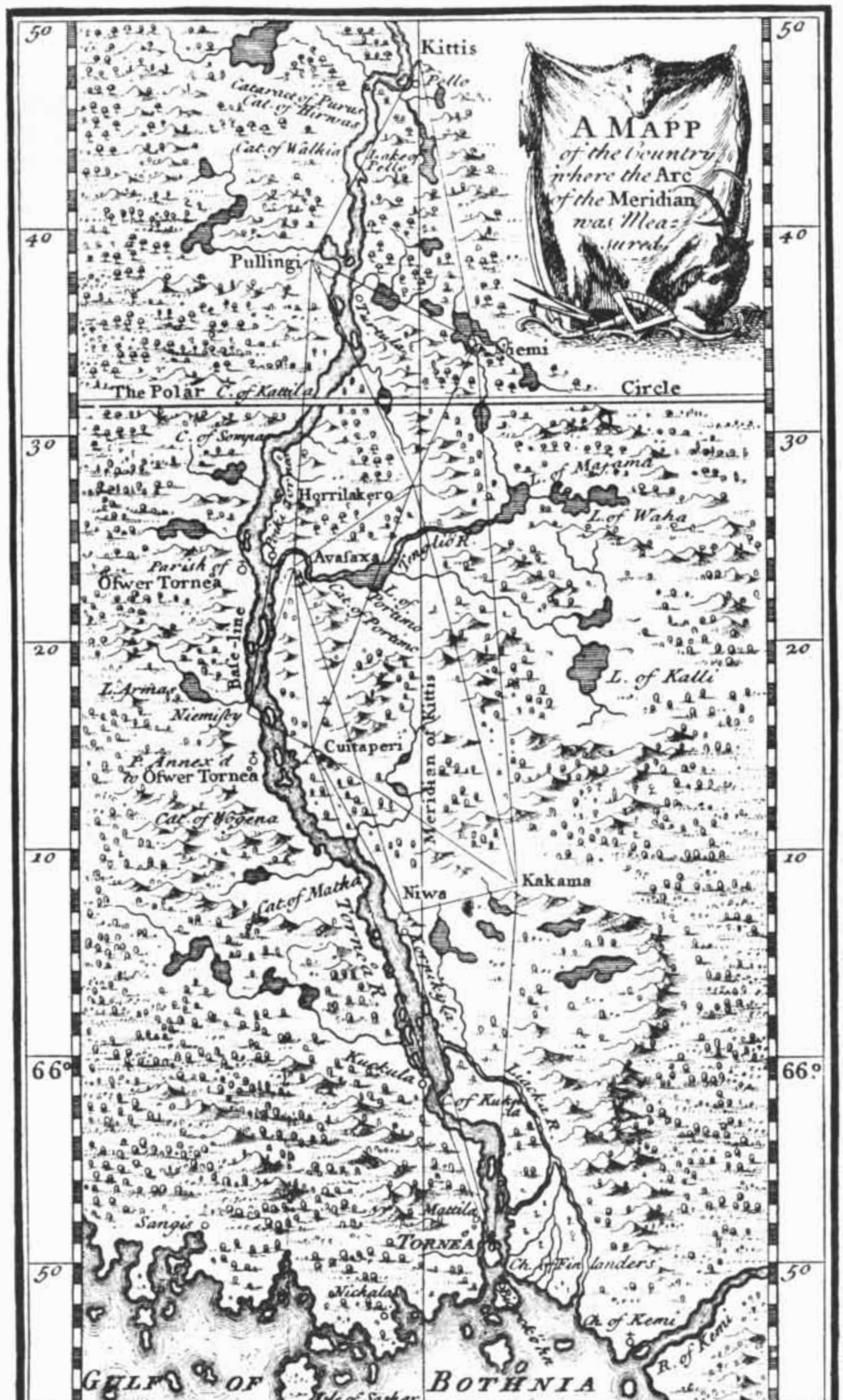
In a tract called *Diatribe du Docteur Akakia* Voltaire ridiculed proposals for the advancement of the sciences which Maupertuis had published in two "letters." Most of Maupertuis's suggestions

IN FUR BONNET Maupertuis posed for a painting by Tournière, from which this engraving was made. Even this headgear was later an object of Voltaire's biting scorn and sarcasm. But as can be seen from the laudatory inscription at the bottom of the engraving, Voltaire was once one of the noted intellectuals who admired Maupertuis and praised his work.

of subjects for scientific investigation strike us today as extraordinarily well conceived and far ahead of his time, but Voltaire saw them only as evidence of Maupertuis's vanity and incompetence.

Witness a sample of his ridicule. Maupertuis had suggested, among other things, that it might be a good idea not to pay doctors when they failed to heal. This prompted Voltaire to ask sarcastically:

"What do you think a man would say, I pray you, who had, for example, 1,200 ducats pension for having talked of mathematics and metaphysics, for having dissected a couple of toads, and for having had himself painted in a fur bonnet, if the treasurer should come to him



MAP OF LAPLAND taken from Maupertuis's report of his expedition shows the triangulations with which he measured precisely the length of a degree of longitude in the Arctic.

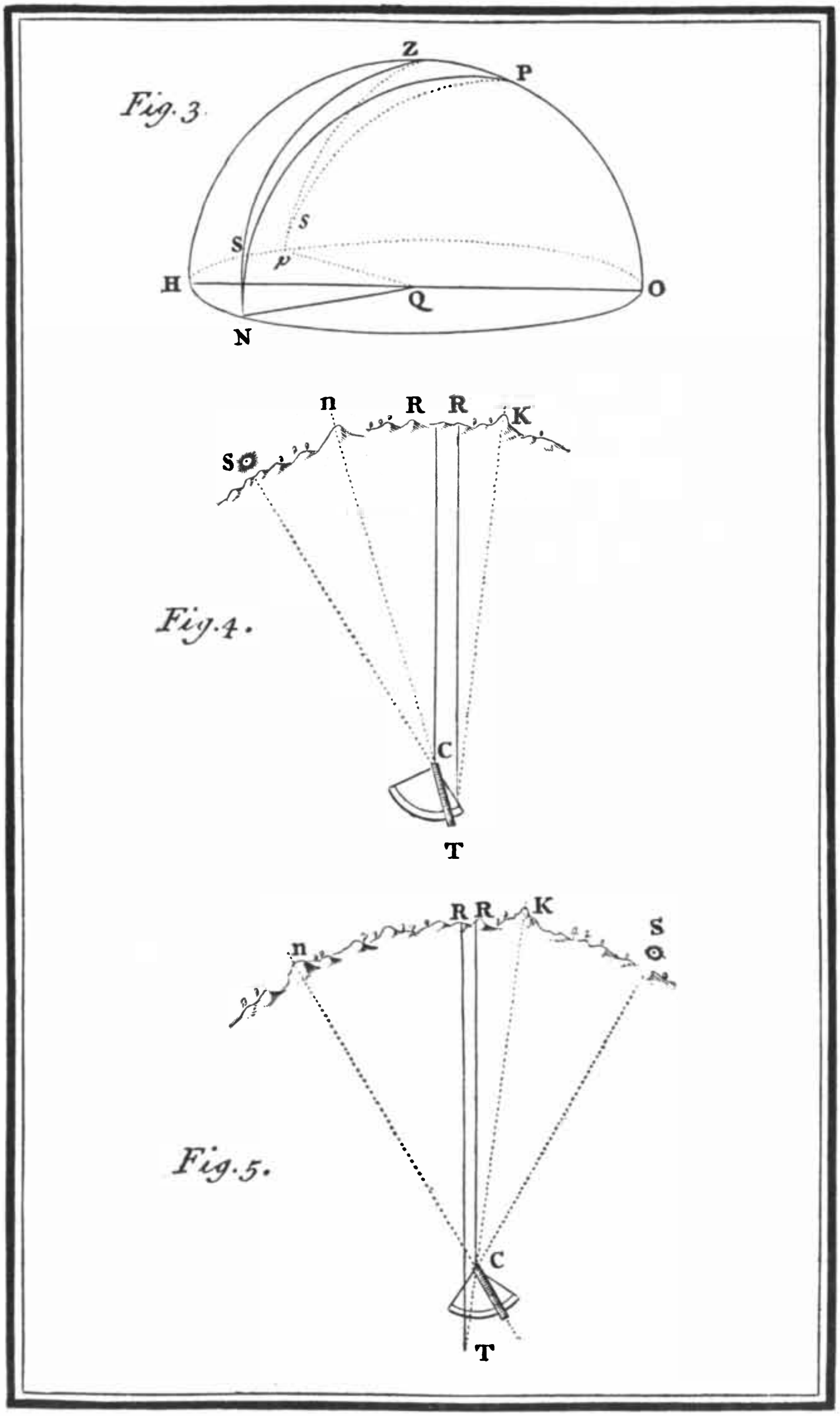
with this language: 'Monsieur, there is a deduction of 100 ducats for your having written that stars are made like windmills; 100 ducats more for having written that a comet will come to steal away our moon and carry its attacks to the sun itself; 100 ducats more for having imagined that comets all of gold and diamond will fall on the earth; you are taxed 300 ducats for having affirmed that babes are formed by attraction in the abdomen of the mother, that the left eye attracts the right leg, etc.? One cannot deduct less than 400 ducats for having imagined understanding the nature of the soul by means of opium and by dissecting the heads of giants, etc., etc.' "

Absurd as Voltaire's diatribes were, they nevertheless had their effect. Although Frederick the Great supported Maupertuis, at least in public, the scientist's reputation never recovered. Until Maupertuis's death in 1759 Voltaire did not relent in his flood of unmerciful, unscrupulous and myopic ridicule. In his *Micromégas* he savagely satirized Maupertuis's expedition to Lapland, though literary critics seem to have missed the connection. It was Voltaire's way of putting Maupertuis's philosophy and science in a Lilliputian scale. Maupertuis had fallen in love with a young girl in Lapland and brought her back with him; during the return voyage the expedition had met with a shipwreck. Voltaire introduced these events into his story, making of Maupertuis and his little "Lap" maiden the butt of some of his nastiest witticisms.

Maupertuis was a powerful and original thinker in philosophy as well as in science. He anticipated the utilitarian philosophy of Bentham and Beccaria, and, rejecting the notion of a Great Design in Nature, discussed the adaptations of plants and animals to their environment in terms which still sound extraordinarily modern:

"Chance, one might say, turned out a vast number of individuals; a small proportion of these were organized in such a manner that the animals' organs could satisfy their needs. A much greater number showed neither adaptation nor order; these last have all perished. . . . Thus the species which we see today are but a small part of all those that a blind destiny has produced."

