SCIENTIFIC AMERICAN

IONIZING RADIATION

FIFTY CENTS

September 1959

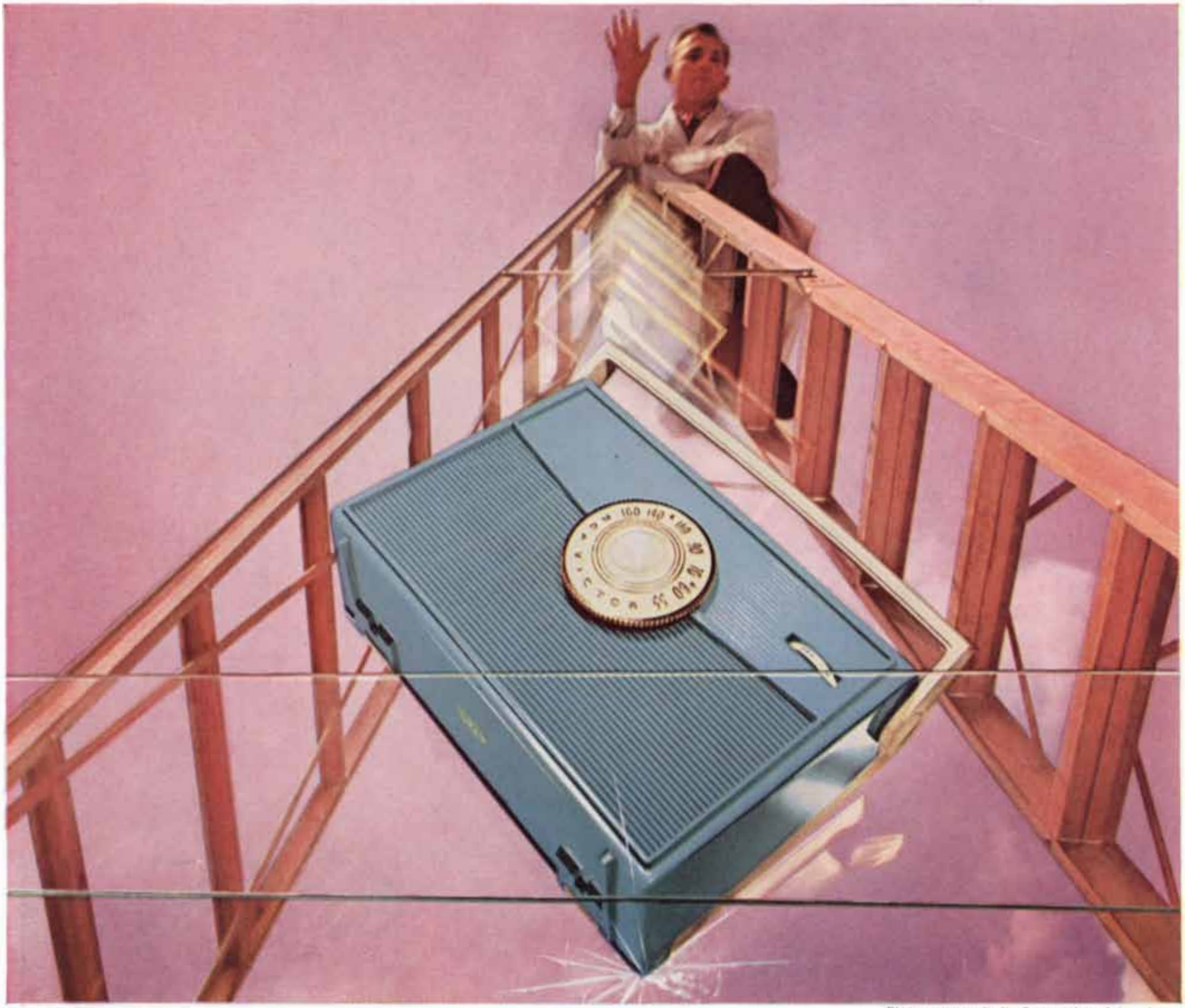

Photo courtesy Radio Corporation of America

Secret of a Smashing Success

Dropped 10 feet—this polystyrene radio case bounced, clattered, *but did not break.* It did not chip or crack—did not show a single mark of its high dive. Dramatic evidence, wouldn't you say, of the remarkable strength being built into modern plastics.

How to make tougher polystyrene—the material used in most radio cases—was long a priority project with all its manufacturers. Concentrated research and development finally solved the problem. The secret of success for many producers: combining the product with PLIOFLEX rubber.

Plioflex, with its unusually light color, high uniformity and particular physical properties, was selected over many other possible modifying materials. Experience has proved it to be the best choice to meet the exacting demands of the plastics industry.

Making more durable, more salable radio cases is but one of the many uses for the many types of PLIOFLEX. How can you use PLIOFLEX to advantage, either alone or in combination with other materials? Find out by writing to Goodyear, Chemical Division, Dept. I-9457, Akron 16, Ohio.

GOOD YEAR

CHEMICAL DIVISION

Plioflex—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio

Established 1845 **SCIENTIFIC AMERICAN** September, 1959 Volume 201 Number 3

ARTICLES

DEPARTMENTS

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THE COVER

The photograph on the cover of this issue, which is devoted to the topic of ionizing radiation, shows a beam of ionizing radiation produced by a two-million-electron-volt Van de Graaff accelerator. At the top of the photograph is the bottom of a "scanner" which spreads the narrow beam of electrons from the accelerator. Blue glow in middle of photograph is emitted by air molecules that have been ionized by the electrons. At bottom are two dishes containing seeds under experimental irradiation. The facility is at the High Voltage Engineering Corporation in Burlington, Mass.

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Cover photograph by William Vandivert

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SHIELD FOR THE
BATTLE OF SURVIVAL
IN SPACE
QMV*
BERYLLIUM
HEAT SINK
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PRODUCED FOR THE NASA SPACE-
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"BERYLLIUM IN
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BERYLLIUM
in PROJECT
MERCURY

PLASTICS PLAY LEAD IN NEW SALES SEASON

Rapid-fire developments in versatile thermoplastic materials herald sure-fire successes on the sales front. As the new products make their public debut, plastics are increasingly conspicuous by their presence. These chemically engineered materials are lightweight, yet strong and durable. They save pennies on the production line, look like a million in the show window.

Take Styron Verelite, newest in the fast growing Dow line-up of polystyrene materials. Designed specially for interior lighting applications such as grids and diffusers for fluorescent fixtures, it's light-stabilized, offering superior resistance to yellowing. It is now available in several granulations for both extrusion and molding.

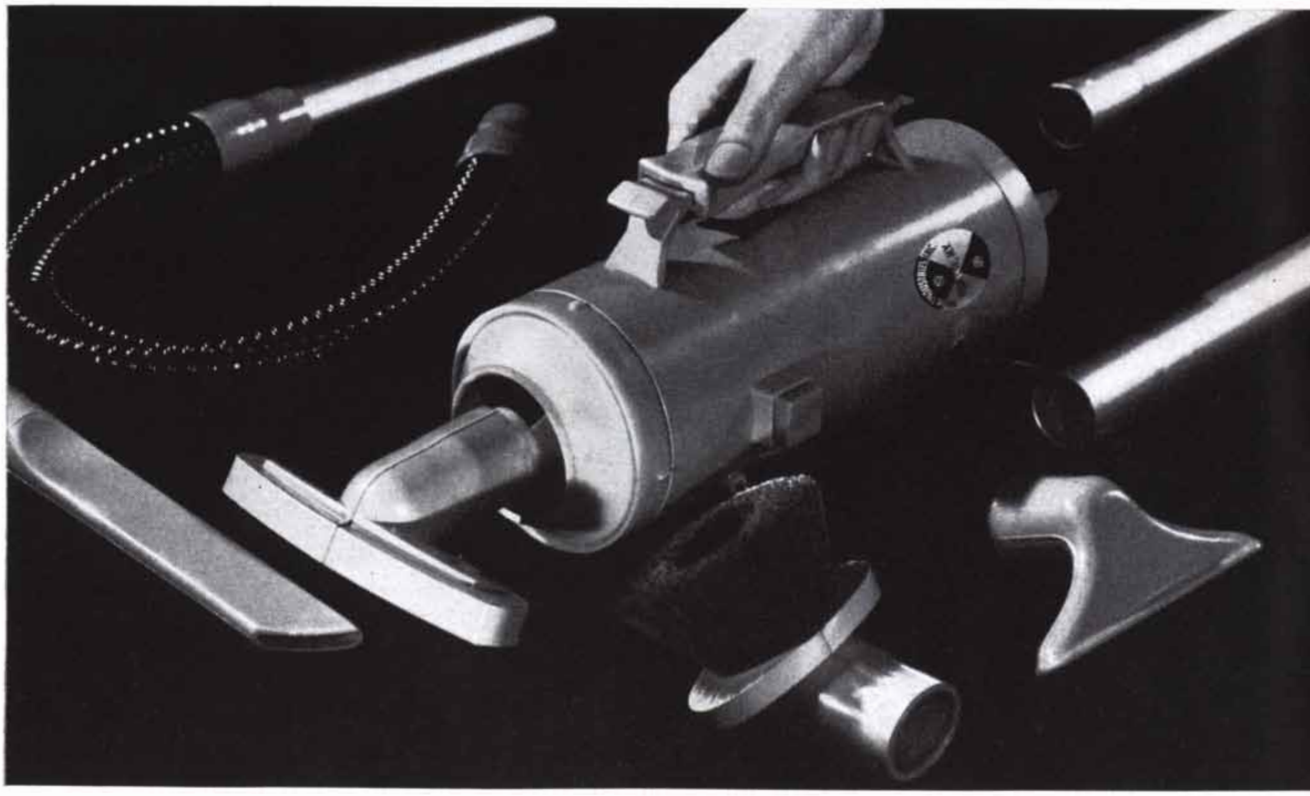
LIGHTWEIGHT STYRON MAKES VACUUM CLEANER SALES HUM

Dow thermoplastic replaces other materials, delivers production economy, attractive appearance.

The manufacturer of the compact vacuum cleaner shown below put plastics to full use in redesigning his product. The result is a lightweight, extremely portable and attractive unit that stimulates sales and gives the production man fewer headaches.

Styron® 475, one of Dow's high impact thermoplastics, was used for the housing and other rigid parts. The flexible parts are vinyl. The cleaner is available in two models, one for the home (pictured below) and one for industrial use. Lightweight Styron 475 makes the industrial version ideal for cleaning radio tubes, electronic equipment and other products with hard-to-get-at corners and crevices.

In addition to a smartly styled appearance and a wide selection of colors, Styron 475 provides a warm touch pleasing to housewives. Compared to materials previously used, it trims costs by eliminating several fabrication and assembly operations. Like all Dow plastics, it gives the designer broad latitude and its quality is consistent and uniform. This contributes to greater production efficiency and fewer rejects.

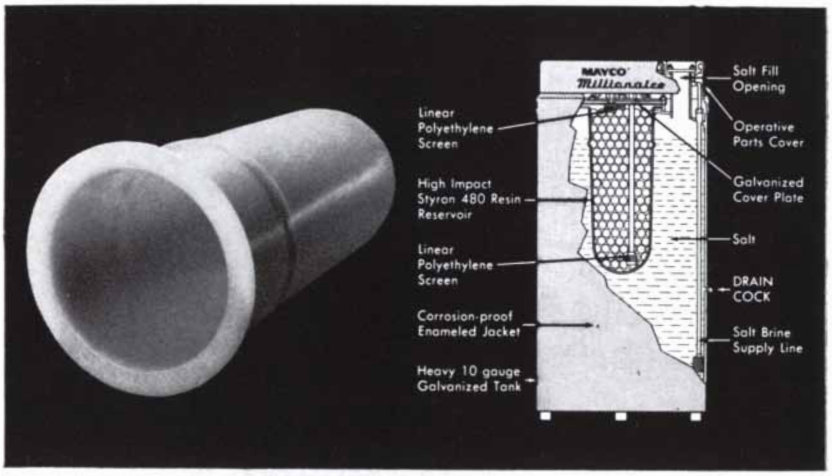


This compact, time and effort saving portable vacuum cleaner lightens the work of the housewife and maintenance man. Its components are molded of tough versatile Styron 475.

PLASTICS PERFORM

when pressure's on

This water softener creates a vacuum in its recharging cycle, producing up to 120 lbs. pressure on every square inch on the surface of the tank. That's one of the many reasons Styron 480, Dow's *extra* high impact thermoplastic, with its great strength was chosen for the job. As Styron is rustproof, there are no corrosion problems. The excellent moldability of Styron helped in making this large, thick-walled tank. This application is typical of many developed for manufacturers by a plastics molder offering integrated design and production services.

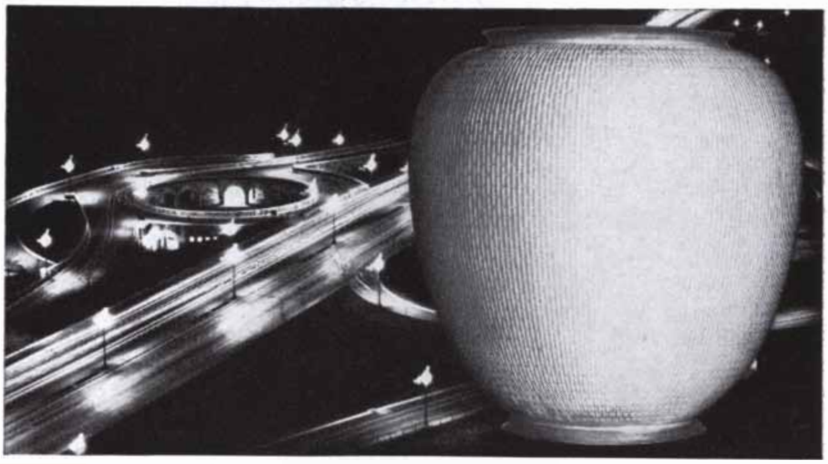


ZERLON* 150:

no break for boys

There'll be plenty of disappointment among the younger set when they discover their sling shots and air rifles won't shatter this street light globe. It's made of Zerlon 150, a new Dow plastic that combines outstanding transparency and strength. When struck sharply, Zerlon 150 "stars" rather than cracking or shattering. This property will sharply reduce maintenance and replacement costs for municipal governments. What's more, Zerlon 150 actually provides better transmission of light than the material normally used in this application. The globe is now in test service in a major U. S. city.

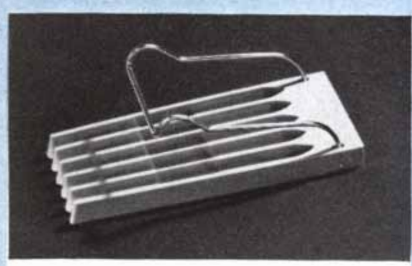
*TRADEMARK



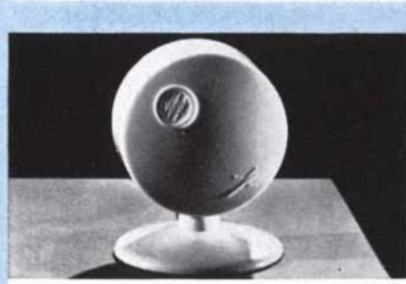
FOUR DISTINCTIVE PRODUCTS MADE OF DOW THERMOPLASTICS

STYRON 475. Even the time-honored thread spool can be improved by plastics! No wood grain imperfections to worry about in smooth-surfaced, colorful Styron 475.

POLYETHYLENE. The extremely intricate mesh design of this lace work bag thoroughly demonstrates the excellent flow characteristics of Dow Polyethylene 990M.



TYRIL®. Tyril, a copolymer of styrene and acrylonitrile, provides rigidity, craze resistance and freedom from cracking in this unique pants hanger.



STYRON 475. Fine surface gloss, impact resistance, color selection and excellent electrical properties make Styron 475 ideal for this indoor TV antenna housing.

FOR MORE INFORMATION . . .

about the versatile Dow plastics and the products discussed on these two pages, write to us today. THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Sales Department 1512EQ9.

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Midland, Michigan

DOW

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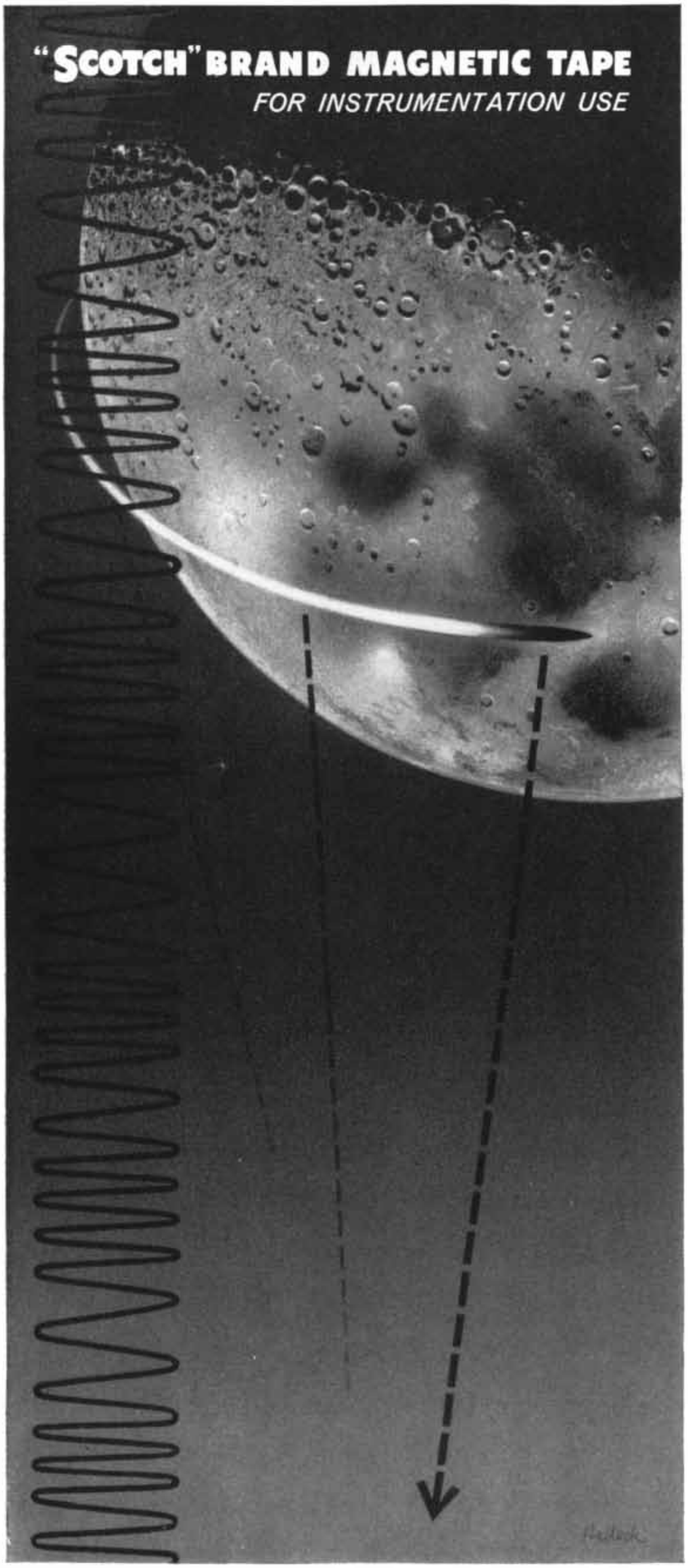


MAGNETIC MEMORY OF 16 CHANNELS OF VITAL STATISTICS —BEAMED FROM A ROCKET IN FLIGHT

Velocity. Altitude! Stress! Strain! Air pressure. Trajectory. Heat and cold. Shooting the moon or downrange, the missile man must record these—and more—when he sends his voyager out in the silent sea of space. For this sensitive task of simultaneously recording up to 16 channels of vital readings on the flight performance of a missile, "SCOTCH" BRAND Magnetic Tape has proven reliability.