It is in his biological ideas that Maupertuis was most clearly gifted with prevision. Here he must be reckoned as fully a century or a century and a half before his time. He was the first person to apply the laws of probability to the study of heredity, and he was led by the



GEOMETRIC BASIS of the Lapland measurements is shown in these diagrams published in 1737 simultaneously by the Berlin Academy of Sciences and the British Royal Society.

facts he uncovered to develop a theory of heredity which forecast the theory of the genes in astonishing detail. He believed that heredity must be due to particles derived both from the mother and from the father, that similar particles have an affinity for each other which makes them pair, and that for each such pair either the particle from the mother or the one from the father may dominate over the other, so that a trait may be inherited from distant ancestors by passing through parents who are unaffected. From an accidental deficiency of certain particles there might arise embryos with certain parts missing, and from an excess of certain particles could come embryos with extra parts, like the six-fingered

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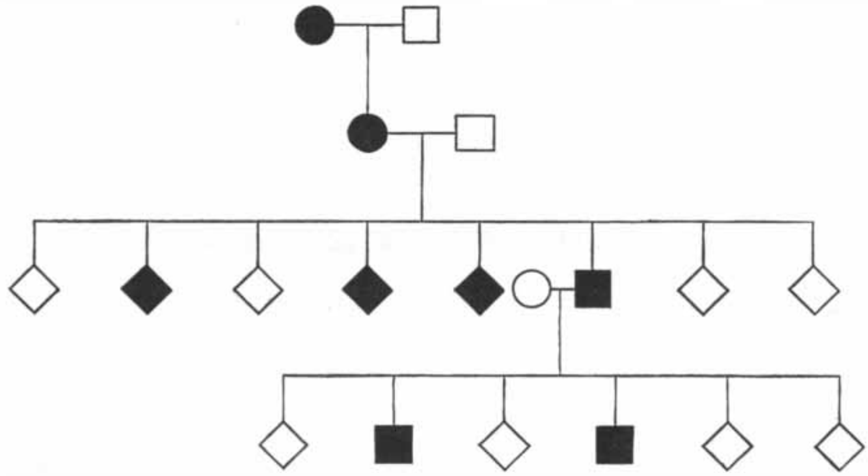

PIONEER WORK IN GENETICS by Maupertuis is illustrated by his analysis of polydactylism among the Ruhe family of Berlin. Circles stand for females; squares for males; diamonds for persons of unknown sex. Black figures indicate those with abnormal number of fingers or toes. Noting the apparent weakening of the trait through successive generations, Maupertuis shrewdly concluded that deviations of nature tend to disappear from heredity.

persons or the giant with an extra lumbar vertebra whom Maupertuis studied. There might even be complete alterations of particles—what today we would call mutations—and these fortuitous changes might be the beginning of new species, if selected by survival of the fittest and if geographically isolated so as to prevent their intermingling with the original forms. In short, Maupertuis anticipated virtually every idea of the Mendelian mechanism of heredity, the Darwinian process of evolution and the De Vriesian theory of mutations as the origin of species. It is not surprising that no contemporary of Maupertuis could truly appreciate his brilliant but speculative synthesis.

The first serious work of Maupertuis in the realm of biology was a small book, published anonymously in 1745 as the *Venus physique*, but in part a year before that with the interesting title *Dissertation physique à l'occasion du nègre blanc*. A young albino Negro brought to Paris had created a great stir. This started Maupertuis to thinking about heredity. Surely the albino condition must be hereditary, for it was said not to be rare in Senegal, where whole families were "white." Maupertuis had also heard of the famous albino Indians of Panama, and discoursed about them with no little sentimentality. "The black color," he said, "is just as hereditary in crows and blackbirds, as it is in Negroes: I have nevertheless seen white blackbirds and white crows a number of times."

Hunting about in Berlin for a case of unusual heredity to study at first hand, Maupertuis learned about the Ruhe family. Jacob Ruhe had six fingers on each hand and six toes on each foot. He had clearly inherited this trait from his mother and she from Jacob's grandmother. Three of Jacob's siblings were also six-fingered and six-toed, while four were normal. Jacob had married a normal woman, and four of their children were normal. Two other sons had extra digits. One of them, however, showed the trait only in part: he had six toes on his left foot and five on his right, six fingers on his right hand and only the stump of a sixth on the left. Maupertuis was interested in this apparent weakening of the trait with time, and it led him to the conclusion that through repeated matings with normal individuals the trait might eventually disappear. In other words, the deviations of nature tend to fade out, and "her *works* always tend to resume the upper hand." Maupertuis evidently had a clear idea that most if not all abnormalities are disadvantageous, and this became an important part of his thinking about evolution.

Maupertuis's idea of attraction between similar hereditary particles derived from the male and female parents was based on current theories of chemical affinity and on the analogy of gravitational attraction. As Maupertuis conceived it, the hereditary particles destined to form the heart had a natural affinity to unite with one another, and also a somewhat lesser tendency to attract the particles of other organs which were destined to form next to the heart. In a work issued under a pseudonym ("Dr. Baumann"), Maupertuis postu-

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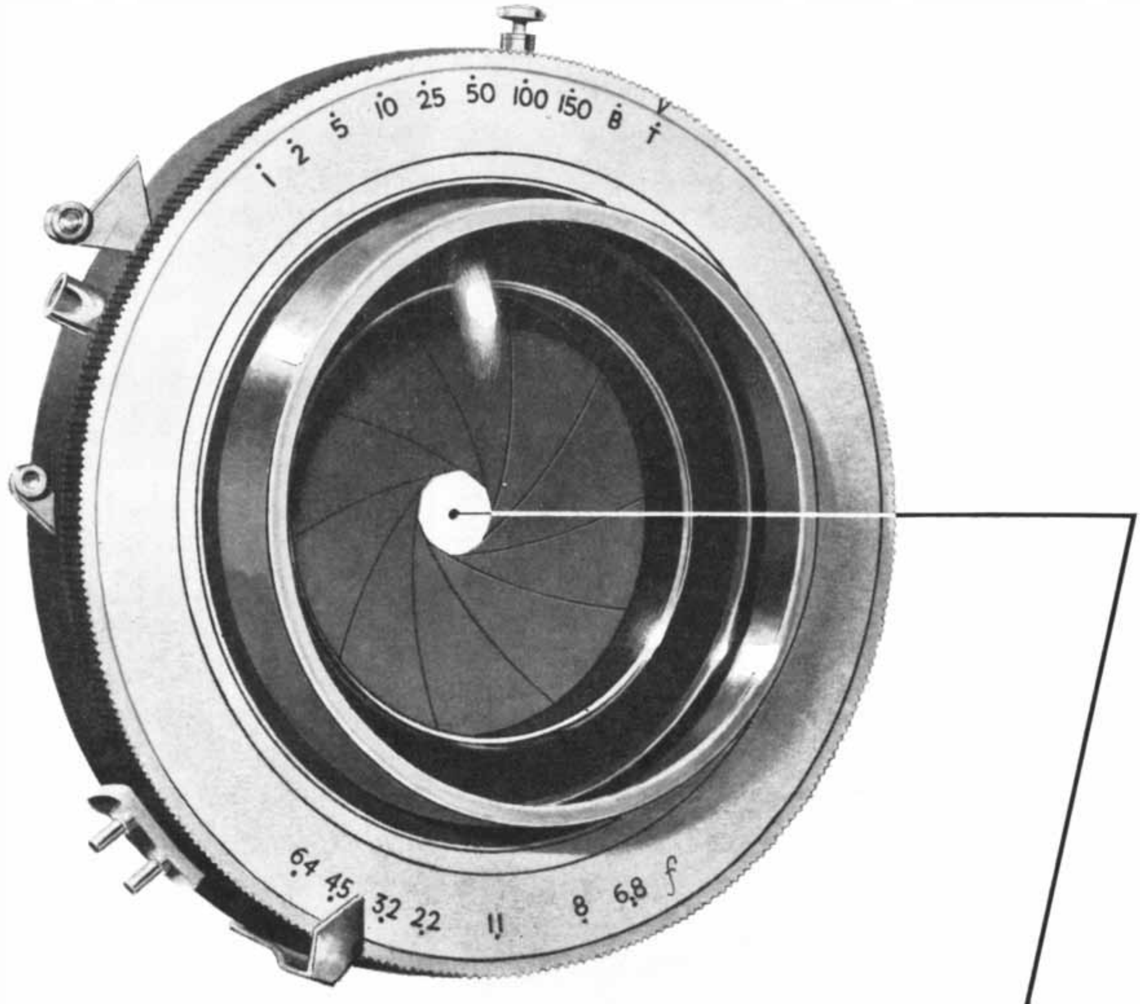
lated that the particles possess a property "akin to that which in us we term desire, aversion, memory. . . . The elements suitable for forming the foetus swim in the semens of the father and mother animals; but each, extracted from the part like that which it is to form, retains a sort of recollection of its old situation; and will resume it whenever it can, to form in the foetus the same part." Of course Maupertuis confused the hereditary particles with the effects they produce and with the parts whose development they control, but that was hardly avoidable at the time. After all, this was nearly a century before the formulation of the cell theory.

In further elaboration of his theory Maupertuis foreshadowed the principle of Mendelian segregation of genes and the explanation of the sterility of hybrids such as the mule. In a hybrid, he suggested, the hereditary particles, having come from different species, do not know whether to combine as in the hybrid or as in the original species, and consequently do neither. In spite of its crudity, the idea is so plainly equivalent in essence to the behavior of the chromosomes in meiosis and fertilization that it is impossible to deny admiration to Maupertuis's perspicacity.

Maupertuis was a great lover of animals. In his home he was constantly surrounded by a formidable array of birds, cats and dogs. "M. de Maupertuis amused himself above all by creating new species by mating different races together," said a contemporary. Unfortunately only one result of these crosses is recorded: having acquired a very unusual Iceland dog with a slate-colored body but a yellow head, Maupertuis undertook to produce a breed with that coloring, and succeeded in transmitting it to the third generation.

His breeding of dogs led Maupertuis to wonder about the fifth digit occasionally found in a dog's hind foot. Is this, he wondered, an extra digit, like the sixth finger in a polydactylous man? Or is it a remnant of a digit once possessed by all dogs? Were dogs originally five-toed on both front and back feet?

His studies thus led him to evolution. Here Maupertuis must certainly be ranked above all other precursors of Darwin. The evidence that species were mutant forms which had become established in nature was to him clear from the artificial breeds of domestic animals. As Maupertuis explained in *Venus physique*, "Nature contains the fund of all these variations; but chance or art brings them out." If the ingenuity of man could