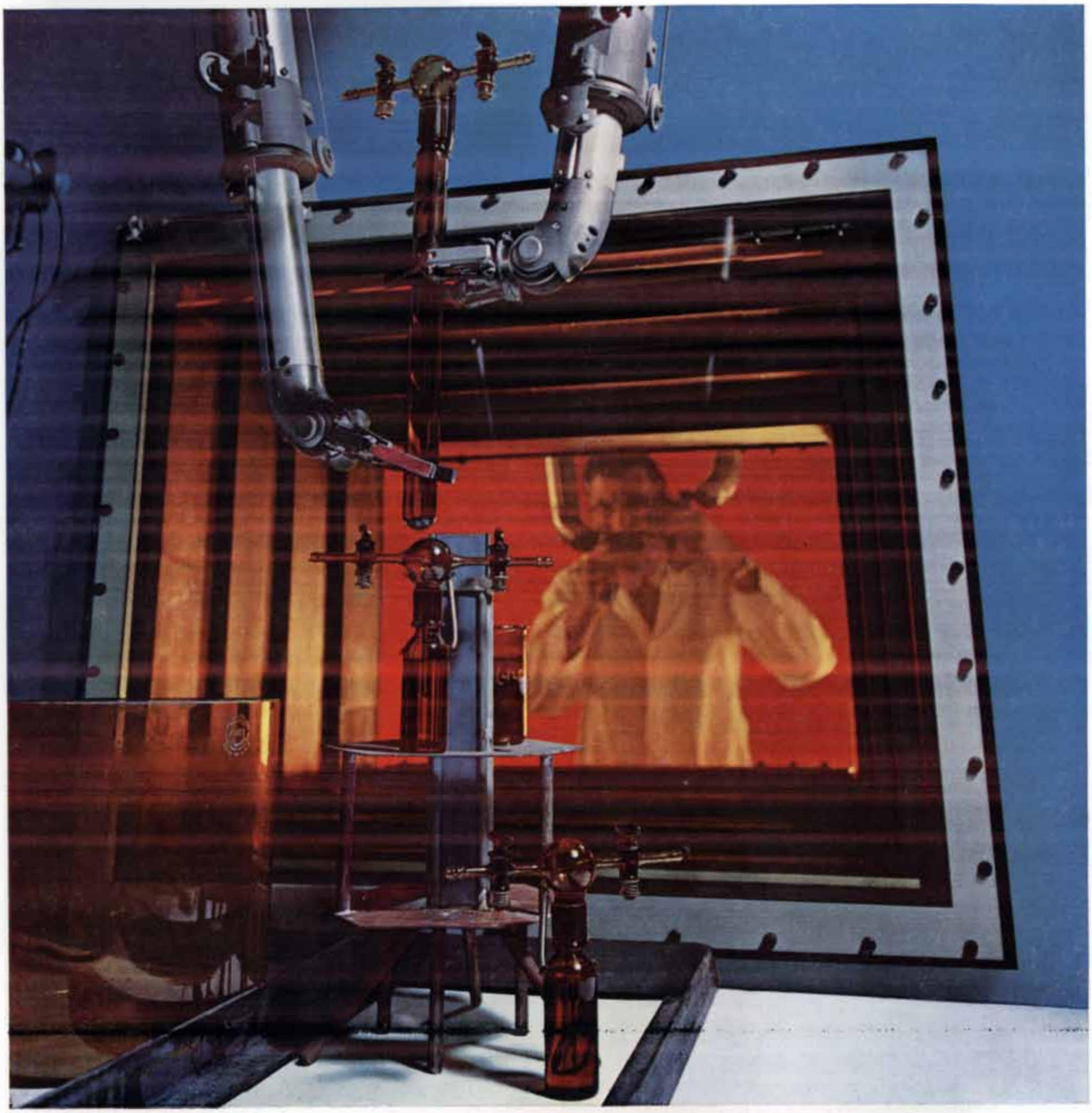
Taken with more-than-human speed and accuracy, these telemetered magnetic notes can be checked and rechecked for clues to improved design.

"SCOTCH" BRAND Magnetic Tape — the first practical magnetic tape made — remains the leader as newer, more sensitive instrumentation tapes are developed for science, automated industry, and business. It will serve you, too. For information on tape constructions for your specific needs, write Magnetic Products Division, Dept. MBO-99, 3M Co., 900 Bush Ave., St. Paul 6, Minn.

"SCOTCH" BRAND Magnetic Tape —the memory of tomorrow

MINNESOTA MINING AND MANUFACTURING COMPANY
...WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY



No darkening, even under the most intense radiation, when you use Corning windows. Whether dry or oil-filled, the windows also resist corrosion and moisture. Windows come as packaged units, ready to install.

Why it's as easy to buy a hot-cell window as a test tube

You leave a hole in your hot cell . . . we'll do the rest.

That's the simple proposition made by the men who sell our radiation shielding windows. And they've backed it up in more than 400 installations.

You tell us the wall thickness and the peak energy level you'll be working at and the viewing area you'll need.

We do *all* calculations, provide designs and materials, and deliver a packaged window that's ready to install.

Three special glasses

We've developed three glasses to answer any radiation problem. The glasses are used singly or in combination, depending on your needs.

Corning Code 8362 is a cerium-stabilized, non-browning lead glass with a density of 3.3 gm/cc and a refractive index of 1.59.

Corning Code 8363 is a special, high-lead glass that weighs in at 6.2 gm cc and equals iron for shielding. R.I. is 1.98.

Corning Code 8365 is a cerium-stabilized, non-browning lime glass. Density is 2.7 gm/cc. R.I. is 1.52.

For complete details on these glasses and the service that goes with them, write for a copy of Bulletin PE-51. One of our men will be glad to work with you on your projects. Corning Glass Works, 49 Crystal St., Corning, N. Y.

CORNING GLASS WORKS
CORNING MEANS RESEARCH IN GLASS

CORNING CAN DO ALMOST ANYTHING WITH GLASS


COUNTERMEASURES and
Instruments for Industry
The I.F.I. "Menagerie Series",
familiar to most electrical engineers,
graphically illustrates the
contributions made by I.F.I. to this
exacting field of countermeasure
engineering upon which our
very survival may well depend...
COUNTERMEASURES and the myxine glutinosa
FORMIDABLE, INDEED, IS THE HORRENDOUS HAGFISH
though small in size, his capabilities are enormous...
COUNTERMEASURES and the testudinidea malaclemys
FORTUNATE, INDEED, IS THE TURTLE
for he carries his countermeasure right on his back
Man on the other hand must devise his own countermeasures if he intends to survive in this day of modern warfare. Instruments For Industry is actively engaged in this field working in close conjunction with the Army, Navy, Marines and Air Force.
An I.F.I. "ceiling of safety" protects these men against surprise ballistic attack.
INSTRUMENTS FOR INDUSTRY,
101 New South Road, Hicksville, L. I.
Enlarged photos of the I.F.I. "menagerie" available on request to Dept. 201.
COUNTERMEASURES and the chamaeleon vulgaris
DECEPTION IS A FORM OF COUNTERMEASURE
and at this the chameleon must be considered an expert
The approach to the problem of survival through countermeasures has been neatly solved by this handsome little fellow. By simply changing his color to match the surroundings the chameleon may take on the appearance of a brown twig, a green leaf or so completely blend into the immediate area that his enemy is hopelessly confused. This, in effect, is countermeasure in the truest sense. To confuse or mislead the enemy is often
the problem faced by the military. Not to be outdone by the chameleon, electronic countermeasures have been developed which effectively confuse the presentations as seen on radar scopes. Defensive action is thereby delayed until too late. In this field, as well as many other forms of countermeasures, Instruments for Industry can apply exacting know-how and skill. The high degree of success achieved by IFI is proof of ability
Only one target is a true target. The big question... which one?
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Graduate engineers with two or more years of circuit application in the fields of electronics or physics are invited to meet with Mr. John Hicks in an informal interview or send complete resume to: Dir. Personnel, I.F.I., 101 New South Road, Hicksville, New York.

8442-AC

POGO-HI
(II E3c)

P-107
AIR LAUNCHED

P-106
GROUND LAUNCHED

AERONCA TARGET MISSILES PERFORM A VARIETY OF MISSION PROFILES... WITH SUBSTANTIAL ECONOMY

The adage "practice makes perfect" keynotes today's concept of missile warfare. Against supersonic targets, there isn't time for "the second barrel". Therefore, extensive operational testing of air defence systems . . . and training programs for personnel who operate them . . . must be conducted to assure national preparedness.

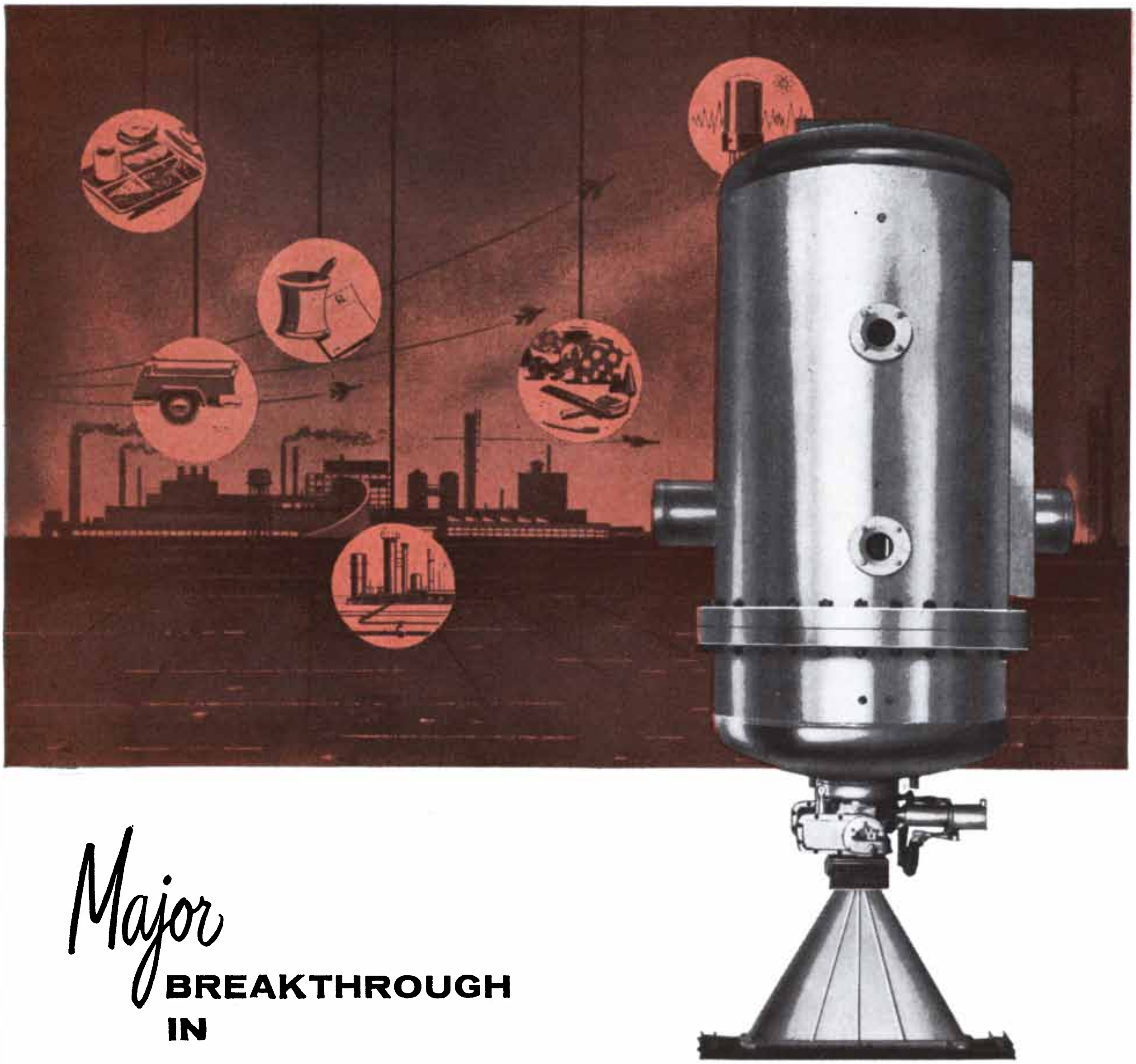
To accomplish this requirement at minimum cost, Aeronca has developed two expendable, lightweight, high-performance target systems under the Design-Tool-Produce envelope concept. These proprietary missile programs, the P-106 and P-107, are designed for supersonic performance and accurate scoring at all required altitudes, speeds and ranges. *And their production cost is projected to be substantially less than any current target missile system!*

Another Aeronca-produced missile project is *Pogo-Hi II E3c*. Ground launched to high altitudes, this target utilizes a radar reflective parachute and an infrared emitter package. It is used as "bait" for such current projects as *Nike, Talos, Sidewinder* and *Falcon*.

With integrated Design, Tooling and Production capabilities, Aeronca can produce weapon systems envelopes at either prime or subcontractor levels.

AERONCA manufacturing corporation
1722 GERMANTOWN ROAD • MIDDLETOWN, OHIO

Operational expansion has created openings for additional senior engineers. Write to W. W. Gordinier, Personnel Manager.



Major BREAKTHROUGH IN

LOW COST* IRRADIATION

New DYNAMITRON** ACCELERATOR
FEATURES 10 TIMES MORE
PRODUCT THROUGH-PUT . . .
SAME CAPITAL INVESTMENT

TYPICAL LOW COST IRRADIATION APPLICATIONS

FOOD — for preservation and spoilage reduction

DRUGS — "cold sterilization" of antibiotics, surgical supplies and human tissue for transplant

RUBBER — vulcanization at a fraction of the time and cost

PLASTICS — cross-linking for increased temperature resistance, strength, insulating properties and chemical inertness

CHEMICALS — initiating and increasing catalytic reactions

PETROLEUM — "cracking" of crudes—higher yields

ELECTRONICS — semi-conductive material research and improvement of wire coatings

RESEARCH — basic research, higher yields, faster data accumulation

This entirely new concept in high voltage particle accelerators has broken the radiation "cost barrier." RDI's technological advance features **compactness, reliability, minimum maintenance** and **operating expenses,** and **low capital cost per kilowatt of radiation energy.**

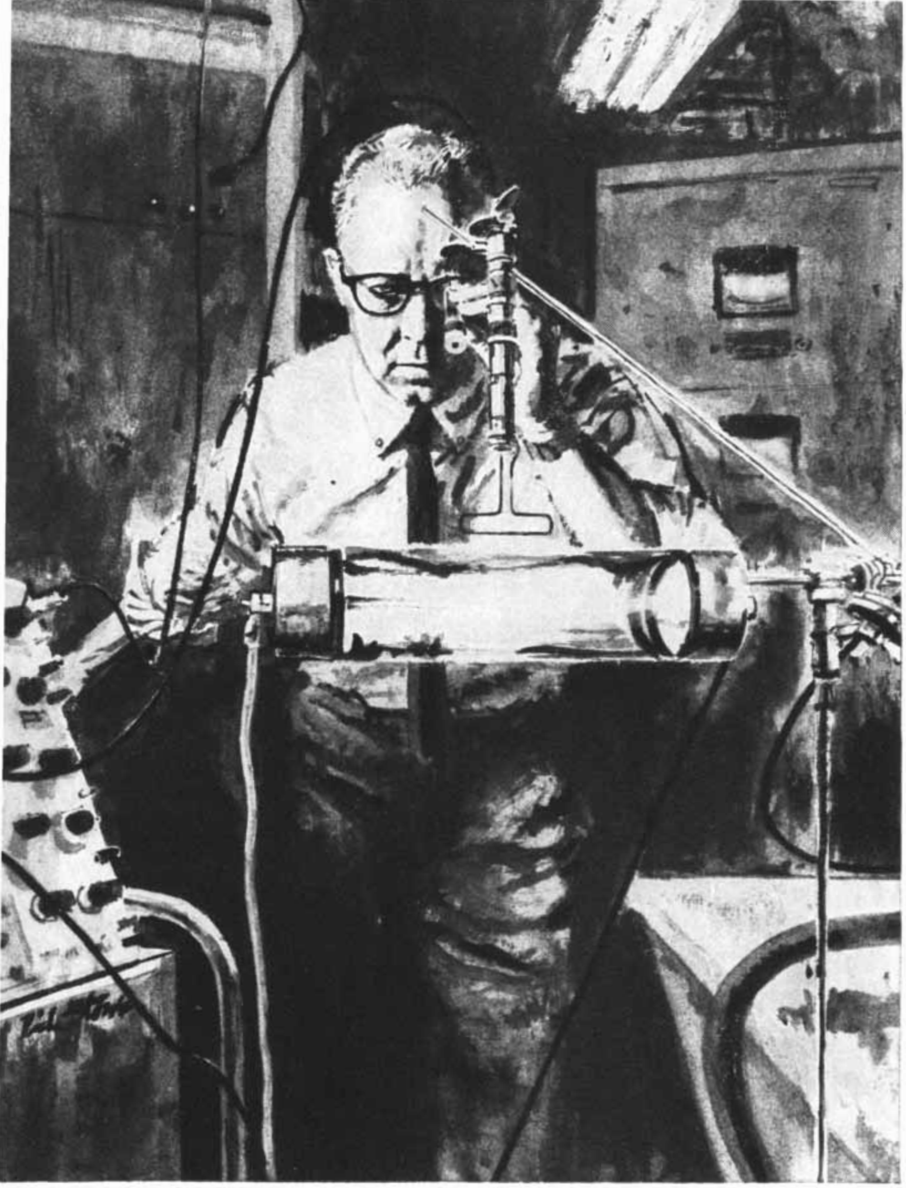
RDI has constructed one of the largest radiation facilities in the country for the purpose of demonstrating practical industrial and military applications.

this is only the beginning—imaginative research and creative engineering will develop more new products and processes. For complete engineering information and technical advantages write today to Application Engineering.