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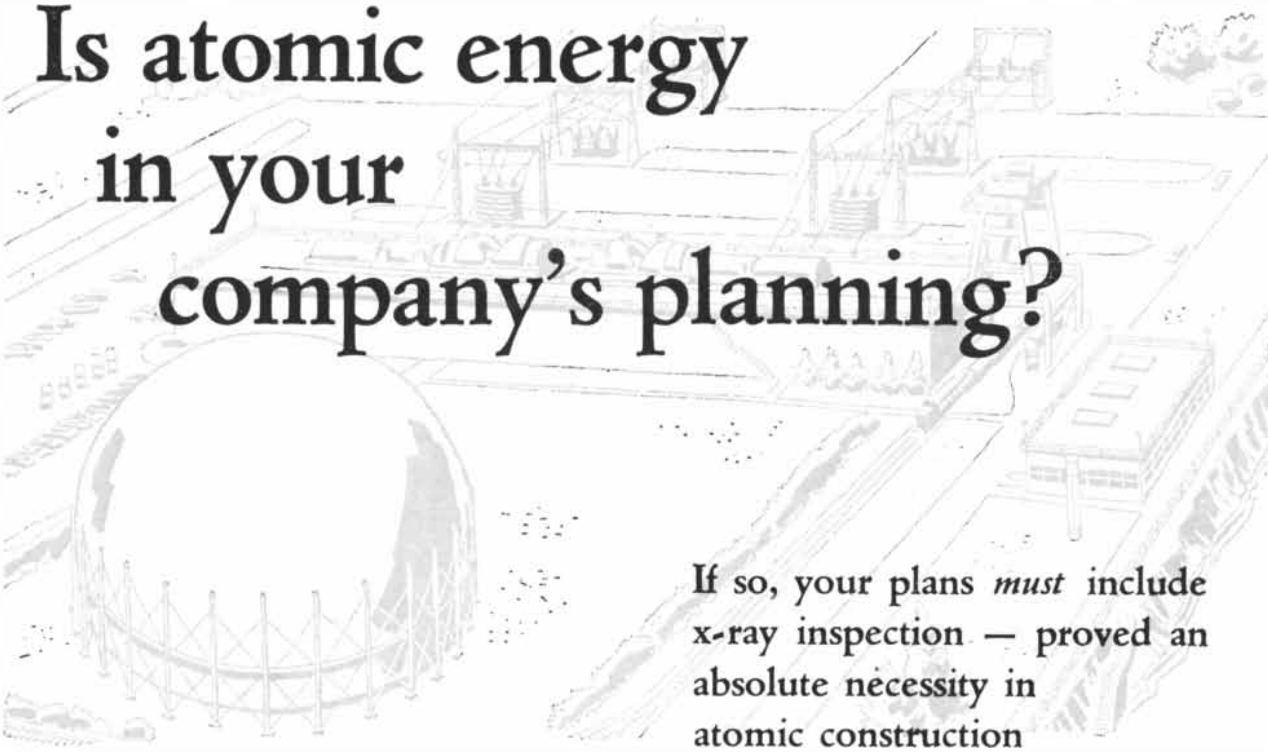
produce species, why not nature, either by "fortuitous combinations of the particles of the seminal fluids, or effects of combining powers too potent or too weak among the particles," or by the action of environment, such as the effect of climate or nutrition, on the hereditary particles? Maupertuis raised the question only as one worthy of investigation, but clearly at this point he anticipated Erasmus Darwin and the Chevalier de Lamarck in suggesting the possibility of evolution through an inheritance of environmentally modified characters. Perhaps, he suggested, the Negro is dark of skin because of the heat of the torrid zone over a long period. The geographical isolation of nature's deviations must play a part here, for in the torrid zone all the peoples are black or very dark, and "in travelling away from the equator, the color of the people grows lighter by shades. It is still very brown just outside the tropics, and one does not find complete whiteness until one has reached the temperate zone. It is at the limits of this zone that one finds the whitest peoples."

Maupertuis's anthropological conceptions were undeniably naive, and Voltaire found them an easy mark. There was pure genius, however, in his final summation of evolution:

"Could one not explain by that means [mutation] how from two individuals alone the multiplication of the most dissimilar species could have followed? They could have owed their first origination only to certain fortuitous productions, in which the elementary particles failed to retain the order they possessed in the father and mother animals; each degree of error would have produced a new species; and by reason of repeated deviations would have arrived at the infinite diversity of animals that we see today; which will perhaps still increase with time, but to which perhaps the passage of centuries will bring only imperceptible increases."

Only now, when the separate strands of genetics, embryology, anthropology and evolution are woven together and the principle of least action is seen to be basic to them all, are we in a position to recognize Maupertuis as one of the greatest luminaries of 18th-century science. He takes his rightful place at last in the company of Lamarck, Alfred Russel Wallace and Charles Darwin; of Johann Friedrich Blumenbach, the father of anthropology; of Gregor Mendel and Hugo De Vries. A man too far before his time, Maupertuis was the most versatile genius of them all.



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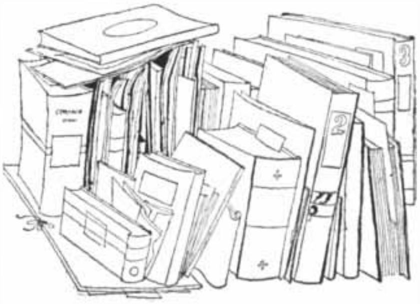

BOOKS

The U. S. personnel security system is arraigned by a distinguished attorney

by Alfred McCormack

THE OPPENHEIMER CASE, by Charles P. Curtis. Simon and Schuster ($4.00).

A distinguished Boston attorney has studied the proceedings before the Atomic Energy Commission, in the case called "In the Matter of J. Robert Oppenheimer," and has written this book for those who wish to understand that puzzling episode.

The Oppenheimer case seems far away, though it was decided only last year. Measured by its effect on the person most concerned, it appears not too important. Oppenheimer chose not to make his defense a cause, but the world of science rose up almost to a man to reject the adverse judgment and to affirm its confidence in him. Since the decision was rendered, he has received a number of awards for public service. Last October he was re-elected unanimously as Director of the Institute for Advanced Study. In December he filled the eminent role of closing speaker, over a nationwide radio hookup, for Columbia University's Bicentennial.

When Oppenheimer was interviewed by Edward R. Murrow on "See It Now" in January this year, the public response to the program was so small that newspaper commentators suggested people had lost interest in the Oppenheimer case. Possibly they were not greatly interested because they could not figure out just what Oppenheimer had been accused of or on what charges he had been convicted. Nevertheless, the case has many important aspects, as this study by Charles P. Curtis makes clear.

Was the decision in the Oppenheimer case one of those occasional departures that occur in the best of legal systems and which, if you think the result was wrong, you must put down to the inability of human beings to govern their common affairs in a wholly wise and logical fashion? Or was the decision the product of a security system which is inherently defective and unsound? Perhaps history alone can answer those questions. If so, Mr. Curtis has kicked off history to a good start. He has formulated the issues in the Oppenheimer proceeding—all of them, the ultimate issues and the subordinate ones, the issues of fact, of probability, of procedure and of judgment—with the utmost clarity. He has performed a skillful, unhurried and thorough post-mortem on the case, examining every vital part.

In design and structure, this is an unusual book. Mr. Curtis has set down his analysis and comment in the form of an annotation on the official record of the case. The relevant passages are reprinted directly from the documents as released by the Atomic Energy Commission, in the original Government Printing Office type. This is somewhat hard on the eyes, but the fascination of the material makes reading easy. Mr. Curtis' own prose is simple and engaging in style, with literary and historical allusions which are pointed and meaningful, and at times quite delightful. He uses the first person singular and addresses his reader as "you". He asks you to consider the evidence and the circumstances that bear on the issues, to use your own common and good judgment and decide how you yourself would have resolved them.

Commencing with chapters called "About this Book", "Who is Oppenheimer?" and "What is a Security Risk?", which are models of condensed introductory statements, Mr. Curtis then presents in full the letter of accusation from William L. Borden to the FBI, that seems to have got the case started. He also presents in full the charges (the letter from Major General K. D. Nichols, general manager of the AEC), the answer (Oppenheimer's letter to General Nichols) and the opinions of the Gray Board, which heard the case. The opinions of the members of the AEC, who rendered the final verdict, are reproduced with only a few omissions, and those are fairly paraphrased. The transcript of the hearing before the Gray Board is organized in successive chapters under the pertinent headings of the "derogatory information" set forth in the charges. The issues are framed or illuminated with generous portions of the testimony by the witnesses before the Board and of the colloquies among the Board and counsel.

The opinions of Oppenheimer's judges are thus closely analyzed and discussed in relation to the evidence. Readers of the book will get a better understanding of the Oppenheimer case than they could get by studying the record itself, even at long leisure. From now on, students of the Oppenheimer case will do well to start with the Curtis book.

The principal thesis of the book is that an intelligent man, using the common sense and good judgment that he would bring to bear on his own affairs, could not reasonably reach the conclusion that Oppenheimer was a security risk. For this reviewer the thesis is amply proved. How, then, did it come about that so able, honorable and distinguished a group as the majority of the members of the AEC did reach that conclusion? The answer seems to be that the Commission's decision was political in character—unconsciously perhaps but still inevitably, because of the circumstances and the time.

Public feeling about subversive influences had been running strong; the Administration had made campaign promises to deal firmly with suspects, however high in rank; the case had aroused intense interest and much discussion; the Gray (hearing) Board had taken the evidence with the utmost seriousness and had reached an adverse decision with apparently great reluctance. In these circumstances it would have been hard indeed for the AEC to make a decision in favor of Oppenheimer. The Commissioners would have had to devote to the case the kind of study and analysis that Mr. Curtis has now given it; they would have had to hear arguments and study briefs.

Whether it was the Commission's own fault or not, the time element did not permit anything of that sort. The duty of decision came to it with the recommendation of General Nichols on June 12, 1954. Oppenheimer's contract with the Commission was to expire on June 30. If the Commission was not to be accused of wiggling out of its responsibility by allowing time to pass, it had to act quickly—much too quickly to permit the calm and unhurried review that would have been necessary for a reversal of the recommendation against Oppenheimer by the Gray Board and General Nichols.

If that be true, then the majority of the Gray Board—Gordon Gray and Thomas A. Morgan—have the chief responsibility for the outcome of the case. It is to their opinion and to the proceedings before them that Mr. Curtis has principally devoted his attention. His handling of the subject is a masterpiece of orderly and logical presentation. He has many criticisms of the proceedings and of the opinions. His criticisms are all sensible and carefully measured; even when they relate to minute details they appear in their true proportion.

Mr. Curtis finds fundamental defects in the conduct of what purported to be, and was frequently stated by the Chairman to be, an inquiry and not a trial. Under the AEC regulations an attorney, Roger Robb, was designated to assist the Board in the conduct of the hearings. Mr. Robb obeyed the impulses of a trial lawyer and, without the Board's seeming to realize what was happening, soon transformed himself into a prosecuting attorney. The result was unfortunate. As John G. Palfrey, professor at the Columbia University School of Law, has said in a recent issue of *Bulletin of the Atomic Scientists:*

". . . What was once designed as a hearing to evaluate a man, fast took on the attributes of a criminal trial. As such, the elaborate safeguards of a hearing became window dressing and a sham that bore no relation to the real protections of the law in a criminal case, such as definition of the crime, the presumption of innocence and the right of trial by jury. The behavior of the puzzled Board reflected its schizophrenic task. The members performed as part jury, part judge, and then as part administrative agency, engaged in a part rule-making, part quasi-judicial proceeding. In the Oppenheimer case, what should not have been formalized was, and what should have been formalized was not."

Defects in examination procedure may have subtle influences on decision. By his conduct of the examination, the Board's counsel created a number of issues of fact or veracity which were pointless if not prejudicial to a fair outcome. He insisted upon cross-examining witnesses without allowing them first to refresh their recollections from documents. He then confronted them with inconsistencies or contradictions between their testimony and the documents. One of those issues—that relating to the views of Dr. Seaborg on the hydrogen bomb—is so silly that it should have been laughed out of court.

In his examination of David Lilienthal the Board's counsel denied the former chairman of the AEC the right of access to documents which would have refreshed his recollection and helped him to give the Board a reasoned exposition of the Commission's point of view on security during his term in office. A substantial part of Mr. Lilienthal's cross-examination was devoted to bringing out lapses of his memory on unsubstantial matters.

What effect the methods of the Board's attorney had on the ultimate result is anybody's guess. But they destroyed the spirit of inquiry, and seem to have affected the attitude of the Board itself. The Chairman, for example, attempted to cut off the testimony of John J. McCloy, former Assistant Secretary of War and High Commissioner to Germany, at a point where Mr. McCloy was trying to explain, out of the wealth of his own experience, why the positive side of security is as important as the negative.

The Board, as everyone knows, found Oppenheimer to be a security risk although it gave him an A-plus rating under each of the two criteria of security. It found that he was completely loyal—and so would not give up secrets deliberately; and it found that he had a high degree of ability to maintain secrecy—and so could be trusted not to give them up indiscreetly. How, from those two premises, the Board majority could take the jump to their conclusion that he was a security risk has been one of the puzzles of the case. Mr. Curtis gives the closest attention to the Board's reasons, and he thoroughly demolishes them. When the words of the Board's opinion are reread after the author's analysis, they sound thin and hollow.