RADIATION DYNAMICS, INC.

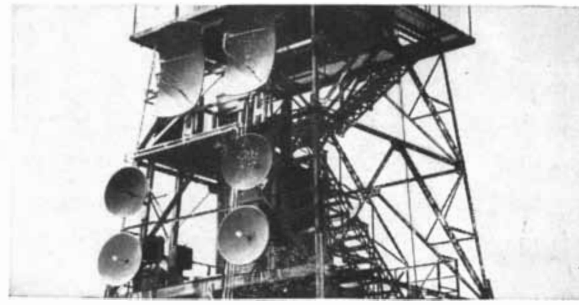
Westbury Industrial Park
Westbury, Long Island

*$4,000 PER KILOWATT OUTPUT
**PATENTED



FIERY GASES glow as Sperry scientist studies magneto-hydrodynamic characteristics of molecules subjected to high current discharge. From this advanced basic plasma research will come microwave energy much more powerful than is now available and will perhaps explain the generation of microwaves by the sun and other galactic bodies.

RESEMBLING SEARCHLIGHTS—radars aboard cruiser *USS Galveston* depend on power from Sperry microwave tubes to launch and guide Navy's Talos missiles on precise course at supersonic speeds.



WORDS OR PICTURES are beamed cross country by microwave relays eliminating wires and damage from storms. Western Union system using Sperry microwave tubes handles up to 2,000 messages simultaneously.

NAVY CARRIER PLANE finds "home" by flying precise guidance signals powered by Sperry microwave tubes in TACAN, tactical air navigation system. (U.S. Navy photo.)

Developing The Power to Explore The Unknown

From harnessing signals that control missiles in flight and guide pilots to safe landings will come greater knowledge of outer space.

ONE OF A SERIES:

THE STORY BEHIND THE STORY
of Sperry Electronic Tube Division

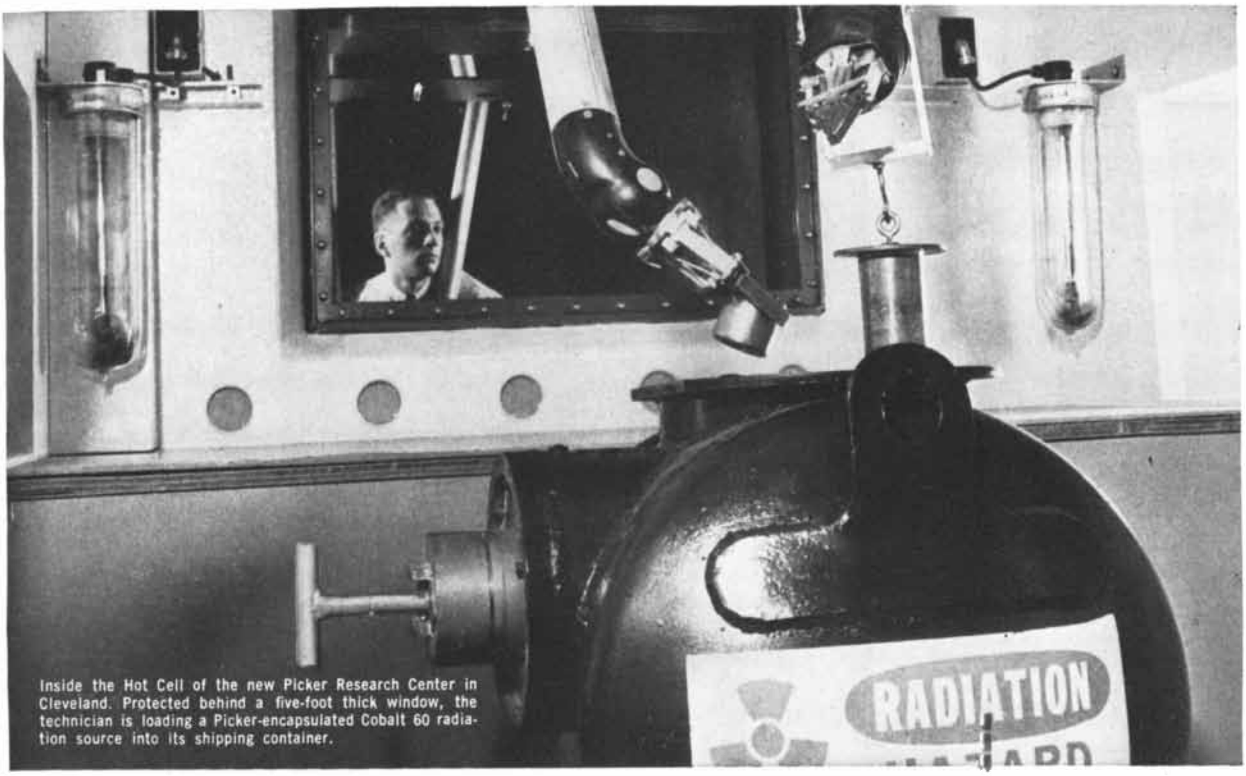
Twenty years ago a group of Sperry engineers began development of odd-looking devices to generate microwave energy. In doing so a new field of science was established—and the world gained a new and previously unharnessed power.

Modern radar, for example, owes its ability to "see" through fog and storm to microwave tubes which beam signals to distant objects—and with such precision that returning signals form distinct images on the radarscope. Communications, national defense, entertainment—even food preservation—all have benefited from the ability to create and control this new power.

Radio astronomy—another new science—now reveals that the sun and other galactic bodies generate microwave energy—and probably have done so since the formation of the universe. Sperry's research of this solar microwave energy may permit radically new types of generators which will lead to a better understanding of outer space.

If you are interested in microwave tubes for any purpose, write Sperry Electronic Tube Division, Sperry Rand Corporation at either of its two modern plants—in Great Neck, New York and in Gainesville, Florida.

SPERRY



Inside the Hot Cell of the new Picker Research Center in Cleveland. Protected behind a five-foot thick window, the technician is loading a Picker-encapsulated Cobalt 60 radiation source into its shipping container.

LETTERS

Sirs:

We have received a large number of letters commenting on our article ["Experiments in Color Vision," by Edwin H. Land; SCIENTIFIC AMERICAN, May]. Because many of these letters are thoughtful and detailed, it has been impossible to give each of them the equally thoughtful and detailed answer it deserves. We are thus compelled to answer the letters collectively. We hope that our correspondents will forgive us for grouping their questions and observations into classes.

Many have been able to repeat our experiments fairly well; many others have had trouble; a few have been so unsuccessful that they have questioned the validity of the experiments. These operational problems are the easiest to discuss and to respond to. When we go back over our work of the past five years and try to understand what we have done to effect continuous improvement in the beauty of our photographs as seen when finally projected, we are impressed by the following considerations:

1. Except for the requirement that the pictures be carefully registered in projection, there are no difficult problems whatsoever in viewing the pictures. Once two good black-and-white positive transparencies are available, they provide as reliable a color picture as any other kind of color photograph.

2. Taking the picture requires insight into the fundamental difference between exposing correctly when color is to be reproduced with two photographs, and exposing correctly when color is to be reproduced with three photographs. This difference exists independently of the eye and is purely photographic. When only two photographs are made, the photograph taken through the long-wave filter is expected to record wavelengths in the scene longer than roughly 580 millimicrons, and the photograph taken through the short-wave filter is expected to record wavelengths shorter than 580 millimicrons. This second photograph is given an unusual burden: it must discriminate between yellows and whites on the one hand, and blues and blacks on the other. The yellows are so close to white in brightness that they are likely to come out as transparent areas on the finished transparency; hence they are indistinguishable from white. Similarly, the dark blues are likely to expose the original negative no more than black; thus they are indistinguishable from black. We have learned over the years to correct these difficulties by suitable exposure, so that the yellows are not overexposed and the dark blues are not underexposed. Now when a color picture is made with three photographs and a blue filter is used for the third, the whites for this third photograph will be fully exposed but the yellows will be only slightly exposed. The blues in turn will be well exposed, and the blacks will of course be dark. Thus the whole photographic scale is available in this third photograph to record what we might call the yellow-blue domain of the scene. The absence of this full photographic scale for yellows and blues when color is recorded with just two photographs may well be responsible for much of the unhappy history of two-color photography. Our work, which has been directed at insights into visual theory using photography as a tool rather than toward producing a color process, seems to have forced us to go farther toward good recording than most of the photographers of the past. It may well be that their occasional successes in handling this particular problem of exposure led to their enthusiasms, and that their failures in handling it led to their final disappointment. Be that as it may, the important point for a theory of vision is that once the photographs are well made, two of them suffice to produce a very satisfying gamut of colors, including those that characterize a slice of lemon, a slice of orange and a banana on the one hand, and Delft blue on the other. If any read-

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er of SCIENTIFIC AMERICAN would like to pursue these experiments further, he need only send me, at 730 Main Street, Cambridge, Mass., a self-addressed envelope. We will be pleased to send him a mimeographed memorandum setting forth the conditions of the experiments in greater detail.

All this leads us to another question raised by some of our correspondents, namely, can two photographs discriminate between a variety of blue of different saturations and a variety of greens? Is it not a mathematical necessity that certain greens will be recorded on black-and-white film like certain blues of different saturation? The answer is definitely yes. If our purpose were to use this particular work to make a "perfect" process for color photography rather than to investigate the visual processes, this would be a matter of concern. It is true that if only two photographs are made, certain greens will be recorded in the same way as certain blues. Nevertheless blues, greens, browns, grays, yellows, oranges, reds and whites are elicited with only *two* packages of information (as represented by the two photographs), and for the most part the colors are correctly associated with the appropriate objects. Furthermore, for nearly every object the color that is elicited cannot be predicted from classical color-mixing theory, *and is predicted quite simply by means of the new coordinate system.*

One must not confuse the question of how many of the range of classical stimuli exist at each point with the question of how many independent packages of information are used and combined to make the final record. It has come to be the custom over the years to characterize this dual projection as a two-color system. However, each point in the image may involve various amounts of James Clerk Maxwell's three primary colors. Thus it should be the burden of the classical color-triangle to predict the color at each point on the basis of the ratio of these three stimuli. But the composite colors that we actually see have no theoretical home until we introduce an idea that Thomas Young thought relevant: Extended areas of the retina are significant in determining the sensation for each point in the image. Thus far no theoretical rationale has been available to take us from the color triangle and its arithmetic to a description of the sensations produced in an image consisting of two packages of information.

We come then to an important group of letters which urge that by combining the color-mixing theory of Maxwell, Young and Hermann von Helmholtz with the well-known phenomena that involve the effect on one point in the retina of stimuli at the other points, one would be led to expect—and it is implied one would be enabled to predict—the particular colors in images. (Most of these phenomena have been classed by writers in the past as adaptation or induction, adaptation implying a time element, and induction the notion that the induced color is not real. Adaptation is defined in *The Science of Color* as "change of sensitivity of the eye to meet the needs of vision," and induction as "adaptation caused by local or momentary exposure." A particularly important example of induction is complementary-colored shadows.) These correspondents feel that we have not given enough attention in our exposition to the history of adaptation and induction. Now insofar as adaptation implies that the colors in our images are the result of extended exposure of the observer's eye to the image, we are convinced that adaptation is irrelevant. We have already given evidence to support this—evidence which in general shows that these colors are immediately apparent. As for induction, insofar as it means that all of the retina which is exposed is involved in the sensation at each point in the image, we are in full agreement; indeed, that is the heart of our position. However, insofar as induction carries with it connotations of curious neurological mechanisms, of anomalies or aberrations, we are cautious about adopting such a term because it carries us from a simple set of laws to dependency on surmises about mechanisms still largely unknown. Insofar as "induced" is used as an antithesis to "real," we must stand our ground and insist not only that the colors produced by induction are just as real as any other colors, but also that without it many of the colors in everyday life would simply not be there.

While we heartily favor placing a high value on induction, we are at a loss to see what there is in the long history of it prior to the work of Deane B. Judd and Harry Helson in 1938 (except for the black-and-white experiment of C. Hess and H. Pretori in 1894) that would enable one to make any quantitative treatment of it whatsoever. From the middle of the 17th century to the middle of the 20th there are endless chronicles of amazement about colored shadows, and a variety of speculations about the reality of these colors so remote from the color associated with the wavelengths or wavelength mixtures of the stimuli. The speculations of von

PINCH PLASMA ENGINE
NEW POWER FOR SPACE VEHICLES

"The experimental model of a new concept . . . a magnetic pinch plasma engine for interplanetary space travel is in operation at our laboratories," *says Alfred Kunen (R) Project Engineer, Plasma Propulsion Project, shown with Milton Minneman of Republic's Scientific Research Staff, during actual operation of the engine.* ➤➤➤ *Republic's plasma engine unique in that it utilizes intermingled positively and negatively charged particles in a single jet thrust, can operate on fuels more readily available than required for an ion engine, and attains greater thrust. By compressing these particles in an invisible cylindrical magnetic girdle and shooting plasma out the rear at tremendous velocities, sufficient thrust is generated to push a vehicle through the near-vacuum of outer space.* ➤➤➤ *Republic is working on advanced plasma engine studies for the U. S. Navy Office of Naval Research and the U. S. Air Force Office of Scientific Research.* ➤➤➤ ***Today's pinch plasma engine is but one of many bold concepts under development at Republic to create for the space world of tomorrow. It is part of Republic's multi-million dollar exploration into the realm of advanced aircraft, missiles and space travel.***

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Republic's new $14,000,000. Research and Development Center, is scheduled for operation early in 1960.

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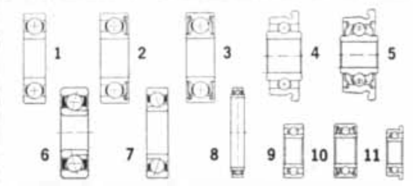
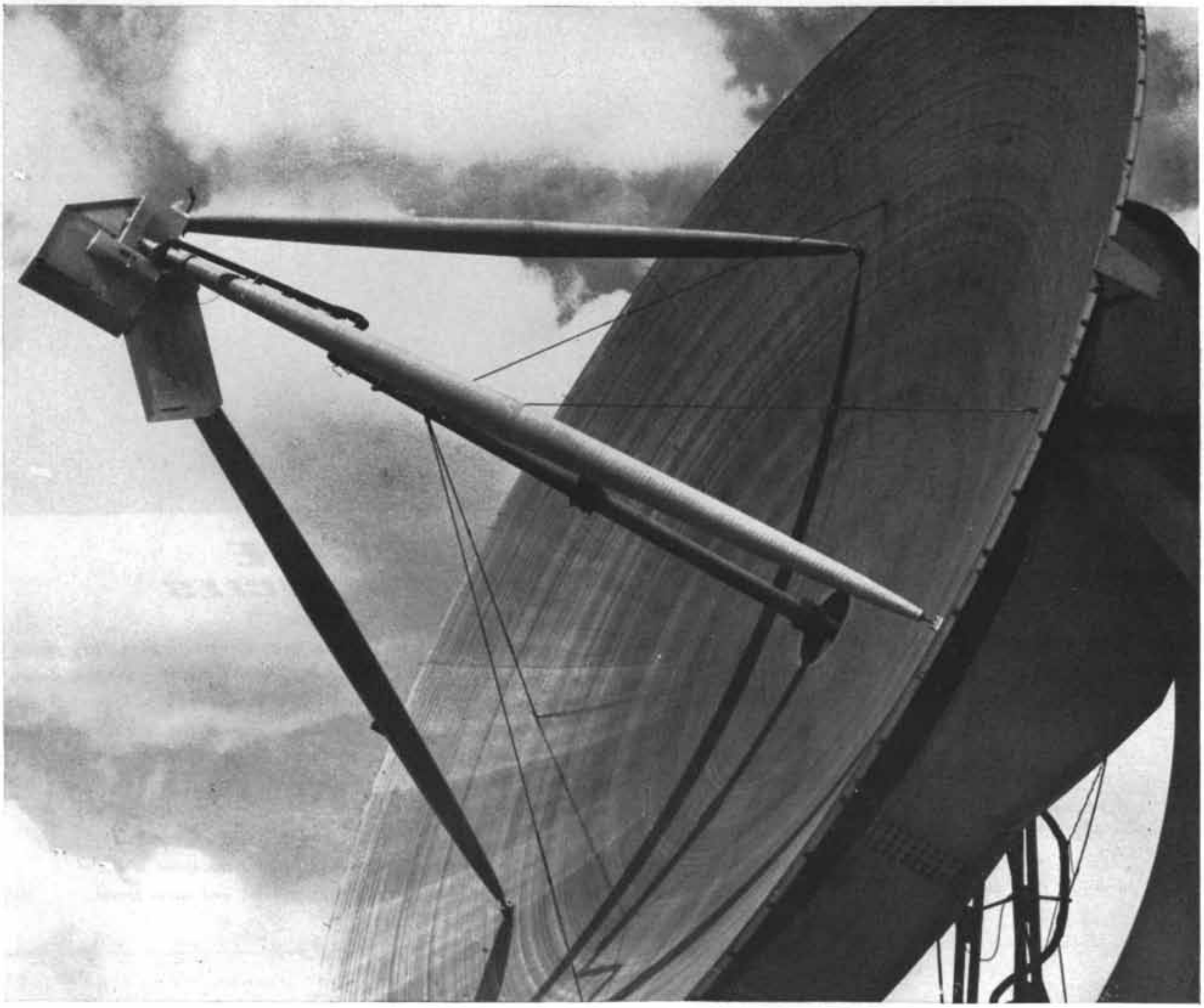
When you are designing new radio telescope equipment . . . a new aerial camera . . . a new process control device . . . a new *anything* that calls for precision instrument ball bearings, you do well to turn to Fafnir. For no matter what your problem is . . . temperature extremes, low torque, load-life, low decibel readings . . . Fafnir can help you solve it. Fafnir has the *diversity* — a wide variety of ball bearing types, designs, steels, and tolerances — and the uniformly high standards of *quality* to meet your needs precisely. The Fafnir Bearing Company, New Britain, Connecticut.



Fafnir instrument ball bearings: Open and shielded types (1 through 5), angular contact (6,7), **torque tube** (8), and open and shielded miniatures (9, 10, 11).