Mr. Curtis recognizes that the members of the Gray Board had taken on a thankless assignment, that they struggled with their consciences and were sorely troubled. His over-all judgment is that their consciences made cowards of them. They chose not to use the common sense and good judgment that would have been natural to them, but rather to give a literal reading to the standard of "clearly consistent with the interests of the national security." They stopped at a doubt and failed to evaluate the weight of the doubt. This conclusion of Mr. Curtis concerning the Board's decision seems a fair one.

If, as they thought, Messrs. Gray and Morgan had no alternative under the security regulations, then the security regulations are forever damned. General Groves, a forthright witness who spoke up for Oppenheimer, said nevertheless that he could not give Oppenheimer a security clearance under the regulations as they existed in 1954. Those regula-

J. Robert Oppenheimer

tions depart so far from our usual American standards as to throw upon the citizen the burden of proving, not his innocence of a defined offense, but his insurability against possible future, undefined offenses. "Clearly consistent with the interests of the national security" is not an objective standard. It is an invitation to a host of subjective judgments, upon which any two men could seldom agree. Indeed, except for Gray and Morgan, who joined in a single opinion, no two of Oppenheimer's nine judges (counting General Nichols as one) were in complete agreement as to what they were doing or why.

It is not surprising, when the standard is so vague and loose, that a security board or reviewing authority should evolve more specific standards out of their own heads. Both the Board and the Commission did just that in a number of instances. A striking illustration is the Gray Board's test of Oppenheimer's conduct in relation to the hydrogen bomb. A scientist presuming to advise officials on policy matters should have, they said, "a genuine conviction that this country cannot in the interest of security have less than the strongest possible offensive capabilities in a time of national danger." They expressed concern that Oppenheimer "may have departed his role as scientific adviser to exercise highly persuasive influence in matters in which his convictions were not necessarily a reflection of technical judgment, and also not necessarily related to the protection of the strongest offensive military interests of the country." What Mr. Curtis has to say about those remarks is worth repeating:

"I do not know whether our policy was then or is now as sole and simple as that 'the strongest offensive military interests of the country.' Gray and Morgan certainly knew more about it than I do, but if our national policy be a simple-minded monomania, which ignores or is ignorant of the manifold of other considerations, political, diplomatic, economic, financial, and which leaves moral considerations to find their own way in, then so much the more need of advice, even from a scientist transcending his special and technical limitations."

In the Oppenheimer case, in conformity with the established practice, reports by the FBI and the security agencies of the armed forces were submitted to the Board and made available to their counsel, but were not disclosed to Oppenheimer or his attorneys. Mr. Curtis has not found anything to indicate that the result was affected by the use of classified security files. But he deplores their use without disclosure to the defense, and points out that that alone prevented the trial from being wholly fair. He reluctantly accepts the sacrosanct character of FBI files, and explains it as based upon our desire to prevent the political use of FBI information. He says: "Here we are willing to sacrifice justice, not for the sake of security, but in the cause of democracy and decency."

To the mind of this reviewer, democracy and decency could be served without the employment of anonymous accusations by documents. Either the files should be disclosed to the defense, or they should be used only as police files are used in criminal cases. There should be a prosecutor in between. Let the prosecutor see the conglomerate of rumor, hearsay and suspicion (and also truth) that the bright young law graduates of the FBI and the counterintelligence units have assembled or their informers have turned in for their weekly wage or their own satisfaction. Let the prosecutor use that material as a district attorney would use it in preparing to go before a Grand Jury—for leads to evidence of probative value and as a basis for the examination or cross-examination of witnesses. But let us stop using unevaluated and unchecked investigators' reports as evidence against accused persons. It is not safe. The job of sifting evidence and arriving at the truth is difficult at best, even for experienced judges dealing with evidence which has been subjected to scrutiny, cross-examination and refutation. In security hearings, where the judges for the most part are inexperienced, it is not safe to trust them with ex parte, untested evidence. Common experience teaches that they are too likely to be misled.

One does not put down this book with any reassurance about the security clearance system for Federal employees. If there ever was a case which should have exemplified that system at its best, it was the Oppenheimer case. The trappings of justice were elaborately preserved. Oppenheimer was represented by able counsel; they were permitted to write briefs and present oral argument. The judges were distinguished, honorable and able. Yet the result, to the minds of a great many thoughtful citizens, was a gross injustice, an affront to the honor and dignity of a man who had deserved well of his country. We can only wonder what has been happening in other security cases, involving civilian officers and employees of less importance and boards of lesser eminence.

This reviewer cannot escape the feeling that the program of wholesale inves-

tigations of Federal employees by police officers has been ill-advised, and that the trial of many of them on anonymous charges has caused much unnecessary trouble and anguish to individuals, produced many injustices and done more harm than good to the civil service. Executive Order 10,450 is one of those short-cuts to security, or rather to an illusion of security, that a people cannot permit itself to take without endangering its liberties. It should be rescinded, and it will be, when we return to a saner day. To that happy end, Charles P. Curtis has made a magnificent contribution.

Short Reviews

Modern Experiments in Telepathy, by S. G. Soal and Frederick Bateman. Yale University Press ($5.00). A formidable mass of experimental evidence for extrasensory perception is presented in this study by two British scientists. The senior author, Soal, a lecturer in pure mathematics at the University of London, started out many years ago with a more or less skeptical attitude toward the so-called psi phenomena. As a result of extensive tests, mainly involving two extraordinarily gifted "percipients" in the business of card guessing, Soal and his co-worker Bateman were converted from doubt to ardent belief. The authors give a brief history of early experiments in parapsychology, including a sketch of the labors of J. B. Rhine, who inaugurated the modern phase of this branch of inquiry. They consider the statistical problems connected with interpretation of the data. These sections are clearly and interestingly written. The main part of the book, which is harder reading, is devoted to a meticulous account of Soal and Bateman's own researches: the layout, the apparatus, the controls and safeguards against fraud or error, the statistical analysis. It is now well known that Soal's "gifted" subjects, Basil Shackleton and Gloria Stewart, failed miserably on the test for guessing cards directly, but their guesses showed an astounding correlation with the card immediately preceding or following the one they were supposed to identify. In some trials these "successes" ran at a rate overwhelmingly higher than what was predicted by chance—the odds being more than a million to one. The entire experimental series seemed to offer proof of some form of telepathy: "pre-cognition" or "post-cognition." Yet the great majority of scientists remain unconvinced by extrasensory research. Some who have taken

careful thought to the matter feel that the conduct of the experiments itself offers orthodox explanations of the bizarre results. In any case the authors deserve admiration for their persistence and energy in carrying out a monumentally tedious series of experiments, and for their forbearance and restraint. Only rarely do they lose their tempers in replying to scoffers, and they indulge in only a few speculations as to the possible nature of ESP. (These suggestions, by the way, are thoroughly unconvincing.) Their book performs a service in presenting by far the fullest, soberest, most scientific account of a research about which there is undeniably a great deal of curiosity.

ELECTRONS, ATOMS, METALS AND ALLOYS, by William Hume-Rothery. Philosophical Library ($10.00). This volume is a revised edition of an attempt to explain atomic theory and kindred matters through the literary device of a dialogue. The conversations take place between a "young scientist" and an "older metallurgist." The older man had his academic training 30 years ago and has since been entirely occupied with industrial problems so that he finds himself entirely baffled by the new talk he hears at a metallurgical society meeting about wave functions, the strange symbol ψ, "weird things called brillouin zones" and various mathematical equations involving $e^{2\pi i}$. The young man offers to enlighten him. The dialogues trace step by step the development of atomic theories, the emergence of quantum and wave mechanics and such concepts as indeterminacy, electron spin and Pauli's principle. The crystal nature of a metal is elucidated, also X-rays, free electron theory, alloy systems, radioactivity, fundamental particles, fission and so on. The discourse, running to almost 400 pages, is lively and instructive, not superficial as such things are apt to be. The metallurgist asks the questions that are in many people's minds and receives clear and explicit answers. The young scientist does not spare him any of the hard mathematics, but the formulas and equations are carefully explained, and their physical meaning is given. Altogether the author, a noted British metallurgical chemist, achieves a tour de force. No better introductory book on a high level has been written on these subjects.

PREHISTORIC PAINTING, by Georges Bataille. Skira ($16.50). In this book are reproduced the incredibly beautiful prehistoric paintings on the walls and ceilings of the Cave of Lascaux, lying in the Valley of the Vézère in southwest France. The cave was discovered September 12, 1940, by four boys from the neighboring little town of Montignac who were bent on probing a hole left some 30 years before by an uprooted tree. The hole was about three feet across and three feet deep, but at the bottom was an opening to a much narrower shaft whose depth was unknown. An 18-year-old youngster, Marcel Ravidat, dug the shaft wider, "then plunged straight in, head first . . . and landed on the pile of loose dirt below." After he had lit his lamp, he called his companions to join him. They explored what came to be known as the "Great Hall" and the "Axial Gallery" of the cave. They noticed markings, then figures of animals. A few persons were reluctantly let into the secret, and by September 21 the Abbé Breuil, a French archaeologist, had entered the grotto and confirmed the boys' belief that they had made a major discovery. Lascaux is "not only the most splendid, the richest of known prehistoric caverns containing paintings" but it provides, according to Bataille, "our earliest sign of art." The paintings are ascribed roughly to the opening part of the Upper Paleolithic Age, about 20,000 years ago. The animals portrayed include cows, bulls, bison, horses, rhinoceroses and deer, and there is a strange painting of a man, evidently mortally wounded, lying alongside a bison pierced by a spear. The unknown artists saw with the fresh, appreciative eyes of children and caught line, form, motion and color with the sympathy and skill of the greatest masters. Pigments, applied to the smoothest areas of the rock walls, were used as they came from their natural sources, "ground fine and thinned with water or mixed with fatty substances. Paint was either liquid or paste-like. Most colors were based on mineral oxides: blacks and browns were furnished by manganese, red ochre by iron oxide." Yellows and blues also appear. The technique of painting was varied. The artists used fingers, pads or wads of vegetable matter, sticks shredded at one end. Another method, still used by the Australian aborigines, was to put colored powder into a hollow tube and blow it over a moistened surface. These and many other details are set forth in the text of Bataille's book, together with an anthropological, archaeological and philosophical commentary. The style is somewhat perfervid, but actually seeing and working with the Lascaux paintings, as the author did, must certainly have been an unforgettable experience. As for the reproductions, each of which is sepa-

rately mounted on a page, it is difficult to imagine how they could have been improved. All who participated in this sumptuous undertaking are to be congratulated: the author, Bataille; the photographers, Hans Hinz of Basel and Claudio Emmer of Milan; the French engravers; the Swiss printers and the publishers.

MINDS AND MACHINES, by W. Sluckin. Penguin Books (50 cents). The various subjects that fall under the head "communication and control" have advanced so rapidly during the past decade that it is hard to keep even moderately well informed as to what is happening in this sphere of knowledge. This book performs a useful task in unifying and explaining in more or less everyday language the results of several different branches of research: automatic computers, brain physiology, thought processes, homeostasis, self-adapting mechanisms and the like. The author, trained both as an electrical engineer and as a psychologist, is well qualified to survey the field. Some of the topics are dealt with less fully than one might have expected or hoped; for example, the intricate ideas of information theory are treated perfunctorily. But on the whole the discussion is sound and clear and the book is unusually successful in explaining how the study of certain complex machines has enlarged understanding of the behavior of the brain and influenced the science of psychology.