FAFNIR
BALL BEARINGS

Guericke, Buffon, Priestley, Rumford, Goethe and Meyer led in this first phase to a solid and extended study by A. Kirschmann in 1890, and to a set of laws embodied in E. B. Titchener's text in 1901, which reads as follows:

"(1.) The contrast-effect is always in the direction of greatest qualitative opposition. (2.) The more saturated the inducing colour, the greater is the contrast-effect. (3.) The nearer together the contrasting surfaces, the greater is the contrast-effect. (4.) Colour contrast is at its maximum when brightness contrast is eliminated. (5.) The contrast-effect is enhanced by the elimination of contours."

Now some of these laws survive in the image situation, but many of them do not. None of them is in any sense a quantitative guide. We simply do not understand how anyone can suggest that these vague statements, largely inaccurate for images, having no quantitative components whatsoever, can be combined with the simple, rigorous, meticulous rules of color-mixing to produce a new arithmetic for predicting colors in images.

We believe that the reason induction did not develop into a science is that those who explored it tended to use what we regard as greatly oversimplified situations. We suggest that here is a domain in which an error in the technique of abstraction, a presumption that simplification of the field of view is permissible to understand the properties of an intricate field, prevented induction from becoming a mature principle. Our plea to contemporary experimenters is that they take any step away from normal, fully populated scenes with the utmost caution. We have shown elsewhere that presentations can be made which should be rich in color classically, but which—because of the hidden order that we have built into the presentation—show in some cases no color, and in others two colors but no color-mixing. On the basis of these experiments we feel strongly that no experimenter should make a general statement about sensations produced by an artificial set of visual stimuli unless he identifies meticulously the whole geometric structure of the field of vision and is willing to limit his conclusions to that particular structure.

It is significant that when Judd and Helson came in 1938 to quantify the appearance of colored objects seen under different illuminants, they could not draw on previous work on induction for any mathematical guidance whatsoever. Their formulas had to be based on direct observations of colors, and had to be elaborated by means of adjustment and correction from these observations. By this important step they erased many of the fallacies in previous thinking on induction, and they introduced into the literature of vision—for the first time, so far as we know—the idea that it is fallacious to divide colors into real and unreal. We feel that the following statement of Helson's marks a significant point in the history of color vision: "The failure to recognize that a single principle operates in every act of vision has been responsible for the many conflicting views regarding the relation of contrast to constancy, of adaptation to constancy, and of constancy to conversion." This is a direct, realistic and unpretentious acceptance of the properties of surface colors as real phenomena. (For a moment this seemed like a period of Renaissance, with Judd and Helson bringing surface colors out of the world of mystery, and with Ralph M. Evans giving brilliant demonstrations by projection of the fact that not only could red and white be used, as was known since the work of W. F. Fox and W. H. Hickey in 1914, but that even red and yellow could be employed to produce sensations ordinarily associated with the short waves.)

Judd and Helson's study dealt with the change of colors of samples with type of illumination and arrived empirically at a workable extension of the three-variable system to a six-variable system. Just how well Judd's formula will correlate with our coordinate system is not yet known, but there is already some evidence from Judd's recent calculations that there will be reasonable correlation. On the other hand, Judd's premises involved proximity in past time in a way that we have not found necessary, and his formulas do not predict the achromatic situations (the images in which colors either do not appear, or stimuli do not mix, even though classically a wide range of colors would be expected) which we believe to be perhaps the most significant part of our work. The use of the photographic medium greatly simplifies the study of the colors and their representation in the coordinate system, since it makes it unnecessary to carry out the computations for each point of the interaction between the illuminant and the absorption spectrum of the object.

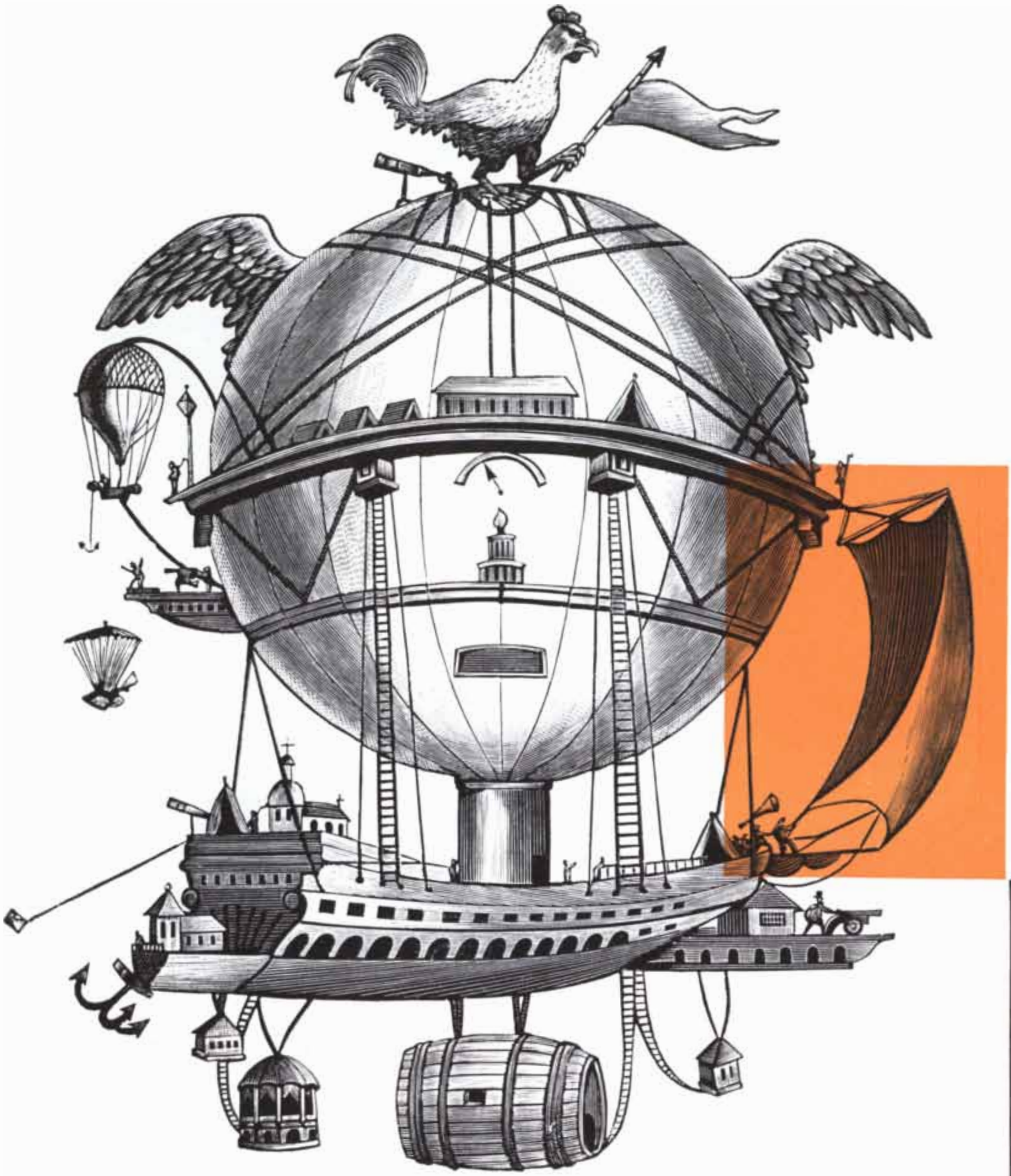
What, then, is the relationship between the vague studies of induction, the precise studies of color-matching and our study of the nature of color in images? An aspect of this relationship is well illustrated by the curve bounding the region of achromatic wash in the diagram on page 89 of our article in *Scientific American*. From some points of view it is not surprising that this curve closely resembles the curve arrived at by W. D. Wright and F. H. G. Pitt that delineates just noticeable differences in wavelengths. To us this is a satisfying example of the relationship between classical theory and the colors in images. We expect that in some such way every single great fact in classical theory will be involved ultimately in the description of colors as seen in images, but curiously not in the direct prediction of these colors. For this a new science of color in images is required.

There has been a group of excellent investigations having to do with neural mechanisms, with receptor theory, with retinal pigmentation, and also with a group of phenomena involved in special controlled situations such as color-matching, saturation, luminosity, purity, etc. There has been missing, however, what we regard as an important, exciting and fruitful investigation: the study of the properties of the whole image. It would be a sad thing for us if it were thought that our interest in this field of endeavor implied any trace of lack of appreciation for the solid values in the other fields of vision, but we would find it equally sad if those who have done so well in these other fields cannot see their way clear to join in this new adventure. The point of departure for this adventure is the discovery that the over-all visual mechanism has the capacity for discerning when an image on one band of wavelengths is functionally related to an image on another band of wavelengths, and has the competence to know, for example, that in spite of variation in ratios of stimuli from point to point in the field of view, no new information has been introduced if one image could have been derived by a simple formula applied to the other image.

We are happy to report that our triple-image illuminating monochromator is completed. We have been studying from the beginning of this investigation the question of whether objects projected with two packages of information and then looked at through a black tube change more than when projected with three. We will now be enabled to answer this question as well as the significant question of the role of the third package of information.

EDWIN H. LAND

Polaroid Corporation
Cambridge, Mass.



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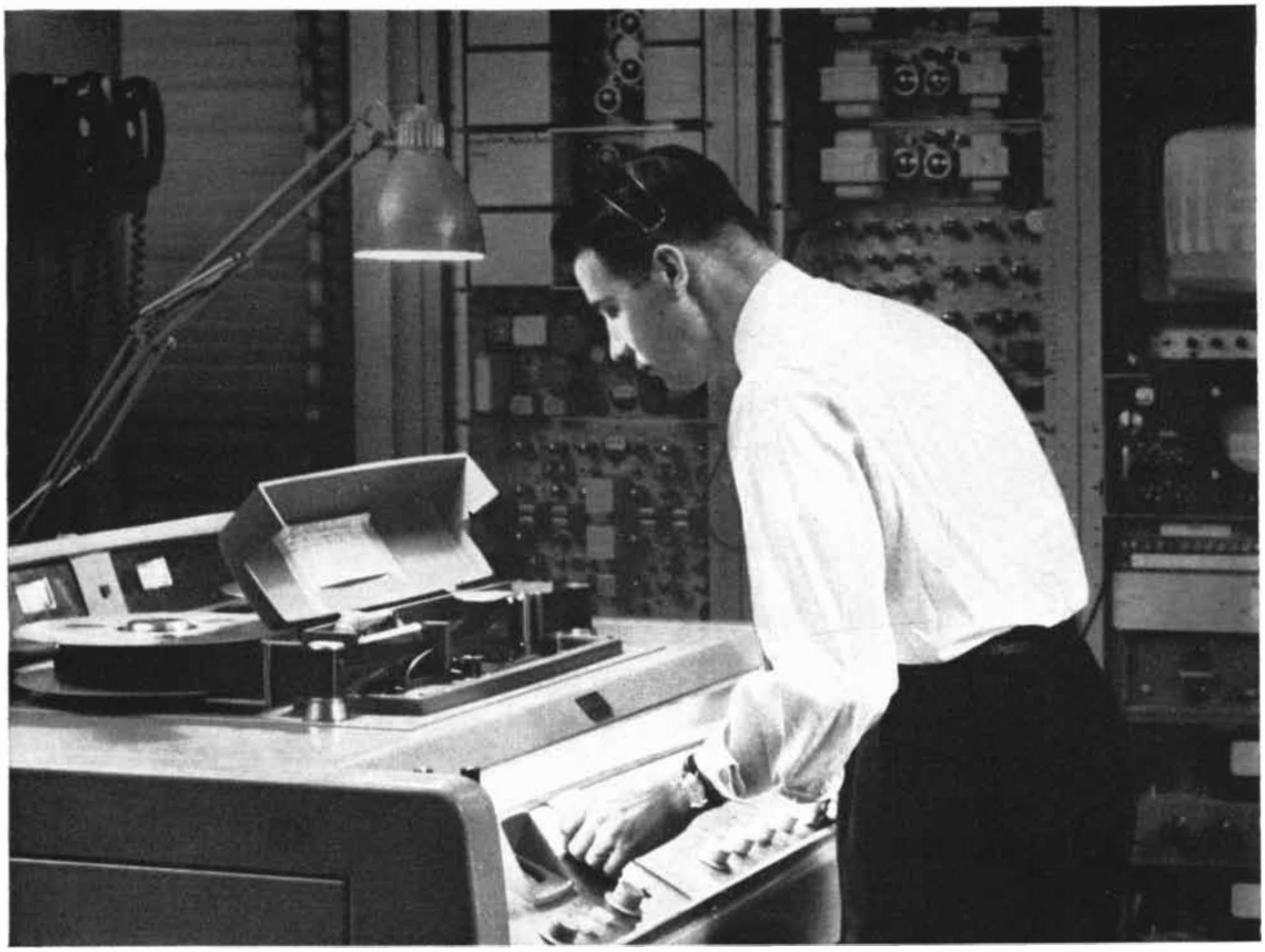
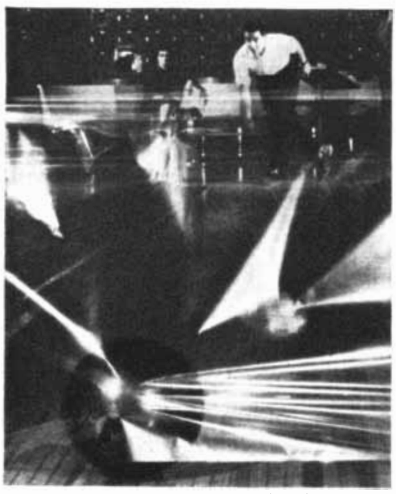


TV producers can cut studio time . . . eliminate costly processing by using video recording tape made with "Mylar".

Tough, thin Du Pont MYLAR helped solve a problem in developing video recording tape for the TV industry



"Mylar" has high strength. With an average tensile strength almost ⅓ that of machine steel, "Mylar" takes the crushing impact of fast traveling bowling ball.

Magnetic recording tape for use in electronic recording of sound and picture for TV broadcasting had to meet new standards of performance. The tape—called video recording tape—had to be thin enough to make intimate contact with revolving recording heads, yet tough enough to withstand relative recording speeds of 1,500 inches per second!

Alert tape manufacturers filled this need by using Du Pont "Mylar"* polyester film as the base for video recording tape. "Mylar", which had already proved its reliability in missile tracking and data computing, provided the necessary strength and toughness in thin gauges to meet the exacting demands of TV recording equipment.

This is but one of the many ways "Mylar" is helping industry improve product performance, develop new products and lower costs. Electric motors, for example, can be made smaller and more efficient with insulation of "Mylar". Manufacturers of electrical cable can cut material costs by using tough, thin "Mylar" as a core binder.

For additional information, write today for our new booklet. E. I. du Pont de Nemours & Co. (Inc.), Film Dept., Room SA-9, Wilmington 98, Del.

*"Mylar" is Du Pont's registered trademark for its brand of polyester film. Du Pont manufactures the base material "Mylar"—not finished video recording tape.

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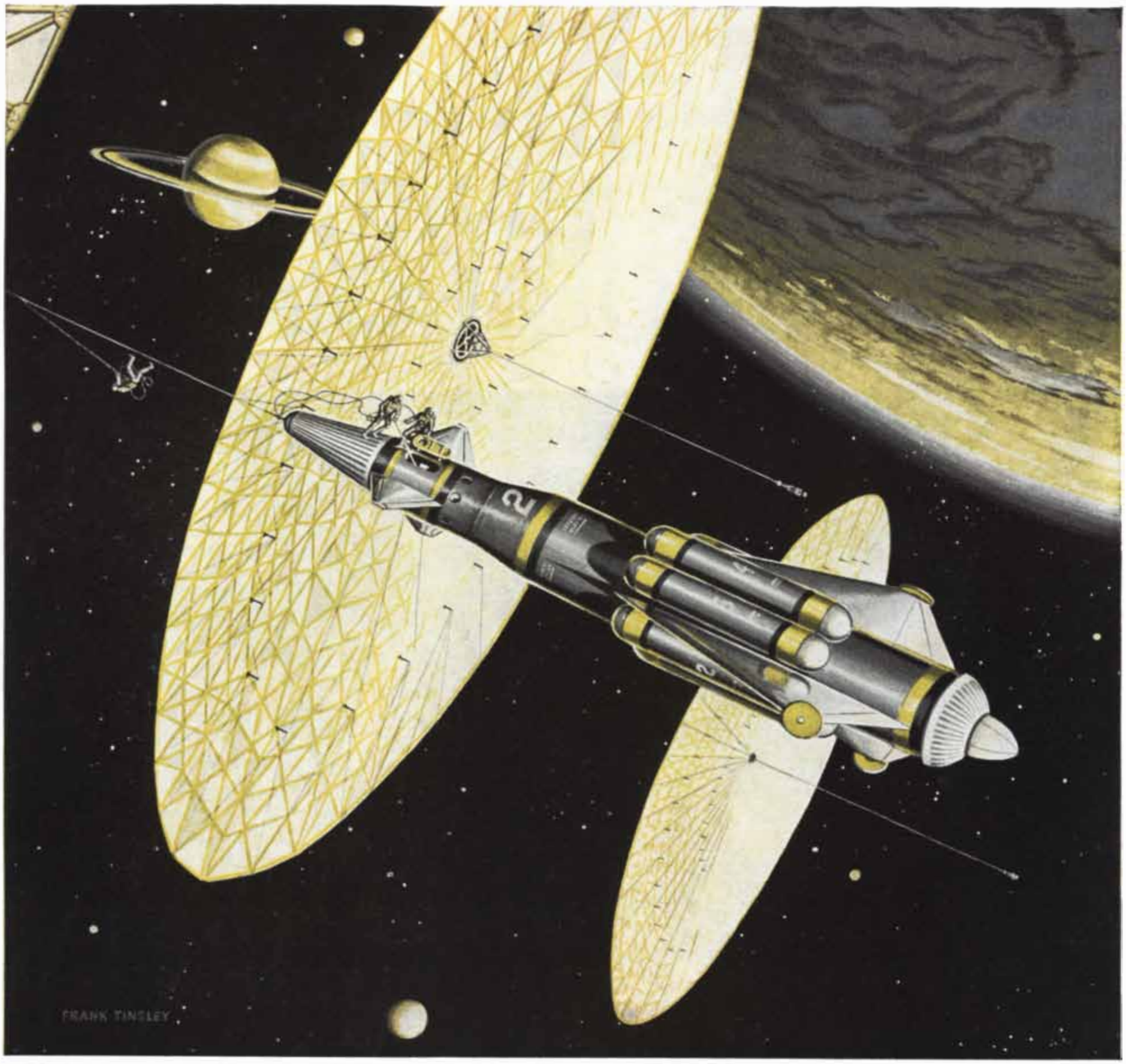


STEPS IN THE RACE TO OUTER SPACE

Solar Wind Ship

The large circular objects are Solar Wind Ships, capable of carrying astronauts on fuel-less journeys through the solar system, using the Sun's expanding flood of radiation— or "trade winds"—as a direct propulsive force. These trade winds are harnessed by sails of plastic film, coated with shiny evaporated aluminum.

Although the push of solar radiation is extremely weak—about the weight of four cigarettes per acre—it is ample in the friction-free, weightless vacuum of space to drive the Wind Ship at a constantly accelerating speed. For long trips into space, sails are several miles in diameter, cross-braced by plastic masts and fine, glass filament rigging. In the center of the sail, an inflated wheel-shaped hull is mounted in a tripod arrangement. This hull, powered by solar batteries, can revolve in any direction, providing artificial gravity for its crew and functioning as a gyroscope to stabilize and control the attitude of the sail.

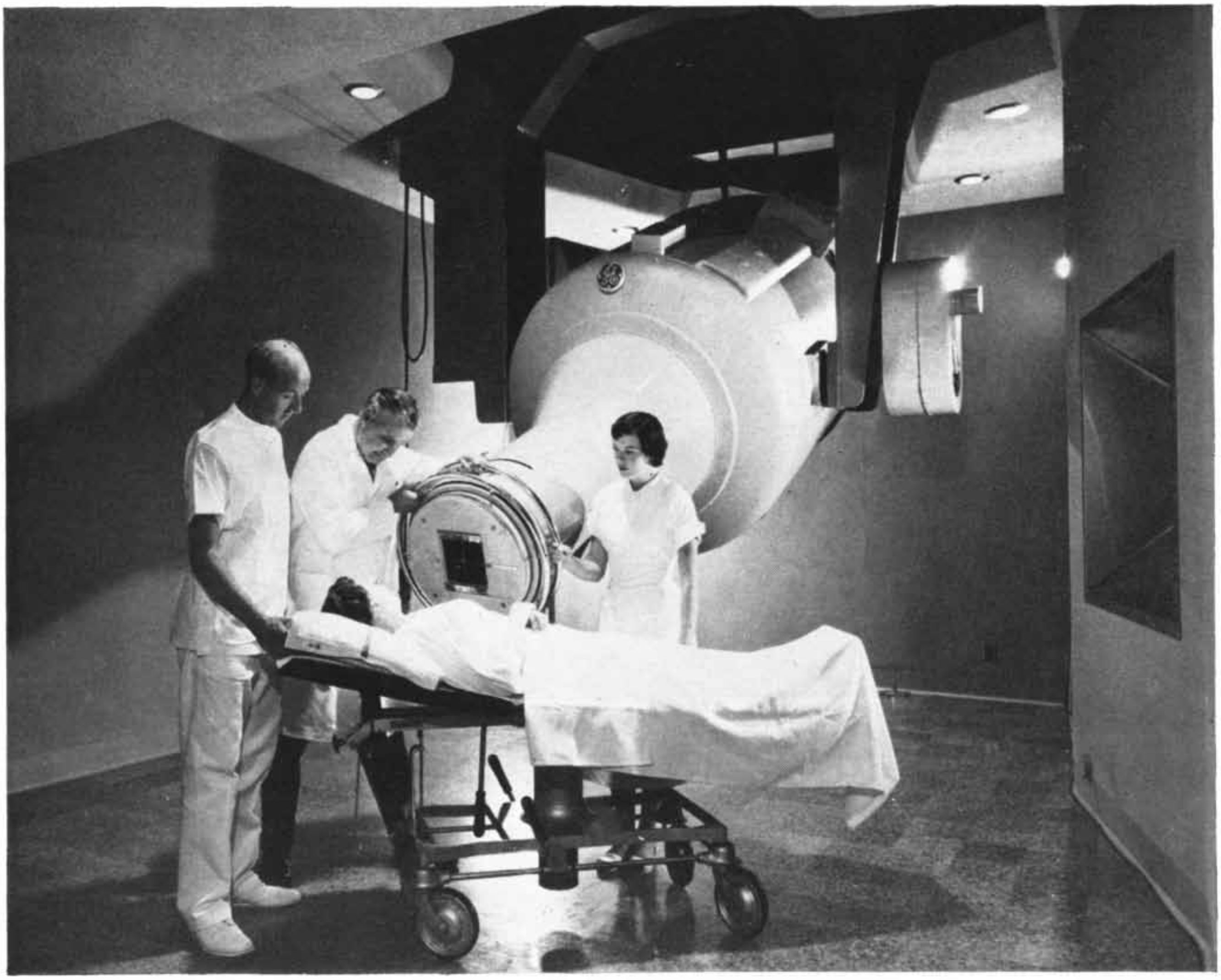
In the illustration, a flotilla of manned Solar Wind Ships is approaching Saturn. To the right is Titan, largest of Saturn's nine moons and the only satellite in the solar system known to have an atmosphere. In the foreground, a crew of astronauts enters a small ferry-rocket, towed behind the Wind Ship. Since the Wind Ship cannot land on any planet, they will explore Titan in the Atomic-powered rocket, then rejoin the fleet for the remainder of the trip to Saturn.

Inertial navigation systems will play an increasing role in the exploration of outer space. ***ARMA***, now providing such systems for the Air Force ATLAS ICBM, will be in the vanguard of the race to outer space. ***ARMA***, Garden City, N. Y. A Division of American Bosch Arma Corp.

AMERICAN BOSCH ARMA CORPORATION

How General Electric X-Ray is harnessing the powers of

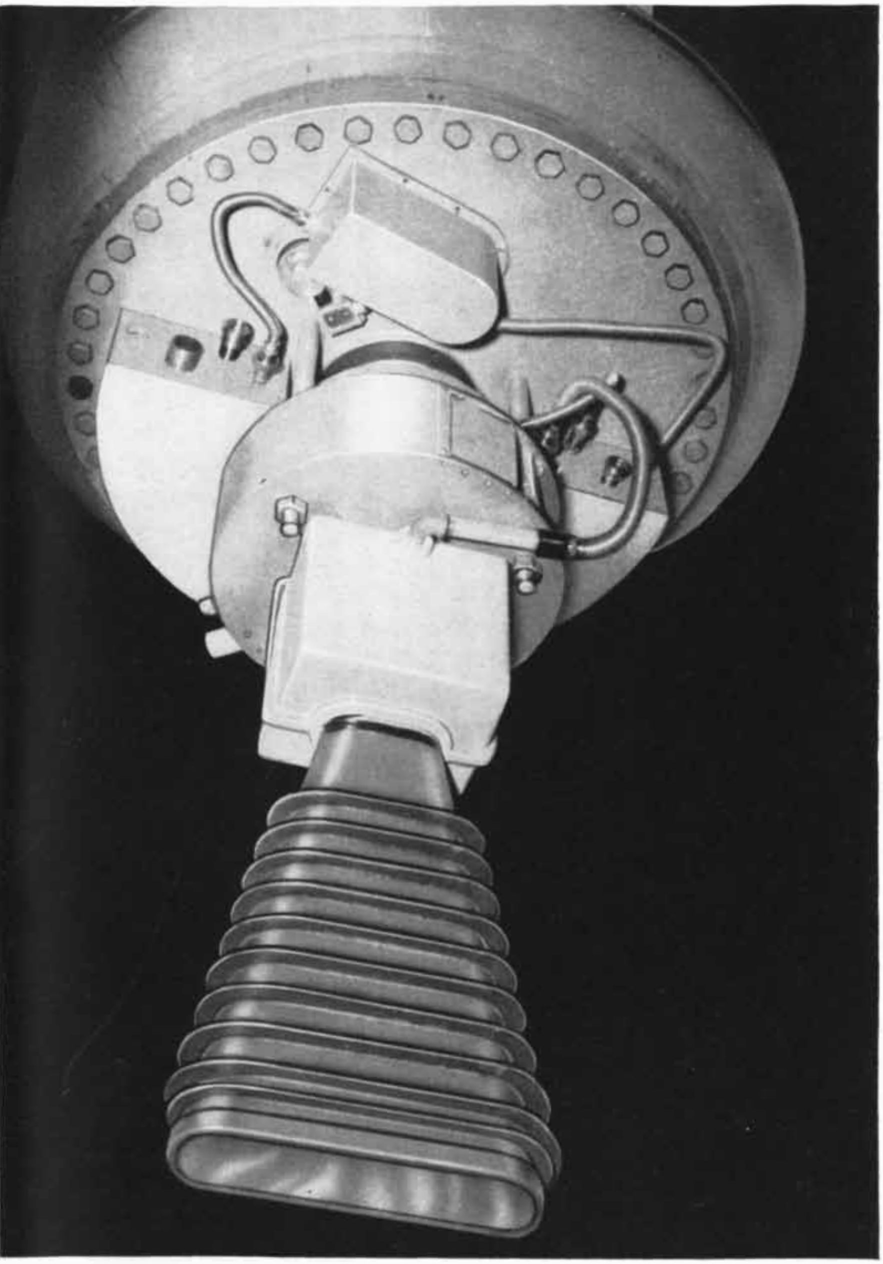
HIGH-ENERGY RADIATION



IN MEDICINE... The two-million-volt G-E Maxitron® 2000 x-ray unit you see here is medicine's heavy artillery in the war on cancer. X-ray therapy has shown itself to be an increasingly effective and valuable weapon in combating this malignant killer.

Today there are nine of these units — and 14 one-million-volt machines — operating in U. S. medical centers. Significantly, not a single Maxitron 2000 tube has ever needed replacement — and the oldest has been in use nine years!

For more than a half-century G.E. has pioneered in the development of x-ray equipment for both diagnosis and therapy ... helping protect the nation's health through detection and treatment of human ills.



IN INDUSTRY... Above: the business end of a 2-million-volt Electron Beam Generator. Expect small miracles from it — you're not likely to be disappointed.

What is it? General Electric equipment that produces high-energy electrons to alter the fundamental structure of matter. *What can it do?* Its high energy radiation beam is being used to cross link plastic for improved properties. Its beam is lethal to micro-organisms — can sterilize, preserve. And who knows what more may come from its unique talents as a chemical agent.

Other General Electric x-ray equipment is serving with distinction in a variety of industrial ways: research, quality control, product development. Above all, G-E x-ray application engineers have the all-important "know-how" you'll not find elsewhere.

More information? Consult the yellow pages of your telephone directory for the name of your nearest G-E x-ray representative, or write X-Ray Dept., General Electric Co., Pub. TT-94, Milwaukee 1, Wis.

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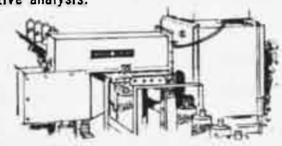
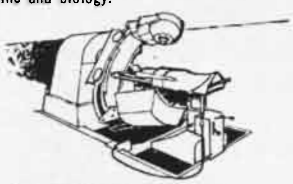
G-E x-ray diffraction and spectrographic equipment speeds quantitative and qualitative analysis.



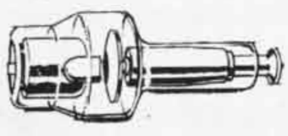
G-E Hytafill measures level in sealed, opaque containers. Same principle is used to gage material thickness.

G-E x-ray microscope opens new fields of research to metallurgy, chemistry, medicine and biology.



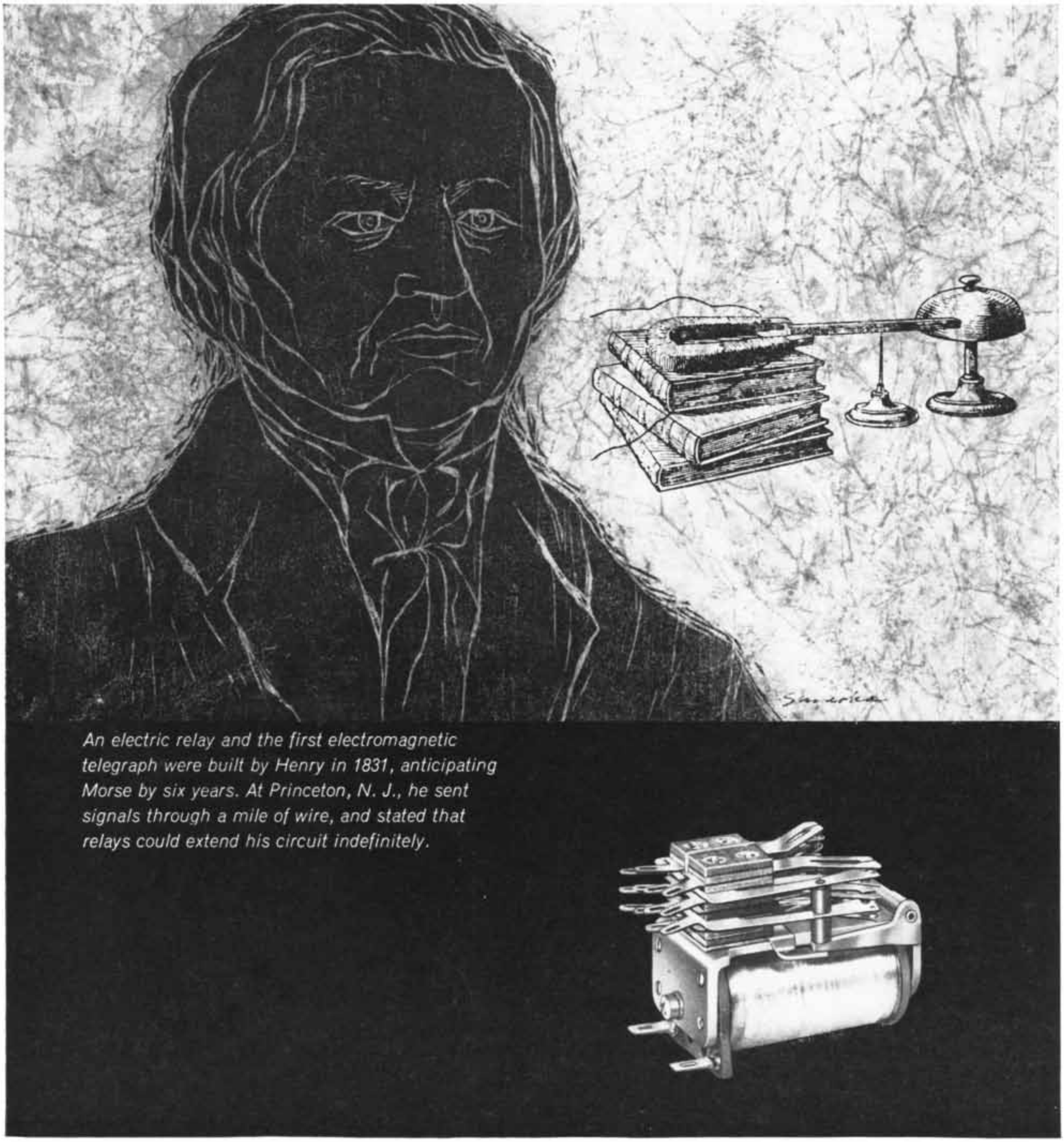
Isotopic teletherapy makes use of radioactive sources.

G-E units for x-ray diagnosis enhance the radiologist's skills.



G-E X-Ray Tube Service maintains complete stocks at 40 convenient factory-operated district offices.

The complete range of G-E supplies and accessories offers the convenience of one source, the assurance of fast service.



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Joseph Henry invented the electromagnetic relay in 1831, and then used it to ring a bell in the world's first telegraph circuit. Since that crude beginning, relays have been refined to remarkable reliability. For example, sixteen of the telephone type shown above, our LS, recently operated under load more than 213,000,000 times before a test was discontinued. A booklet giving complete engineering data of the test is yours for the asking.

Our engineers follow Henry's imaginative, yet practical, approach to scientific problems. Being relay specialists, they combine a firm knowledge of the state-of-the-art with creative initiative. The result is a reliable product designed for economical installation on modern production lines and delivered to you at the lowest possible cost.