SCIENCE AWAKENING, by B. L. van der Waerden. P. Noordhoff Ltd. ($5.90). The history of mathematics is harder to follow than the histories of other sciences. The language of course presents difficulties, but there is also the more serious obstacle that the origin of early mathematical ideas is rarely self-evident. Ancient theories of physics, of natural history or astronomy or medicine are understandable; we see how such notions evolved and we can fit them into the development of thought. Not so with the Babylonian sexagesimal system, the Egyptian methods of computation, the Greek concepts of proportion, the Pythagorean approach to numbers. This book by a noted modern student of algebra attempts to explain the beginnings of mathematical science, to trace the roots of number systems and the practical arts of computation, to describe the emergence of algebra and geometry and of rigorously logical methods of proof. It is unquestionably the best published survey of Egyptian, Babylonian and Greek mathematics. Quoting at length from

Herman A. Liebhafsky, Ph.D. (Chem.) Univ. of Calif. (1929), joined the General Electric Research Laboratory in 1934. Since 1951 he has been *Manager, Physical Chemistry Research.* In addition to his work in instrumental analysis, Dr. Liebhafsky has been connected with the mercury boiler, the chemistry of oxide-coated cathodes, corrosion problems of all kinds, analytical methods for silicones, and rocket propellants. He has published more than ninety papers in these fields.

X-rays speed materials analysis

Dr. Herman A. Liebhafsky of the General Electric Research Laboratory finds new uses for invisible rays

The use of x-rays as a non-destructive tool of analytical chemistry is rapidly growing in popularity among chemists, because for many purposes it provides them with a new order of speed and accuracy in determining constituents difficult to detect.

Over a period of more than ten years, Dr. Herman A. Liebhafsky and his associates at the General Electric Research Laboratory have contributed to the development of x-ray *absorption* methods for a wide range of materials. Their fundamental work has led to the development of the x-ray photometers, which have proved exceedingly useful in the atomic energy program and in the petroleum industry.

More recently, Dr. Liebhafsky has turned his attention to research on x-ray *emission* spectrography. This new analytical technique has proved especially valuable for the rapid quantitative determination of heavy metals in certain alloys, for the measurement of very thin films of one metal on another, and for the identification and determination of trace materials.

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cuneiform texts, van der Waerden presents a remarkable picture of Babylonian accomplishments. The Babylonians solved equations with one and two unknowns and problems involving quadratics and cubics; they knew the summation of arithmetical progressions; they were able to find Pythagorean numbers; they understood proportionalities arising from parallel lines and the famous right angle triangle theorem ascribed to Pythagoras; they devised the formula for the area of a triangle and of a trapezoid, for the volume of a prism, a cylinder, a frustum of a cone, and a frustum of a pyramid with square bases. And this by no means exhausts the list of their mathematical triumphs. In his account of Greek mathematics, occupying three quarters of the volume, the author seeks to establish the connections between the Mesopotamian advances and the work of Thales, Pythagoras and their successors. Here he offers conjectures and interpretations based upon slender evidence, a practice which he himself condemns elsewhere in the book in tilting at the conclusions of other historians. Still, a very strong case is built for the conclusion that Greek mathematicians were immensely indebted to older cultures. The book is sometimes well above the heads of the general audience to whom it is addressed, but in spite of this and a number of other shortcomings it will richly repay a reader willing to give it his attention.

THE HUNTING WASP, by John Crompton. Houghton Mifflin Company ($3.00). When nature-story telling is served up as agreeably as in this book, it is hard to resist. The author is an imaginative British popularizer who has read widely in naturalist literature and has also made many first-hand observations of insect life. He is a very good reporter when not romancing. This volume chronicles the murderous adventures of various species of hunting wasp—a solitary breed, the female of which provides food for its offspring by paralyzing the victim with a sting and then hauling it off to a nest where the grub can dine at leisure on stupefied but strictly live meat. The quarry includes caterpillars, beetles, bees, grasshoppers, flies, ants and spiders. The hunting wasp knows just where to inject its poison in each so that its prey is rendered helpless yet remains alive. Crompton's book would have been better had he done less sentimental embroidery. The hunting wasp is a fascinating subject on its own, without being presented as a tiny vehicle of human emotions—by turns "gleeful," "solicitous," "gloating," "gentle," "intrigued," "relieved," "brutal," "indecisive," "whimpering," "sorrowful," "sadistic," and so on and on.

Geschichte der Mathematik, by Joseph Ehrenfried Hofmann. Walter de Gruyter & Co. ($2.40). This compact, authoritative, handsomely printed little paper-back in the now happily resumed Göschen series covers the history of mathematics from the Babylonians to the advent of Fermat and Descartes. Ancient mathematics is treated somewhat sketchily because the author feels that this period is adequately dealt with in other short histories; on the other hand considerable space is devoted to developments in the Middle Ages and the Renaissance. The survey also outlines the bearing of mathematics on advances in related disciplines such as astronomy and mechanics. Densely written but valuable for the more experienced student. Excellent bibliographies.

Notes

The Works and Correspondence of David Ricardo: Vol. X, edited by Piero Sraffa. Cambridge University Press ($4.75). This 10th volume of Sraffa's monumental edition of Ricardo contains miscellaneous biographical material, including letters, a memoir of Ricardo by one of his brothers and Ricardo's own *Journal of a Tour on the Continent, 1822.*

An Introduction to the Theory of Numbers, by G. H. Hardy and E. M. Wright. Oxford University Press ($6.75). The third edition of this excellent book, revised by Professor Wright, contains a good deal of new matter, including the recently discovered elementary proof of Euclid's Prime Number Theorem.

Evolution of the Vertebrates, by Edwin H. Colbert. John Wiley & Sons, Inc. ($8.95). This work by a leading paleontologist is not only admirably designed as a textbook but will also appeal to the general reader.

From Classical to Modern Chemistry, by A. J. Berry. Cambridge University Press ($4.75). A valuable collection of historical sketches. They treat developments in the theory of heat, concepts of chemical energy, electrolysis, physical optics and chemistry, molecular magnitudes, chemical formulas, valency, radicals and constitution.

THE AMATEUR SCIENTIST

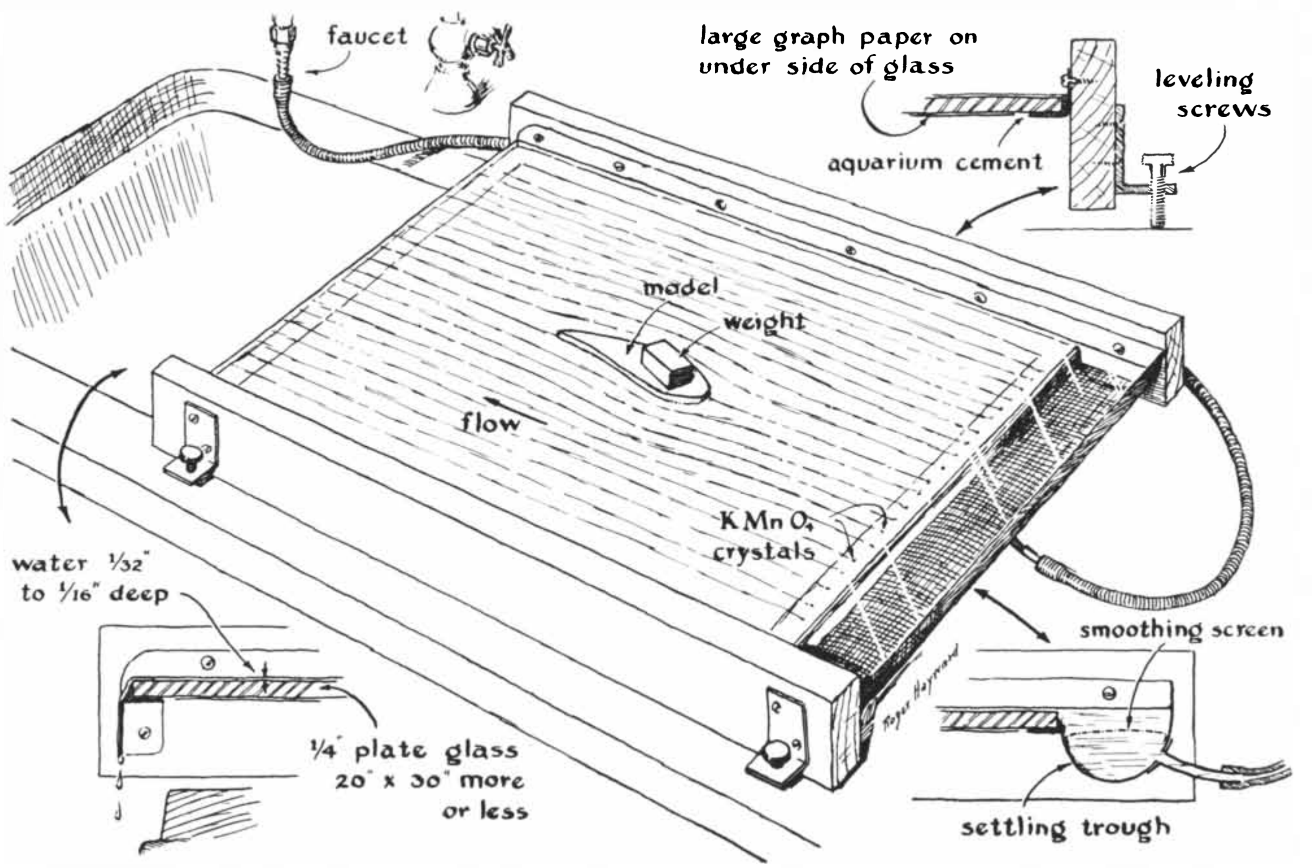
Some simple apparatuses for studying the dynamics of airflow and waterflow

The problem of shaping a surface to some desired contour occupies amateurs in many fields. Where the basic design is firmly established, as in telescope making, the problem is mainly one of craftsmanship. It may not be easy to make a telescope mirror of high precision, but the maker knows in advance exactly what shape he must try to achieve. In what follows we are going to consider a type of project in which the object is to discover the best or most efficient shape.