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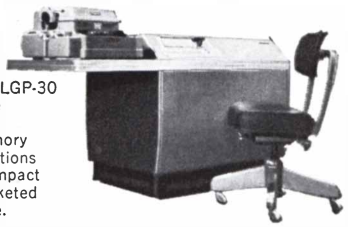

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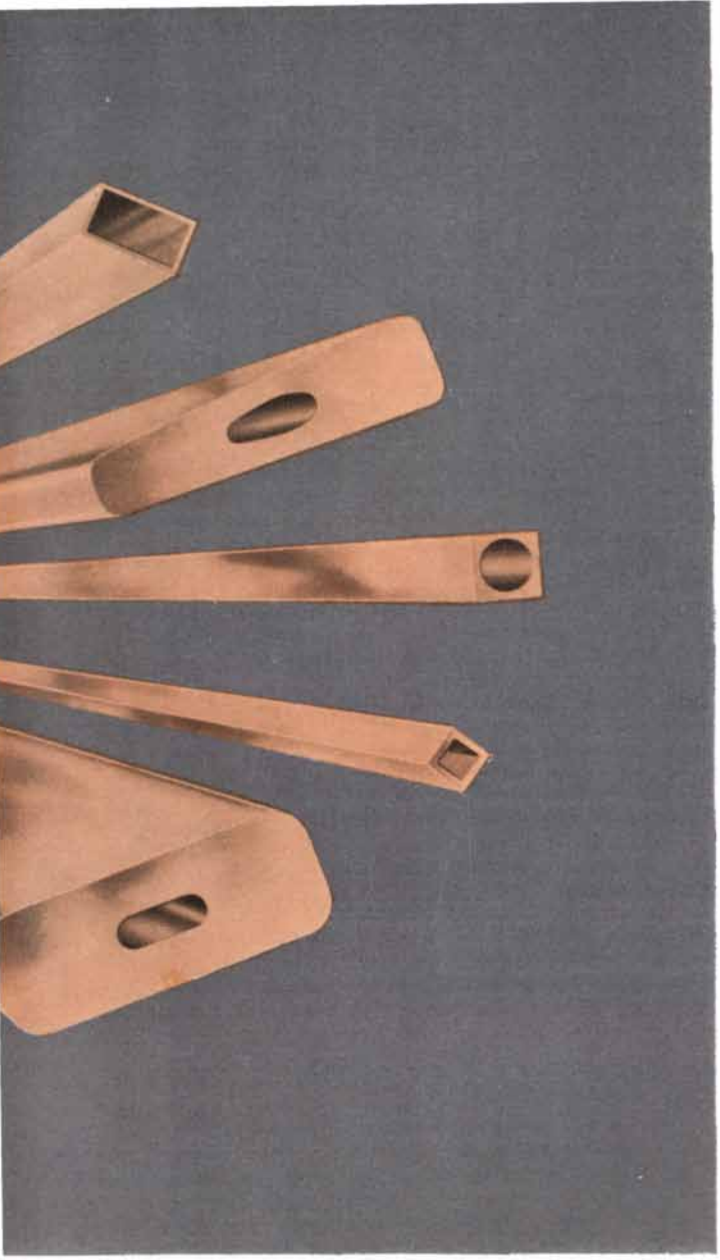

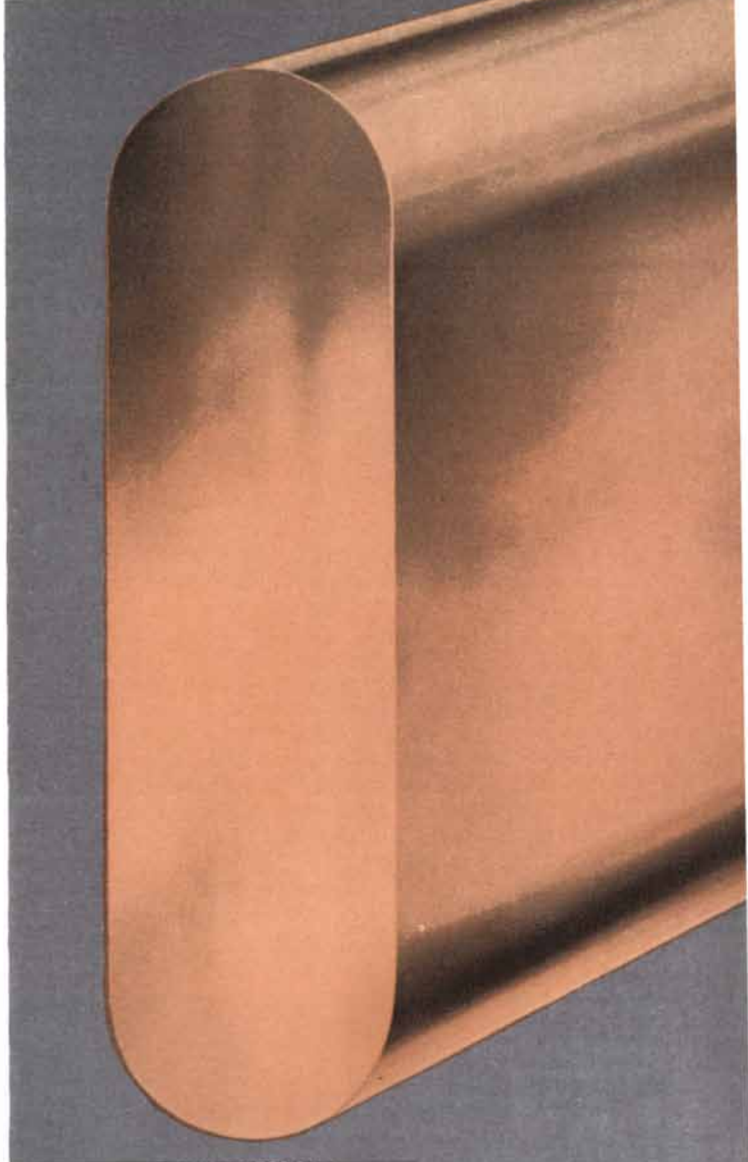

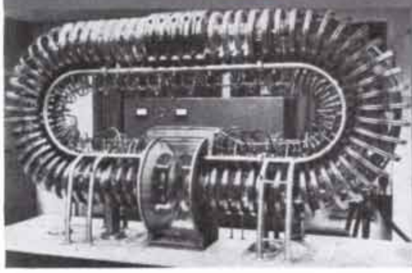

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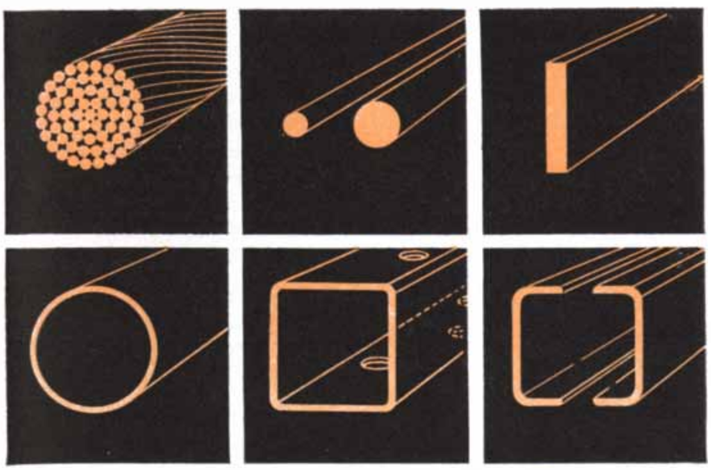

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200,000 KW AT 750 VOLTS is maximum peak rating of twelve d-c generators providing power for the confining field coils in C Stellarator being built in the new fusion research facility at Princeton University. This power is needed to establish the maximum 50,000-gauss magnetic field, forming the walls around the reaction aimed at reaching 100 million degrees. A.E.C. demonstration model above shows one form of the Stellarator tube that has been considered. The big copper bus (top), 9 square inches in section and silver plated, will carry the tremendous power from the generators to the coils around the Stellarator tube. The American Brass Company has furnished the mile of bus required for the job to specifications of the Allis-Chalmers Manufacturing Co., Milwaukee, Wisc., which is assisting in the design and building of the C Stellarator.

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THE P-E SPECTRUM

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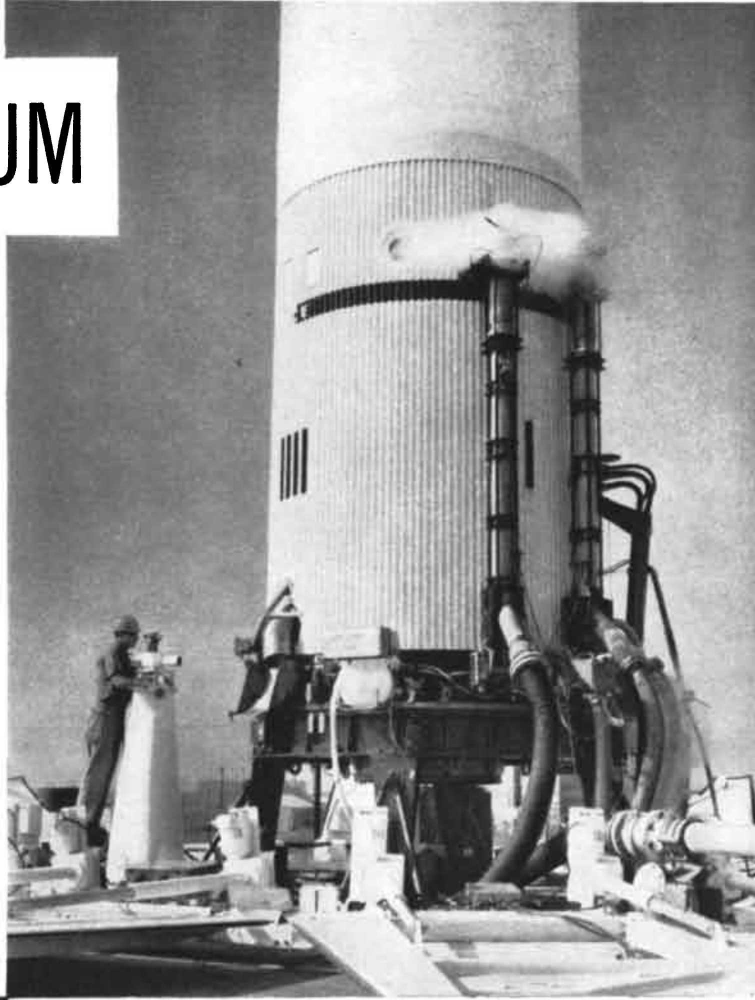

NEW FAMILY OF AUTO-THEODOLITES "SQUARES-UP" MISSILE GYRO CONTROLS BEFORE LAUNCHING

A new family of theodolites, sensitive to a fraction of a second of arc, or approximately the angle subtended by a dime a mile away, is helping to obtain the high order of accuracy demanded in long range missiles.

Shown in use here is a short range theodolite, one of two used to align Ford Instrument Company's inertial guidance system on the Army Jupiter.

These precise electronic-optical systems, developed by Perkin-Elmer, monitor the inertial guidance systems of missiles up to the moment of launch by continuous observation of the azimuth angle formed by the missile gyro platform, the theodolite and a known reference mark. Automatic correction signals, as required, are transmitted to the missile's gyro platform via a closed loop system between the theodolite and the missile. P-E theodolites provide working distances ranging from 0 to 1500 feet.

These theodolites are another example of Perkin-Elmer's ability to combine electronics and optics into high-accuracy systems.

LOW-COST INSTRUMENT ATTRACTS NEW USERS FOR INFRARED, SURVEY SHOWS

Since Perkin-Elmer introduced the first low-cost infrared spectrophotometer two years ago, infrared has become as basic a tool in the laboratory as the analytical balance. A recent survey of 150 representative purchasers of the P-E INFRACORD® spectrophotometer reveals that over half are first-time users of this powerful analytical technique.

A typical INFRACORD user, Endo Laboratories Inc., of Richmond Hill, New York, employs the instrument to check both pharmaceutical raw materials and final product. These quality-control tests take a fraction of the time previously required for conventional wet methods. For example, the conventional method of assaying Endo's Coumadin Sodium or Percodan, an analgesic preparation — complicated mixtures of narcotic alkaloids, sedatives and other drugs — in some cases took almost three days. With the INFRACORD, Endo chemists make a positive determination in 25 to 30 minutes. In raw material checks, the instrument provides a permanent record of its analyses for comparison with spectra of standard purity materials.

The INFRACORD is another example of P-E's more than fifteen years of infrared experience and development.

For information on Perkin-Elmer and the products it makes for a wide range of growing industrial, scientific and defense markets, write Perkin-Elmer Corporation, 915 Main Ave., Norwalk, Connecticut.

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FINE OPTICS • PRECISION ELECTRONIC COMPONENTS

Survey parties from USS Skate, surfaced in Polar ice, exploring the great ice pack. OFFICIAL U. S. NAVY PHOTO

UNDERWATER "TV EYE" USED BY ATOMIC SUB SKATE TO SURFACE WITHOUT DAMAGE IN POLAR ICE PACK

On its historic cruise to the Arctic, the atomic submarine Skate was able to find areas in which to surface though the average thickness of the ice was 12 feet. This epic event marked the first time a submarine was ever able to surface directly at the North Pole!

The answer: an underwater "TV eye"—a unique, closed-circuit television system developed by Bendix-Friez that enabled the Skate's crew to "see" the perpetually dark and treacherous underside of the craggy ice pack.

Consisting of a television camera mounted on the bow and viewing screen inside, this super-sensitive electronic device, which magnifies light many thousands of times and literally sees in the dark, helped locate "ice lakes"—spots where the ice was thinnest so the Skate could surface without damage. Even during the winter when sunlight is negligible, either above or below the surface, it presented a probing picture never before seen by man.

There are a host of products designed and built by Bendix at work beneath the sea . . . sonar devices to detect enemy submarines; telephones for submarines; depth recorders; "fish finders"; "brains" to guide torpedoes and undersea missiles plus new types of hydraulic equipment for steering and diving operations and for controlling a score of other all-important submarine functions including periscopes, radar antenna and snorkels.

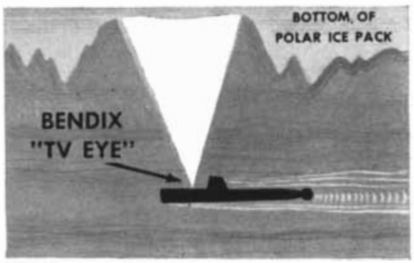
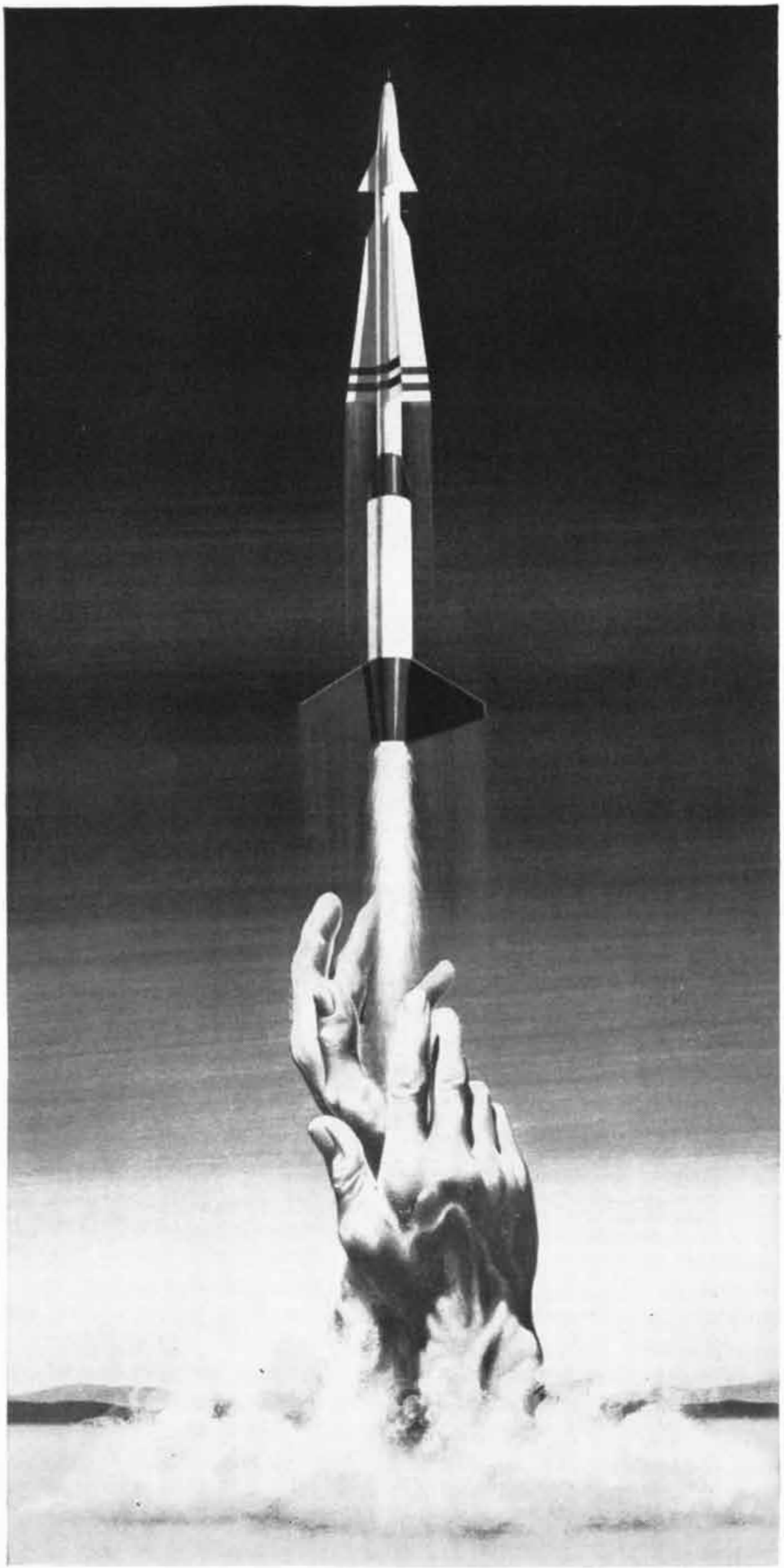


Diagram shows how Bendix electronic eye views underside of ice pack.

A thousand products **Bendix** AVIATION CORPORATION Fisher Bldg., Detroit 2, Mich. *a million ideas*



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Alpha Corporation was established to expand upon Collins Radio Company's extensive program of design, engineering and installation of complex communication and navigation systems. The entire systems division of the parent company, including its executives and space age specialists, is being consolidated with Alpha. Further, responsibility for the vast projects for government and industry in the Collins systems program is being assumed by Alpha . . . with its greatly augmented staff of designers, engineers, scientists and constructors. Alpha is geared to handle turnkey technical projects of all magnitudes . . . on this continent and in foreign fields. In addition to intricate electronic equipment, Alpha will design and construct related roads, towers and buildings. Alpha trains client personnel or staffs and operates finished installations. Alpha, using the best equipment from throughout industry . . . is the hallmark of world-wide systems management dependability.

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Alpha capabilities include technical systems management in all fields, with special emphasis on: • Space vehicle tracking and communication
Test range instrumentation and communications • Voice, teletype and data transmission • Aircraft modification and overhaul
Integrated shipborne, airborne, and ground communications • High capability remote control and switching

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

SEPTEMBER, 1909: "The search for the North Pole, which began in the Middle Ages, seems to have culminated in the success of Dr. Frederick A. Cook of Brooklyn, N. Y. Although no definite scientific proof is as yet available of Dr. Cook's claim, there can be but little doubt of his great triumph."

"Within a few days after the announcement of the discovery of the North Pole, it was followed by news that another American explorer had reached the same goal. After Commander Peary's expedition of 1906, when he reached 87 deg. 6 min. N. lat., then the 'farthest north,' he determined to make one more effort to reach the Pole. The *Roosevelt,* equipped by the Peary Arctic Club with all the material and scientific instruments which have been proved to be most essential in polar exploration by Commander Peary's 23 years of experience, left New York on July 6th, 1908. The ship proceeded *via* Etah in Greenland to Cape Sheridan in Grant Land and there the expedition passed the winter. The sledge expedition for the Pole left the *Roosevelt* in three divisions on February 15th, 21st and 22nd, the total of all divisions being seven whites and 59 Esquimaux, with 23 sledges drawn by 140 dogs. All the divisions assembled at Cape Columbia by February 27th. Open water delayed the entire party till March 11th, when the lead was sufficiently frozen over to be crossed. A few days later the ice parted exactly where the main party was encamped, nearly causing the loss of dogs and sledges, but after an exciting period dashing from one moving floe to another, better going was reached. After having crossed the 88th parallel Capt. Bartlett, the sturdy navigator of the *Roosevelt,* who has borne the brunt of the pioneering work, reluctantly turned back with the two Esquimaux of the last supporting party, the provisions carried being insufficient to last more than six men and 40 dogs for the week or more estimated to be required to reach the Pole and return. Peary then determined to try and reach

Edwin Felch, project director in charge of developing the Titan guidance system, holds the "voice" of the ICBM.

VOICE OF A GUIDED MISSILE

This is a missile-borne transmitter. It is the "voice" of a missile in flight . . . part of a new radio-inertial guidance system developed by Bell Telephone Laboratories for the Ballistic Missile Division of the Air Force.

This versatile system helped deliver the nose cone of a Thor-Able test missile precisely to its South Atlantic target area—5000 miles from Cape Canaveral, Florida. So accurately was the nose cone placed that a waiting group of ships and planes retrieved it in a matter of hours. It was the first nose cone ever to be recovered after so long a flight.

The command guidance system which made such accuracy possible combines precision tracking radar with a special Remington Rand Univac computer. Fed a steady stream of signals from the missile-borne transmitter, the ground-based equipment compares the missile's flight path with the preselected path. Corrective steering orders are computed and transmitted automatically to the missile. The ground station monitors the progress of the flight continuously and obtains immediate evaluation of mission success. And since the principal control equipment is kept on the ground, expendable hardware in the missile itself is minimized.

This radio-inertial guidance system is a product of the Bell Laboratories-Western Electric development-production team. It is in production at Western Electric for the first operational squadrons of the Titan intercontinental ballistic missile.

Bell Labs scientists and engineers developed the world's most versatile telephone network and much of our nation's radar. They have constantly pioneered in missile systems. From their storehouse of knowledge and experience comes this new achievement in missile guidance.

BELL TELEPHONE LABORATORIES

World center of communications research and development the Pole in five forced marches allowing less than a day for each. An observation at noon on April 6th showed that they were only a little over three miles from the Pole, so the remaining distance was apparently covered before a rest was taken. The first 30 hours at the Pole were spent in making observations and taking pictures. A sounding was made through a crack in the ice five miles from the Pole, 1,500 fathoms of wire finding no bottom. Speed was urgent on the return journey and Peary was singularly fortunate in escaping open leads in the ice, which had delayed the return of the supporting parties. By continued rapid traveling, Cape Columbia was reached on the 23rd of April. On July 18th the ice was sufficiently open for the *Roosevelt* to be removed from her berth. She fought her way south and reached Indian Harbor September 5th to send the now historic telegram: 'Stars and Stripes nailed to North Pole.' "

"The natural feeling of exultation following the announcement of the discovery of the North Pole was quickly dimmed by the criticisms and accusations which followed the first cable dispatches, which made it patent to all that the claim of one of the explorers was to be disputed by his rival. We have here no mere difference of opinion between two private individuals. One of the disputants, at least, by virtue of the fact of his bearing a high commission in his country's service, must necessarily speak and act as a distinguished representative of his native land. Whatever of disappointment or of fancied or actual wrong may have been felt by the sender of that accusing dispatch from Labrador, any consideration of the dignity of the Navy and of the nation should have sealed his lips."

"The first real aviation meeting held anywhere in the world took place last week near the city of Rheims, France. Altogether there were 38 aeroplanes entered in the various contests and races, for which $40,000 in cash prizes were offered. Glenn H. Curtiss won the Bennett International Aviation Trophy, averaging 47.04 miles an hour for the 20 km. (12.42 mi.) course. In addition Mr. Curtiss carried off the first prize ($2,000) in the 30-kilometer speed contest. The real race was between Curtiss and M. Louis Blériot, the champions of the biplane and the monoplane type of flying machine respectively. The other speed contest, for one circuit of the 10-kilometer course, was won by M. Blériot, who covered the distance at

47.78 miles an hour. A record for distance was made on August 26th by M. Hubert Latham with his No. 29 Antoinette monoplane. The flight, totaling 95.88 miles, was a complete vindication of the Antoinette motor which, it will be remembered, failed Latham twice when he attempted to cross the English Channel. The height competition was also won by Latham, who reached a height of 155 meters (508.5 feet), as recorded by a barometer upon his monoplane."

" 'A knowledge of the mass and size of the two units of electricity, the positive and the negative, would give us the material for constructing what may be called a molecular theory of electricity, and would be a starting point for a theory of the structure of matter; for the most natural view to take, as a provisional hypothesis, is that matter is just a collection of positive and negative units of electricity, and that the forces which hold atoms and molecules together, the properties which differentiate one kind of matter from another, all have their origin in the electrical forces exerted by positive and negative units of electricity, grouped together in different ways in the atoms of the different elements.' Sir J. J. Thomson."

SCIENTIFIC AMERICAN

SEPTEMBER, 1859: "A party of American engineers, under the charge of the Navy Department, are about to proceed to the Isthmus of Darien to search for a practical route for a ship canal across the Isthmus; they are instructed to explore the coast of the Caribbean Sea with a view to test statements that there is such a depression of the eastern Cordillera as to admit of the easy construction of a ship canal; the country west thereof to the Pacific Ocean being without any considerable elevation. Should the party not be able to find the gap referred to, they may proceed to the Pacific side of the continent, and seek a practical route for a canal along the line traversed by Surgeon Caldwell, U.S.N., in 1857. This gentleman, inspired by the reports of old residents in respect to the existence of a region nearly level stretching across the continent, proceeded with a small party from the excellent bay of San Miguel, several miles in a north-easterly direction, up the

Photo: Courtesy Electric Boat, Div. General Dynamics Corp.

U.S. Atomic Subs Depend On N/D Ball Bearings In Over 100 Vital Positions!

Some of the most unique and precise equipment ever engineered is in United States atomic subs . . . with New Departure bearings in many vital positions!

In the submarines' guidance system, New Departure gyro ball bearings help contribute to unerring undersea navigational accuracy. These bearings have been credited with reducing random drift rate to 0.25 degrees per hour.

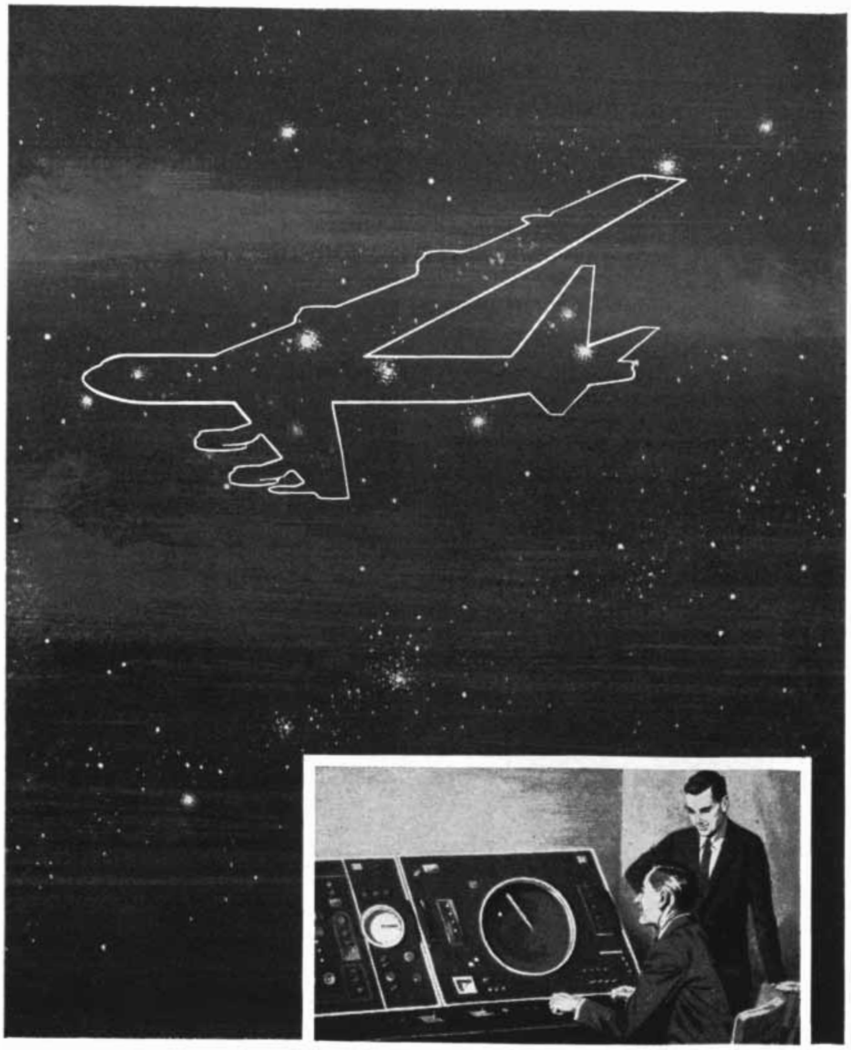
Many of the atomic power plants that have supplied record-breaking propulsion without refueling, are equipped with New Departure precision ball bearings in reactor control arms, water pumps, and other essential applications.

If you have a vital precision bearing problem, why not call on N/D, too? New Departure's advanced facilities for research, development and production, are your assurance of the ultimate in ball bearing design and precision manufacture.

NEW DEPARTURE

DIVISION OF GENERAL MOTORS, BRISTOL, CONN.

NOTHING ROLLS LIKE A BALL



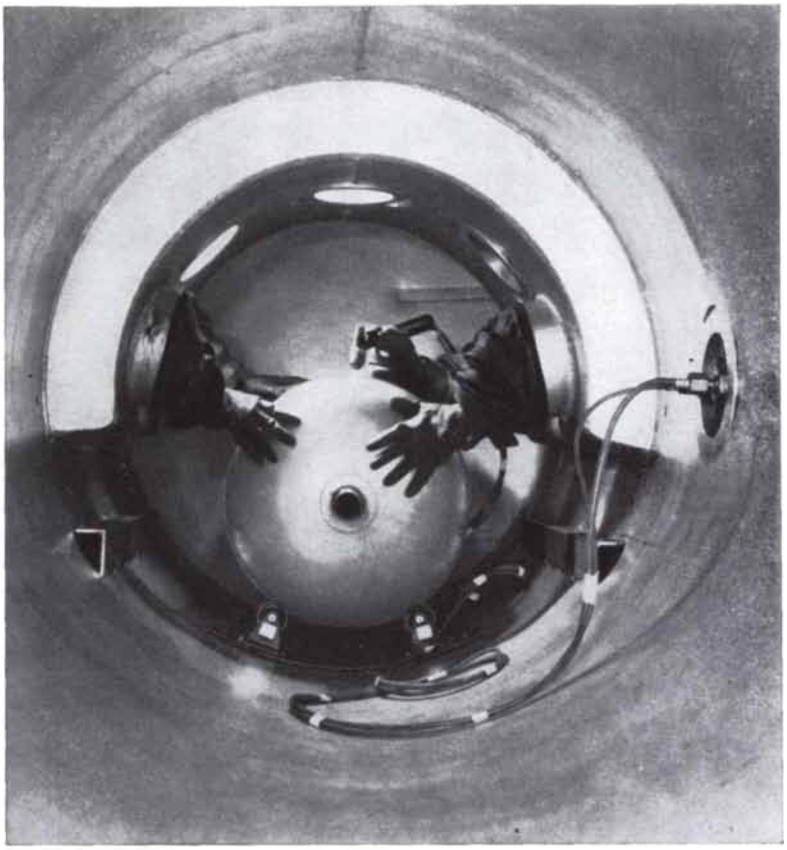
navigable river Savana, and thence east across the country to a point not far in a direct line from the Atlantic."

" 'Messrs. Editors:—I have just observed, in the Scientific American of the 3rd inst., an error in your notice of the "great trial of reaping and mowing machines which recently took place at one of the royal farms in France." You stated as follows:—"After a few turns in the field, the contest lay beween Burgess & Key's (Allen's Patent) and Wood's (stated to be Manny's Patent) reapers, in which the former took the lead, and was unanimously awarded the first prize; the latter the second." I herewith send you an extract from the Paris correspondence of *The New-York Tribune,* in regard to the trial referred to, the publication of which extract in your journal will correct the previous error, and be only an act of justice to myself. The Paris letter writer states "Three prizes were to be given to each class; a large gold medal, the 'prize of honor' to be given to the incontestably best machine among them all, and the first of the three prizes for foreigners, were handed over to Mr. McKenzie, who ran with the machine sent by the Burgess & Key from London, which is the original McCormick reaper." As may be inferred from the above extract, Burgess & Key, of London, are licensees and manufactures of my reaping and mowing machine.' C. H. McCormick."

"The great event of the past week has been the departure of the *Great Eastern* down the river Thames on her first trial trip to sea. Fears were entertained that when the fastenings were loosened she would not be very manageable, but it is stated that the very first turn in the river demonstrated that she was as completely under control as any river steamer. Thus far the *Great Eastern* has given evidence of being the fastest steamship in the world. This she ought to be, as, according to scientific deduction, ships increase in speed according to their size, if the model is good and the power proportional to the tonnage. On Sept. 8th she left the Nore and steamed off majestically for Portland (England), where she was to remain until Sept. 17th, on which day she will proceed to Holyhead, and from that port will commence her transatlantic voyage. It was anticipated that she would reach Portland, Maine, in from six to seven days after leaving Holyhead. Should this trip prove successful, the Cunard Company will at once undertake to build a vessel of equal size."

HAYNES ALLOYS

RESEARCH REPORTS



Developing new metals and improving current ones to combat the devastating effects of high heat, corrosion, erosion, and abrasion, are the primary objectives of the advanced Research and Development Laboratories at Haynes Stellite Company. HAYNES Tantalum, described below, is one of their more recent achievements. Others will be described in future Research Reports.

Design engineers, metallurgists, and physicists may see in these new metals and alloys opportunities for a breakthrough in applications where limited properties of other metals have presented obstacles. Our research scientists, engineers, and technicians will gladly help you discover whether they can help improve your products.

HAYNES Tantalum

Close to 100% pure, chemically. It is produced by the consumable-electrode process. Practically inert to a wide variety of corrosive media, with these added advantages: *Wide* sheets with improved welding characteristics, making it easier to use in chemical and pharmaceutical equipment where corrosion and product contamination must be minimum. Pictured is tantalum reactor liner being welded inside tank of inert gas.

LARGEST Tantalum Lined Reactor

An outstanding example of what can be accomplished with the greater sheet width and improved welding characteristics of HAYNES Tantalum is shown above. The vessel—the largest tantalum-lined reactor ever constructed—is a 30-gallon unit designed to operate at 630 deg. F. and 500 psi. Every part that will be exposed to corrosives, including the agitator, is made, or sheathed with, HAYNES Tantalum. For full details on this new material, write for descriptive booklet.

HAYNES ALLOYS

HAYNES STELLITE COMPANY

Division of Union Carbide Corporation

Kokomo, Indiana

UNION CARBIDE

Address inquiries to Haynes Stellite Company, 420 Lexington Ave., New York 17, N. Y.

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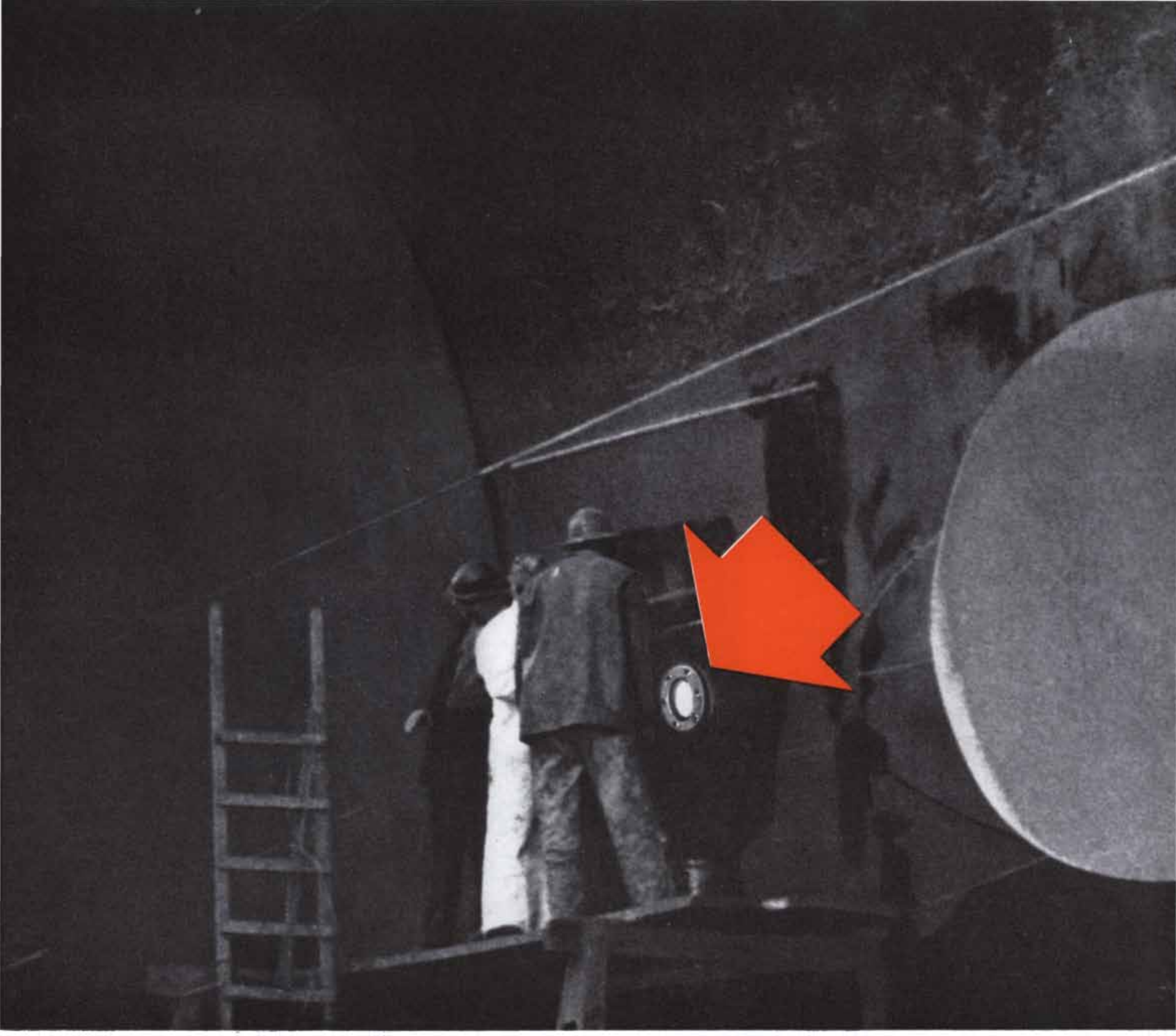


PROTECTION OF SHIP'S HULL AND PROPELLER AGAINST CORROSION...

Where any metal but Platinum

PLATINUM DOES IT FOR LESS. Experience proves that platinum anodes used in the impressed current system of the type shown provide sure protection of ship hulls and propellers against corrosion... and do so economically. Equipment (called CAPAC* and designed by Engelhard Industries, Inc., Instrument Division) is being used on commercial vessels and pleasure craft as well as on atomic submarines and other Navy ships.