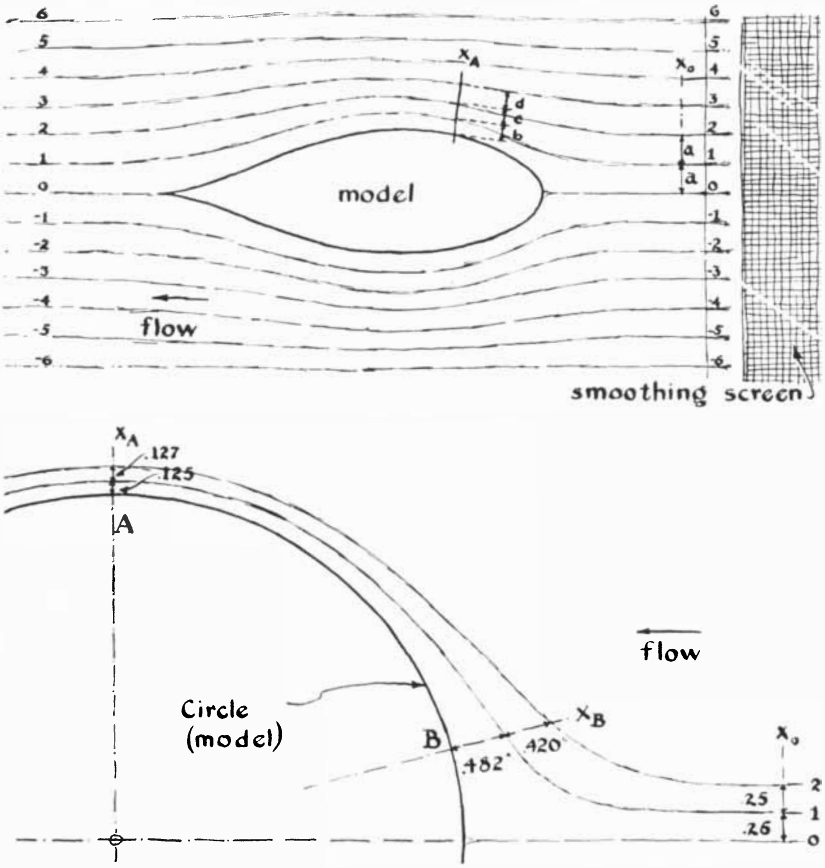
This problem applies whenever one sets out to build a racing sloop, an airplane or even a kite. Any boy can make a kite that will climb a hundred feet or so. But to design one which will fly higher than all competitors with a given length of string is a challenge of astonishing sophistication. The performance of a kite, like that of a glider, an airplane or any other vessel in a fluid medium, depends critically on the shapes of its working parts.

Two types of force are of prime interest to those who must design hydrodynamic and aerodynamic shapes. One is summed up in the aerodynamic term "lift." Here the major effect acts at right angles to the motion of the fluid. It accounts for the rise of a kite or an airplane and for the ability of a sailboat to tack against the wind. Generally shapes which create forces perpendicular to the streamlines manage in one way or another to cause the fluid (air, steam or water) to flow at greater velocity on one side of the object than on the other. This differential motion causes a drop in pressure on the side of higher velocity, and the object tends to move in that direction. If you hold a sheet of paper horizontally and blow over its upper surface, the sheet will not bend down but will jump up momentarily, because of the reduction of air pressure on top. The effect explains why gusts of wind sometimes lift the roofs off houses, why ships traveling close together may be sucked together and why it is dangerous to stand near the edge of a railway platform when a train speeds by.

The second interesting force, exerted in the direction of the flow, is called



The Hele-Shaw apparatus with a model in place



Streamlines around an airfoil (above) *and a cylinder* (below)

"drag." The air drag on the tail of an ordinary diamond-shaped kite is partly responsible for keeping it heading into the wind. A box kite will rise higher both because it is lighter and because there is less drag on its surfaces. The force of drag is due to friction between adjacent air layers of different speeds around the airfoil. Anything that promotes turbulence in the air layers increases drag. At a speed of 200 miles per hour an airplane's wings with protruding rivet heads and lap joints show almost 50 per cent more drag than when the wings are perfectly smooth.

An impressive array of devices, ranging from mile-long towing basins to yard-long shock tubes, has been devised for investigating the forces of fluid flow. Most of them are beyond an amateur's resources. But Francis W. Niedenfuhr, an instructor in engineering mechanics at Ohio State University, describes for this department an ingeniously simple apparatus which anyone can make to study fluid dynamics. He writes:

"The letter from J. J. Cornish in your May issue about his aerodynamic smoke tunnel brought to mind another series of experiments which can be performed by amateurs interested in either hydrodynamics or aerodynamics. I refer to the Hele-Shaw apparatus, which enables you to see fluid flow and to measure the resulting forces in two dimensions.

"Sir George Stokes first proved that when a thin layer of viscous fluid such as water is made to flow between a pair of parallel plates, the streamlines approximate those of a theoretical nonviscous liquid. Ludwig Prandtl subsequently pointed out that air behaves as a nonviscous fluid outside the boundary layer. H. J. S. Hele-Shaw constructed an apparatus based on Stokes's observations and made useful measurements concerning the flow around ship hulls. Although the proofs presented by Stokes apply to flow between two parallel plates, Hele-Shaw found that good results can be obtained by letting water flow in a thin sheet over one plate, leaving the top surface of the water free. The device is useful for investigating the performance of airfoils, because the air flow over a long narrow wing is essentially two-dimensional except near the tips.

"In the Hele-Shaw apparatus a thin sheet of water flows very slowly over the surface of a glass plate around a cross-section model of an airfoil, a set of sails or a ship's hull [*see drawing on opposite page*]. The streamlines are made visible by means of a dye, such as potassium permanganate. They can easily be photographed for close study, and the flow lines will yield quantitative results concerning the pressure distribution over the model.

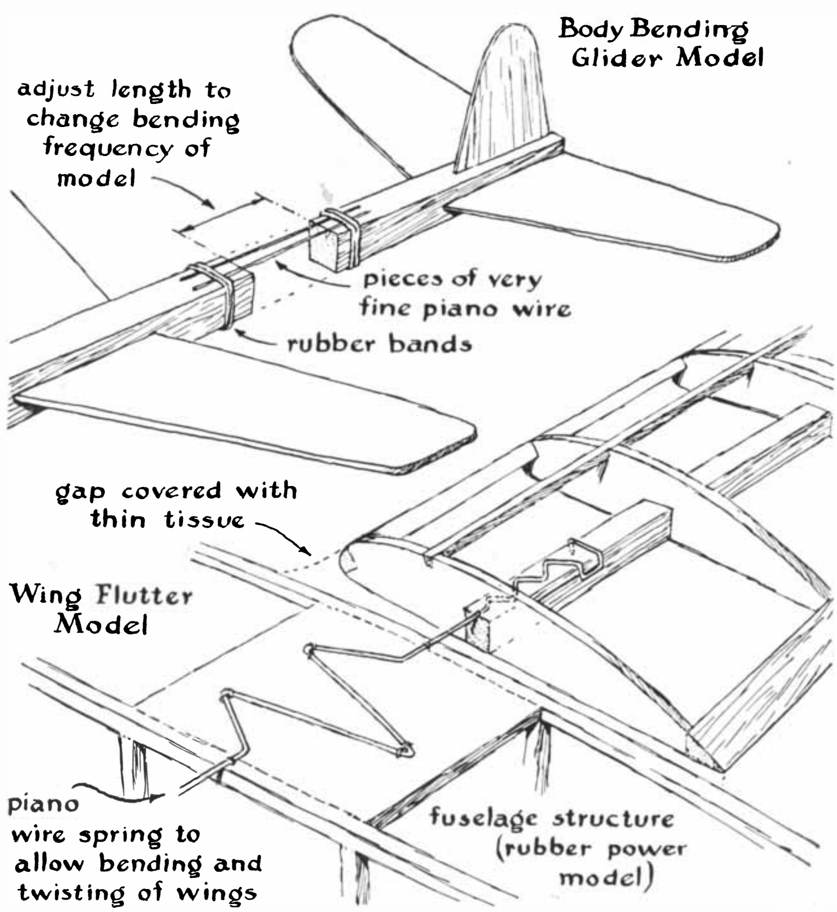
"It is obvious that when an obstruction reduces the area through which a given amount of fluid flows, the velocity of the flow must increase. Where the streamlines flow around the model, they will be crowded into a narrower area. By measuring the distances between streamlines (marked by filaments of dye) at various points along the flow channel, we can get an idea of the relative velocities and pressure distributions at these points.

"The construction of the Hele-Shaw apparatus is not difficult. The plate over which the water flows can be a piece of plate glass about 30 inches long and 20 inches wide. To enclose the sides of the channel a metal angle along each side, sealed to the glass with aquarium cement, will serve. The plate is leveled by means of leveling screws in the frame which supports it. A film of water is fed onto the plate from a settling trough fitted with a smoothing screen [*see drawing on page 124*].

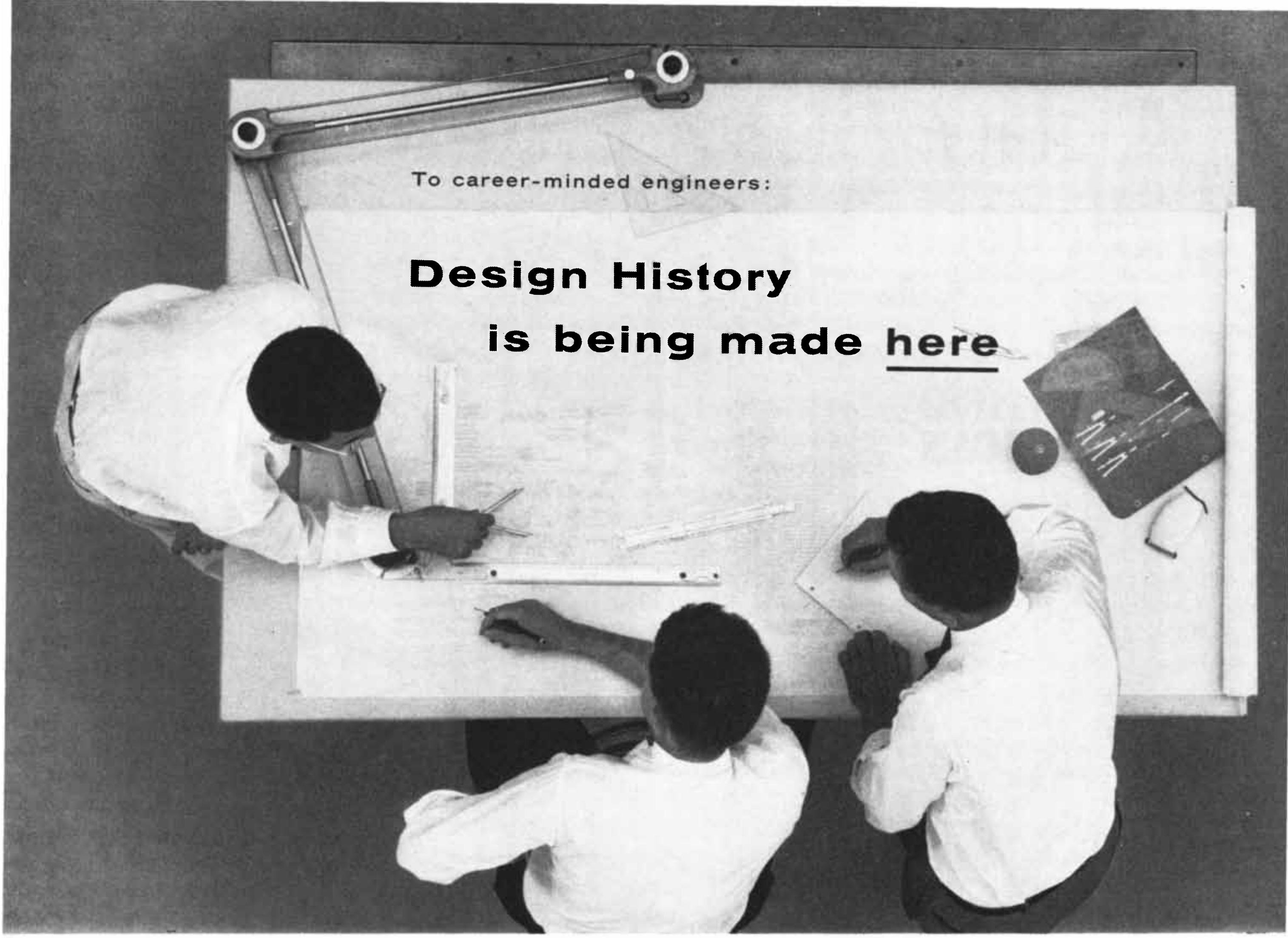
"When the plate has been set up and leveled, water is made to flow very slowly over the surface in a film of uniform thickness. The plate should first be thoroughly washed with soap and rinsed with strong ammonia water so that its whole surface will be wetted to make the film uniform. A small squeegee or an automobile windshield wiper will help in the cleaning job.

"The model to be placed in the stream can be made from a sheet of balsa wood a quarter of an inch thick. If the model is to represent a sail, it will need to be thinned to a section one sixteenth of an inch thick. After cutting the model, sand its lower surface as flat as possible and waterproof it with two coats of dope. The model can be held in place on the plate either with cement or by a weight on it. If you put a large sheet of graph paper beneath the glass plate, it will be easier to make measurements of the distances between streamlines.

"When the film of water has assumed a uniform flow, place a crystal of dye directly upstream from the model, so that the filament of color will flow around it. At what is called the 'stagnation' point, just in front of the model,



Flexible models for showing oscillation effects



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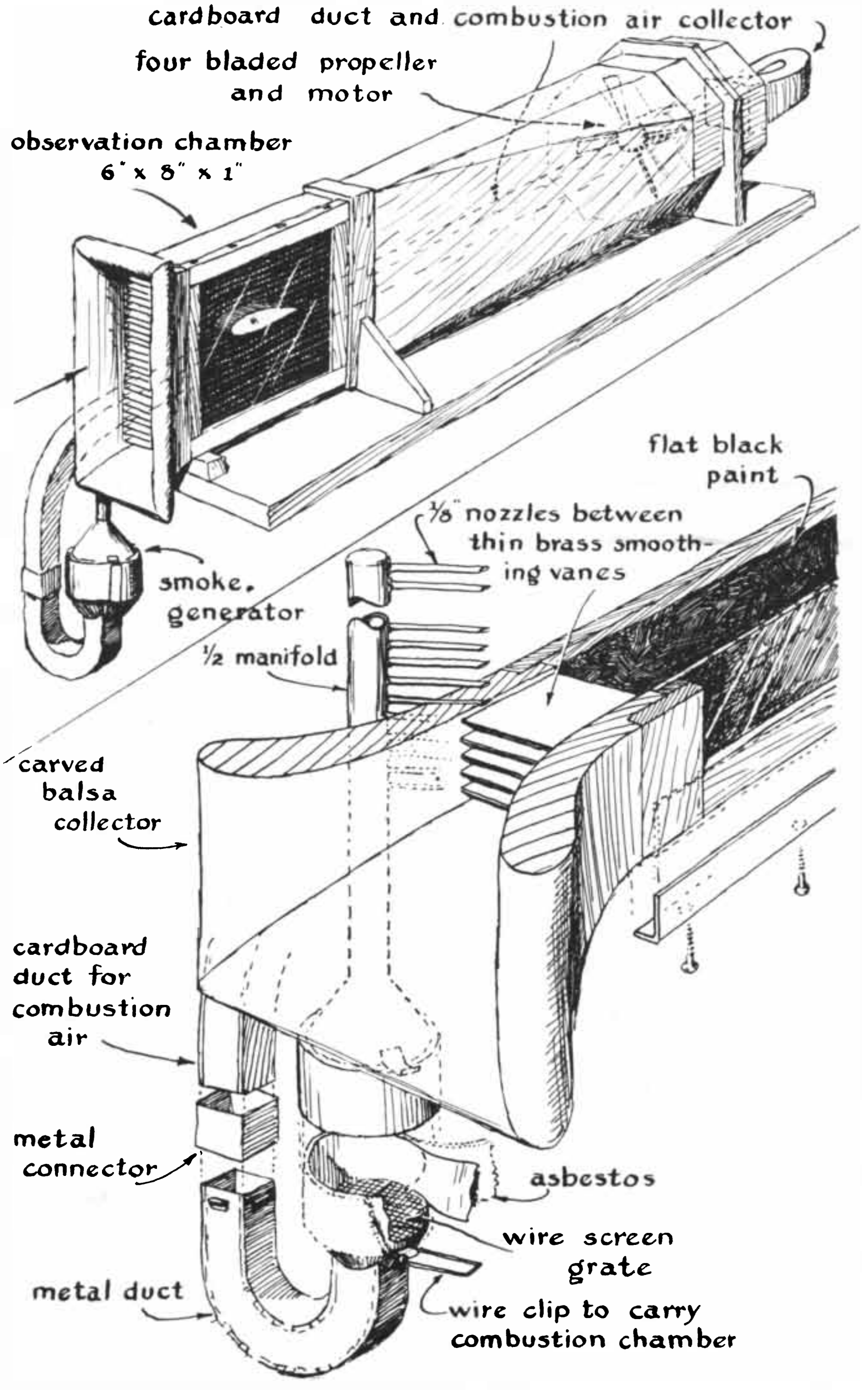

A homemade smoke tunnel

the streamline splits in two, one half flowing around each side of the obstruction. The two halves of the filament come together again at the trailing edge and re-form a single filament. The split streamline defines the boundary layer of flow around the model.

"Now if you place other crystals of dye at uniform intervals (say every quarter inch) in a row along the starting edge of the plate, they will generate filaments which will flow in parallel lines downstream until they come to the region where the model diverts the flow. There the parallel filaments will curve and be pushed closer together or farther apart, depending upon the shape of the model.

"Now a couple of simple formulas enable us to calculate the comparative velocity of flow and the pressure at various points around the model. These quantities can be computed simply from the distance between the filaments,

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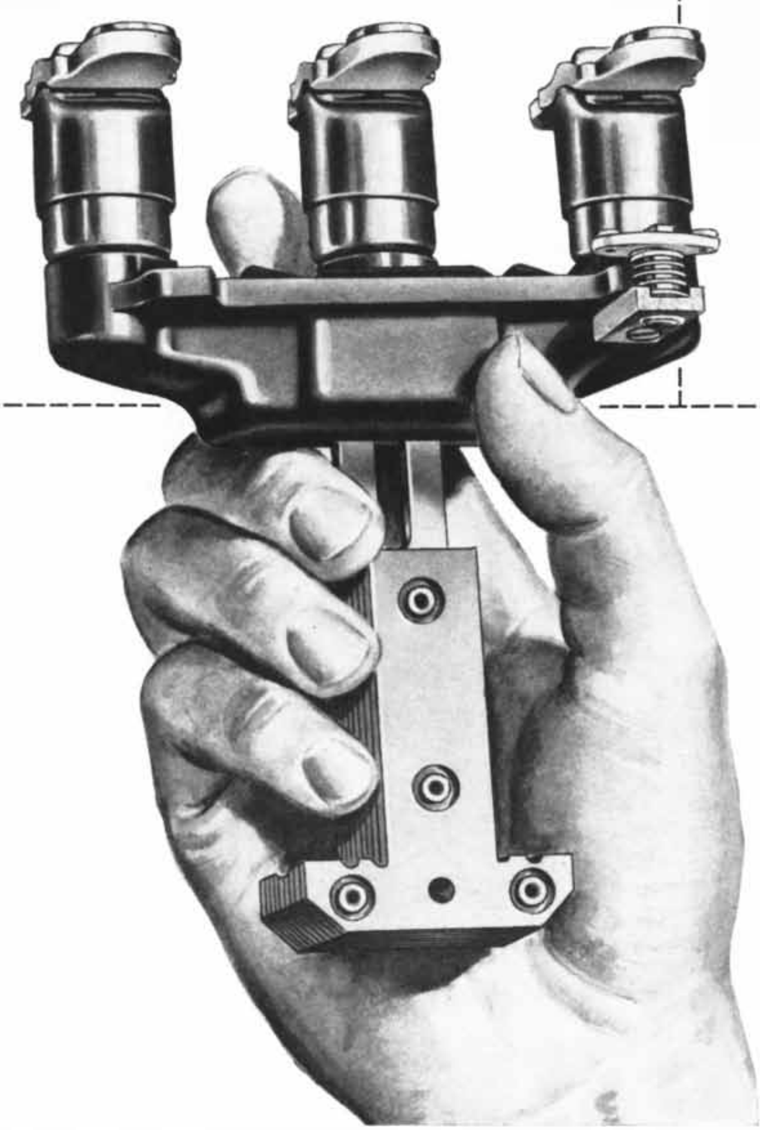

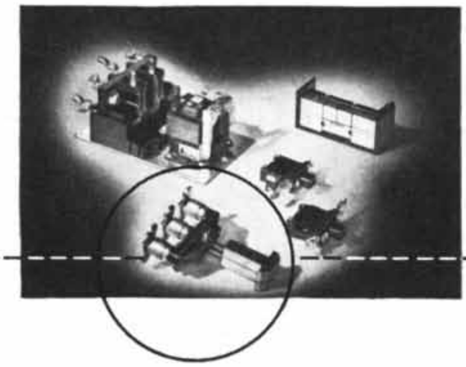

Disassembled view of the Bulletin 709, Size 2 motor starter. The solenoid plunger, which is encircled, is the only moving part.

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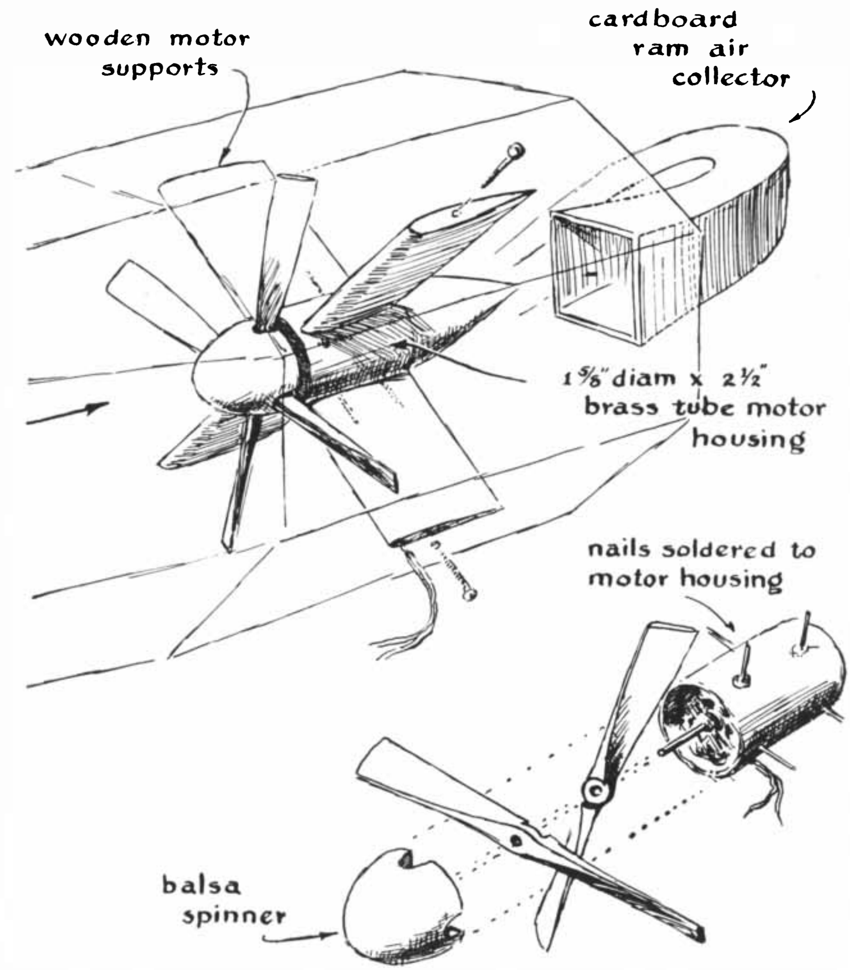
or streamlines, at those points. Where the stream is flowing freely and uniformly, before it reaches the model, the average velocity between one streamline and the next, multiplied by a certain constant, is equal to the reciprocal of the distance between the streamlines: *e.g.*, 1/ ¼ when the distance is ¼ of an inch. The general formula is $VC = 1/D$, with *C* standing for the constant and *D* for the distance between streamlines. At a point upstream from the model the distance between streamlines may be expressed by *a* [*see upper drawing on page 125*]. The equation then reads $VC = 1/a$. At a point *A* on the model, where the distance between the surface of the model and the first streamline is *b*, the equation is $V_AC = 1/b$. Now we can eliminate the *C* by division and get the ratio $V_AV = a/b$. In other words, the ratio of the original distance between filaments to the distance between filaments at a given point on the model is a measure of the change of velocity of flow at the model. When the distance between filaments narrows, the flow speeds up in proportion to the reduction of the distance.

"Similarly we can calculate the change in pressure at a given point on the model by another formula. The difference between the pressure in the free stream and that at a point on the model is equal to $k\ [(V_A/V)^2 - 1]$, the letter *k* standing for a constant.

"Let us illustrate the method with a specific problem. The model is a circular obstruction [*see lower diagram on page 125*]. At the starting line of the flow the streamlines are a quarter of an inch apart. At point *B* on the leading side of the circle the distance has widened so that the first streamline is .482 of an inch from the surface of the model. Thus $V_B/V = .25/.482$, or .518. This means that the velocity of flow between the model and the first streamline at point *B* is .518 of the original velocity. The change of pressure there is $k(.518^2 - 1)$, or $-.732k$. The minus sign corresponds to the fact that the pressure is inward.

"At point *A* on the model the distance to the first streamline narrows to an



Draft mechanism for the Mitrovich smoke tunnel

eighth of an inch, and $V_A/V = .25/.125$, or 2, meaning that the velocity of flow is double that in the free stream. The pressure here falls by 3k.

"By plotting the pressure distribution at various points over the surface of a model, you can compute the lift that will be exerted on a given shape at a given angle to the direction of the stream flow.

"Another project which may interest amateurs is the study of the flight dynamics of flexible model aircraft. Small wooden gliders are adaptable to this study.

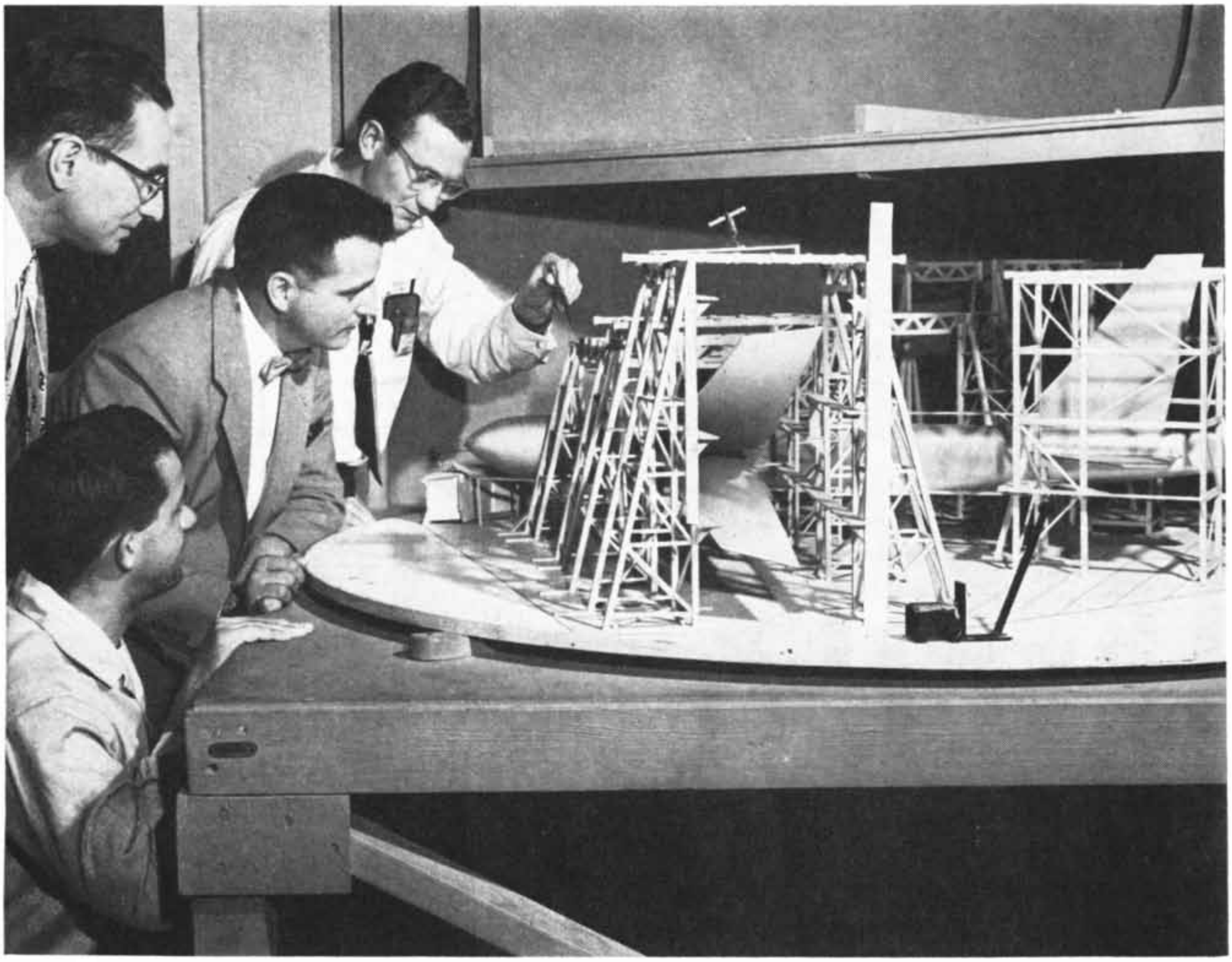
"When an airplane flies through a gust of wind, it may nose up and down slightly with an oscillation of a certain frequency. The airplane's fuselage, being elastic, also bends at a characteristic frequency. When the two modes of vibration chance to coincide, the airplane begins to gallop through the air, bending and pitching in an oscillation of growing amplitude.

"The phenomenon can easily be demonstrated with a model glider. To make the usual stiff model sufficiently flexible, you can introduce springs consisting of piano wire into the structure of the frame. With a little ingenuity you may also discover how to produce wing flutter in the craft by inserting elastic hinges at appropriate places in the wings [*see diagrams on page 126*]. To demonstrate the classic flutter effects the wing should be allowed to bend upward and twist about its center at the same time.

"As airplanes have gone to higher speeds and lighter structure, the problems of flutter and aeroelasticity have become very important to the aircraft industry. While an amateur has little hope of solving these complex problems, experience gained with models will prove valuable if he ever turns professional."

Dushan Mitrovich, a high-school student of Chestnut Hill, Mass., submits the design of a smoke tunnel which he built at home [*see drawings on page 128*]. Photographing the streamlines of smoke around a model, he can calculate pressure distributions by the same method employed with the Hele-Shaw apparatus. An advantage of Mitrovich's smoke tunnel is that it is somewhat more convenient in a workshop which lacks running water and a drain.

"The tunnel," writes Mitrovich, "has a bellmouthed air inlet made of four pieces of balsa. The observation chamber measures six inches high, eight inches long and an inch wide. The entering air flow is straightened by a grid of 23



Boeing engineers work with stimulating associates

Many engineering skills are represented in this picture. Mechanical, civil, electrical and aeronautical engineers—in almost equal proportion—work closely together in planning and conducting the structural test of airplanes such as the B-52. This stimulating contact among experts in every field is typical of Boeing projects. It makes a good engineer even better, and helps his professional growth.

In no other industry does the engineer have the opportunity to evaluate so completely through destruction testing the structural integrity of such a large and complex product. It is a "classical" challenge for mechanical and civil engineers. It tests the instrumentation ingenuity of the electrical engineer and gives aeronautical engineers an opportunity to proof-check their design by translating theoretical air loads into practical test loads.

A variety of immediate problems and "years ahead" projects involving these same skills and their infinite variations are under way now at Boeing. The application of rocket, ram-jet and nuclear propulsion to current and future aircraft and missiles is typical of projects in active study. Applied research in the development of materials and components to withstand the tremendous heat and stress of flight at supersonic speeds offers even further opportunities for the expression of engineering talent.

More than twice as many engineers are with Boeing now than at the peak of World War II—evidence of the company's solid growth. This outstanding group of engineers has been responsible for such aviation landmarks as the KC-135 jet tanker-transport, the BOMARC IM-99 guided missile, the global B-52 jet bomber, and the B-47 jet bomber, present backbone of the Strategic Air Command.

If you want breadth of contacts, job variety and professional growth, it will pay you to investigate Boeing. There is always room for additional creative engineers on Boeing's design, research and production teams.

JOHN C. SANDERS, Staff Engineer—Personnel
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thin brass vanes, each two inches long and spaced at quarter-inch intervals. The diffuser, made of quarter-inch plywood, starts as an oblong rectangle and gradually becomes an octagon at the exhaust end.

"The air is drawn in by a pair of crossed, nine-inch propellers notched front and back so they fit into each other and rotate in the same plane [*diagram on page 130*]. They are housed in the octagon at the exhaust end and driven by a 15-volt, direct-current motor of the kind used in model trains. The propeller-motor assembly is supported in a brass tube, two inches long, which is held in the center of the octagon by four streamlined struts. A spinner on the propeller and faring aft of the motor streamline the whole power plant.

"The smoke generator, located below the air inlet, consists of a cylinder four inches in diameter and two and one half inches long. The funnel-shaped top feeds smoke to a half-inch manifold fitted with 24 smoke nozzles. The nozzles are made from eighth-inch tubing flattened slightly into ovals at the point of discharge. They enter the inlet at an angle of 45 degrees and end flush with the inner wall halfway between each of the smoothing vanes.

"Construction details of the smoke generator are obvious in the drawing. I burn joss sticks (available in Chinese stores) to generate the smoke; they work better in this tunnel than cigarettes, which produce too much heat, or titanium tetrachloride, which is corrosive and clogs the nozzles. The joss sticks, cut to a length of about one inch and impregnated with a few drops of lighter fluid, are placed on the wire mesh, which serves as a grate. To provide enough air to keep them burning, the propeller must be running when the generator is put in place. The pile is ignited, permitted to burn for a few seconds and then blown out. It continues to deliver a dense smoke.

"Air speed in the experimental chamber can be varied between 4 and 15 feet per second by adjusting the input voltage to the motor. The rear wall of the chamber is painted flat black. Illumination for photography is supplied by two 25-watt tubular bulbs equipped with cardboard reflectors. They are placed about three inches from each side of the chamber. To counteract reflection from the glass front of the chamber, I place a sheet of flat-black cardboard in front of the tunnel and photograph through a hole cut in the center for the lens. My models are made and tested by the procedures recommended by J. J. Cornish."

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