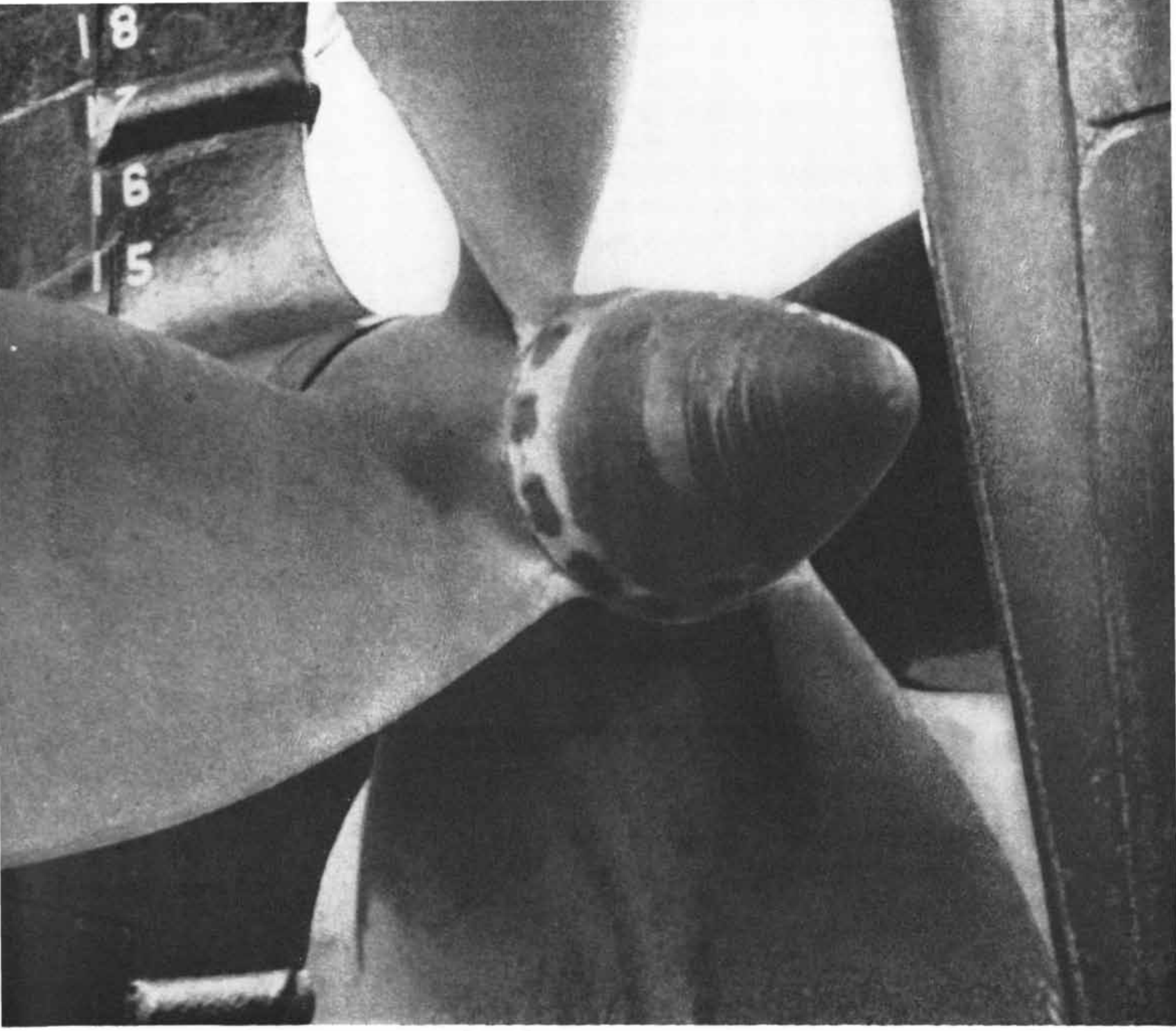
Who would think that the platinum metals provide a practical way to protect steel against attack by sea water?

But that's how underwater corrosion is being defeated today. In an automatic system, CAPAC*, devised by Engelhard Industries, Inc., Instrument Division, comparatively small anodes feed a corrosion-stopping protective electrical current to the hull and propeller.

Long life... obtainable only with platinum surfaced anodes.. .brings the real cost of this underwater protection system so low that it has become standard equipment on week-end sailors' steel-hulled pleasure boats.

A platinum metal may economically solve your problem

Where underwater hull protection is a problem... where a combination of severe corrosion and erosion must be met, as in the case of spinnerettes for rayon production... where wear-resisting, non-tarnishing surfaces are required, such as for printed electrical circuits... where product purity must be retained despite high temperatures, as in the case of lens glasses . . . or



would cost too much...

where peak catalytic efficiency is required. as in the refining of high octane gasoline... the platinum metals have proved to be the most economical for certain critical equipment.

Industry is going to higher temperatures and higher pressures. Perhaps your own progress has been blocked by the limitations of materials to withstand such severe conditions. The platinum metals have removed many barriers. Have you considered them for your problem?

Platinum, palladium, rhodium, ruthenium and iridium have unique potentials, well worth your attention. Specialists are prepared to work closely with you in evaluating these metals for new commercial and scientific uses.

As a first step, write us for additional data on the outstanding characteristics and successful applications of the six platinum metals and their alloys—indicating your field of interest or how we might be of assistance.

*Registered trademark of Engelhard Industries, Inc.

CAN THESE PROPERTIES OF THE PLATINUM METALS HELP YOU?

Exceptional Chemical Inertness
Superior Wear Resistance
High Temperature Stability
Peak Catalytic Activity
Low Vapor Pressure

The six platinum metals are:

PLATINUM • PALLADIUM • RHODIUM
RUTHENIUM • IRIDIUM • OSMIUM

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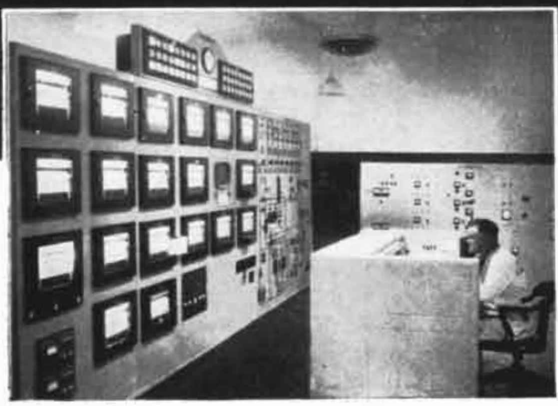
RADIATION EFFECTS REACTOR (RER)

Now in Operation

A part of the Georgia Nuclear Laboratories located near Dawsonville, Georgia, the RER is an Air Force owned facility (AFP #67). RER is operated by Lockheed Nuclear Products as a part of its diverse activities in the design and development of nuclear power applications.



LOCKHEED NUCLEAR PRODUCTS

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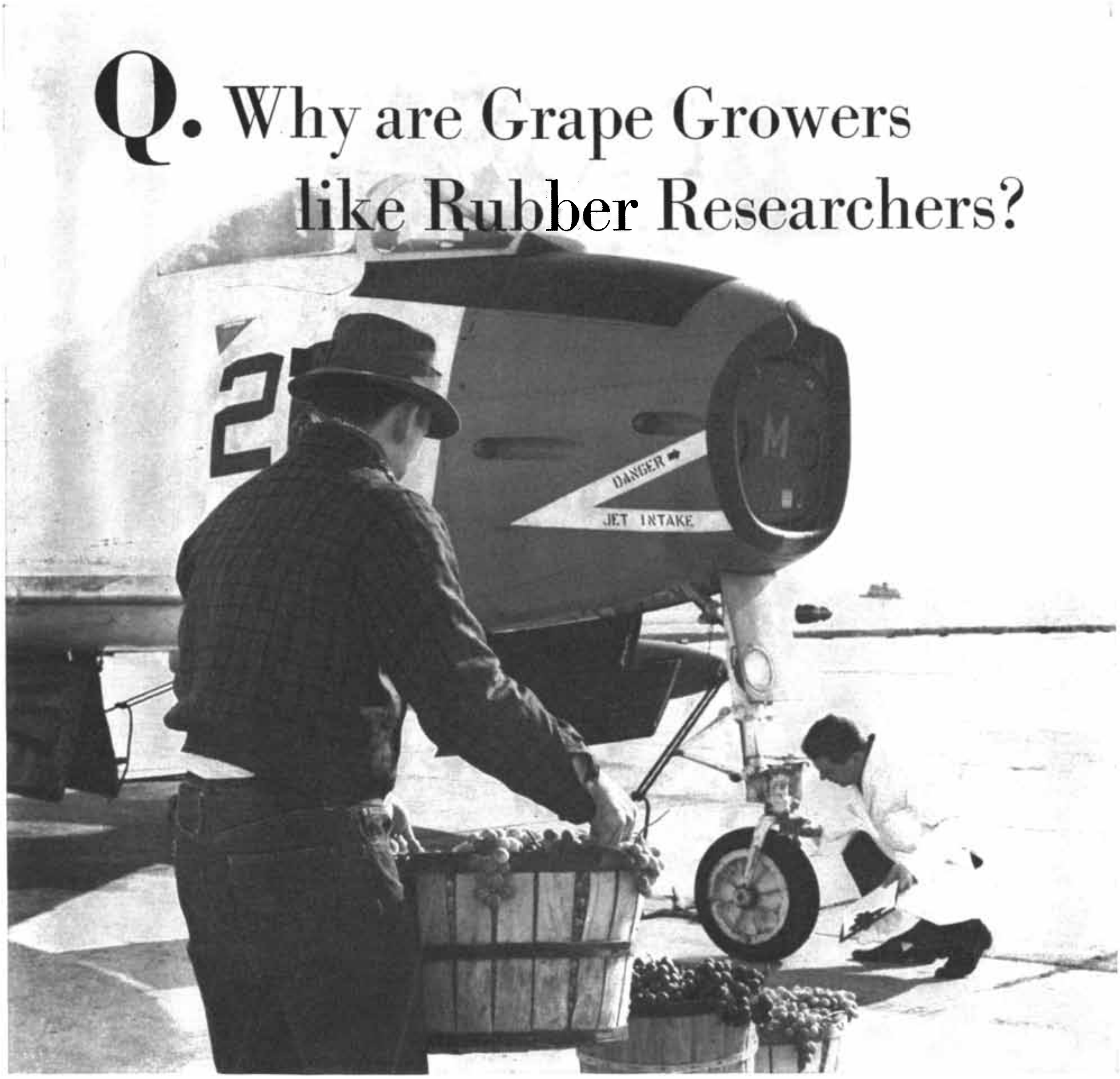
LOCKHEED AIRCRAFT CORPORATION

Georgia Division

Q. Why are Grape Growers like Rubber Researchers?



A. ***Exciting advances in both fields are directly related to chemical progress pioneered by Merck.*** Thanks to GIBREL® — Merck's new plant growth stimulant — grape growers are able to increase berry size and crop yield by as much as 50%. Farmers everywhere are vitally interested in more efficient crop production with GIBREL. Its "vitamin-like" action triggers normal growth in many plants by supplementing the growth-promoting substances naturally found in plants.

Another Merck chemical, MAGLITE® Y, meets the special processing requirements of the rubber industry's most important new synthetic—a heat-resistant elastomer with promising applications in jet aircraft tires and other rubber products that must perform under extremely high temperatures. A reactive magnesium oxide, MAGLITE is also available in D, K and M grades that are particularly well suited for various product or processing needs of many different elastomers.

MAGLITE and GIBREL are representative of Merck research and production that speed progress in nearly every field served by chemistry. For technical information bulletins on either product write to Department SA-4.

MERCK & CO., INC. · Chemical Division · **Rahway, New Jersey**

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SETTING THE PACE

Entering an entirely new field of science involves many firsts . . . but unquestionably, one stands out: THE FUNDAMENTAL DECISION . . . in this case—to convert enriched UF_6 to uranium metal and compounds for use in nuclear reactors. Mallinckrodt made this decision and acted on it . . . before any sizable commercial market was evident. As a result, Mallinckrodt was FIRST . . .

. . . to develop processes meeting requirements for safety and criticality.

. . . to receive a license from the A. E. C. to convert uranium hexafluoride.

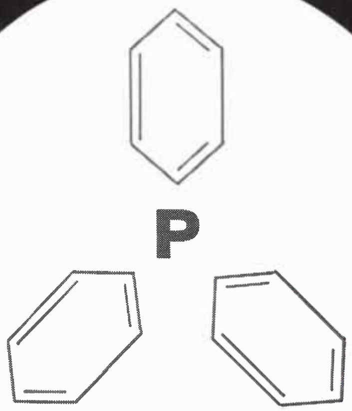
. . . to receive a permit from the Bureau of Explosives covering the design of shipping containers acceptable to the Bureau and the I. C. C.

. . . to manufacture and ship uranium metal and compounds both domestically and in export.

. . . to develop processes for materials with special physical characteristics such as UO_2 Shot (spherical) and UO_2 Special Dense (for swaging).

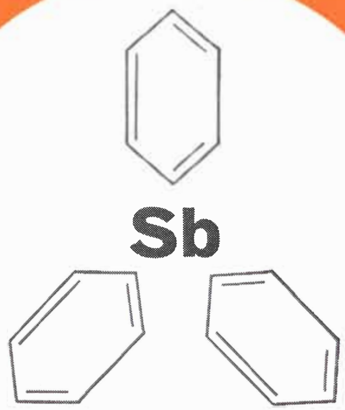
. . . AND NOW—Mallinckrodt has erected the most modern and automated facility for producing ceramic shapes of UO_2.

2 new M&T Organometallics



TRIPHENYLPHOSPHORUS

- Forms phosphonium salts
- Forms oxides and sulfides
- May be halogenated to triphenylphosphine dihalides
- Wittig reaction intermediate to convert an aldehyde or ketone to an olefin.
- Is a white crystalline solid
- Available in 10, 50 and 150 lb. fiber drums



TRIPHENYLANTIMONY

- May be halogenated to triphenylantimony dihalides
- Forms Stibonium salts
- Co-catalyst in converting trienes to aromatics and hydroaromatics
- Reacts with nitric-sulfuric acids to give trinitro derivatives
- Is a white crystalline solid
- Available in 10, 50 and 200 lb. fiber drums

Triphenylantimony and triphenylphosphorus are two more results of M&T's long standing leadership in the development of organometallics. Requests (on letterhead, please) from development men for literature and samples will be welcomed. Ask, also, for a complete list of M&T organometallics.

M&T's "ORGANOMETALLICS UNLIMITED"

$$R_n M^* X_m$$

R = alkyl or aryl groups
M* = Sn, Sb, P, Si or Bi
X = electronegative groups

This general formula has been the basis for hundreds of organometallics prepared by M&T. Let us check our files on any compound of specific interest in your development work.

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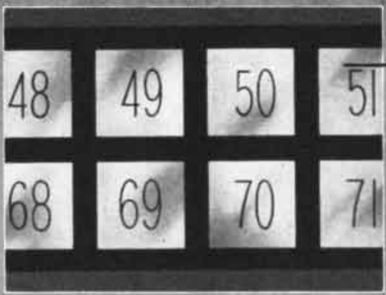
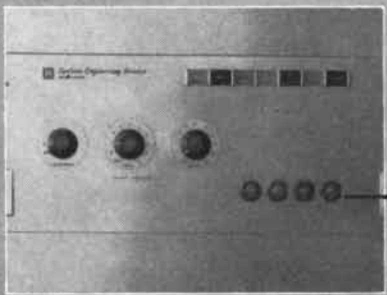
Sn Sb P organometallics
Si Ti Zr and inorganics

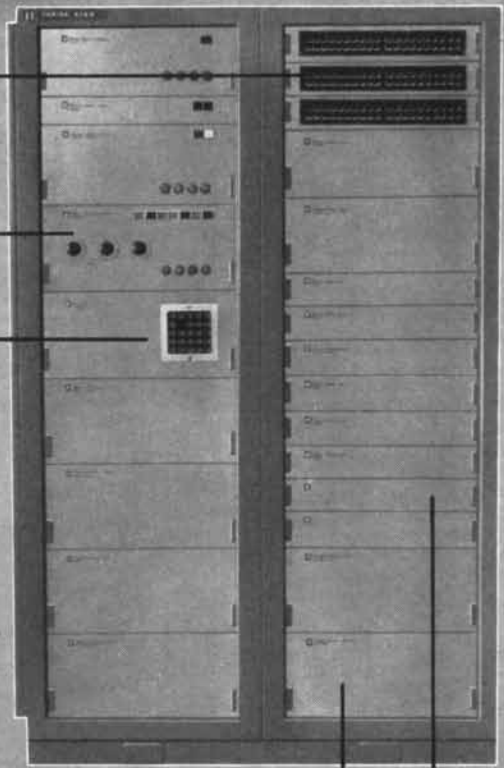
New packaged

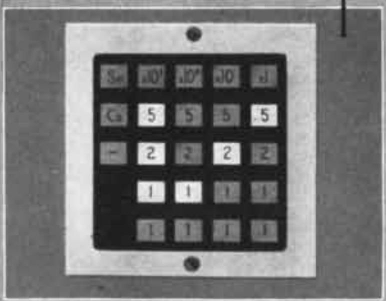


THREE 40-POINT ANNUNCIATORS make it easy for the operator to tell at a glance which variables are off-normal.

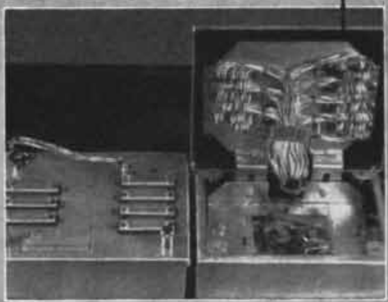


DIGITAL VISUAL DISPLAY and variable selector switches make it easy to select any single variable and watch all trends and changes continuously.





SERVICING IS SIMPLIFIED by an indicator-light panel showing the completion of each step in the analog to digital conversion. The sequence programmer can be changed from automatic to hand advance to permit operator to check each step.



UNIQUE INPUT SELECTOR is unusually dependable because of its sealed, oil-immersed construction. Servicing is normally limited to visual inspection every 6 months. Drawers pull out so voltage checks can be performed without shutting down system.

PINBOARD PROGRAMMING adds flexibility. You can change the logging or scanning sequence at will . . . substitute one type of input for another. Range, span, and zero adjustment are set by inserting pins in their proper places. No calculations are required. The pinboards are pinned in familiar units of measurements.

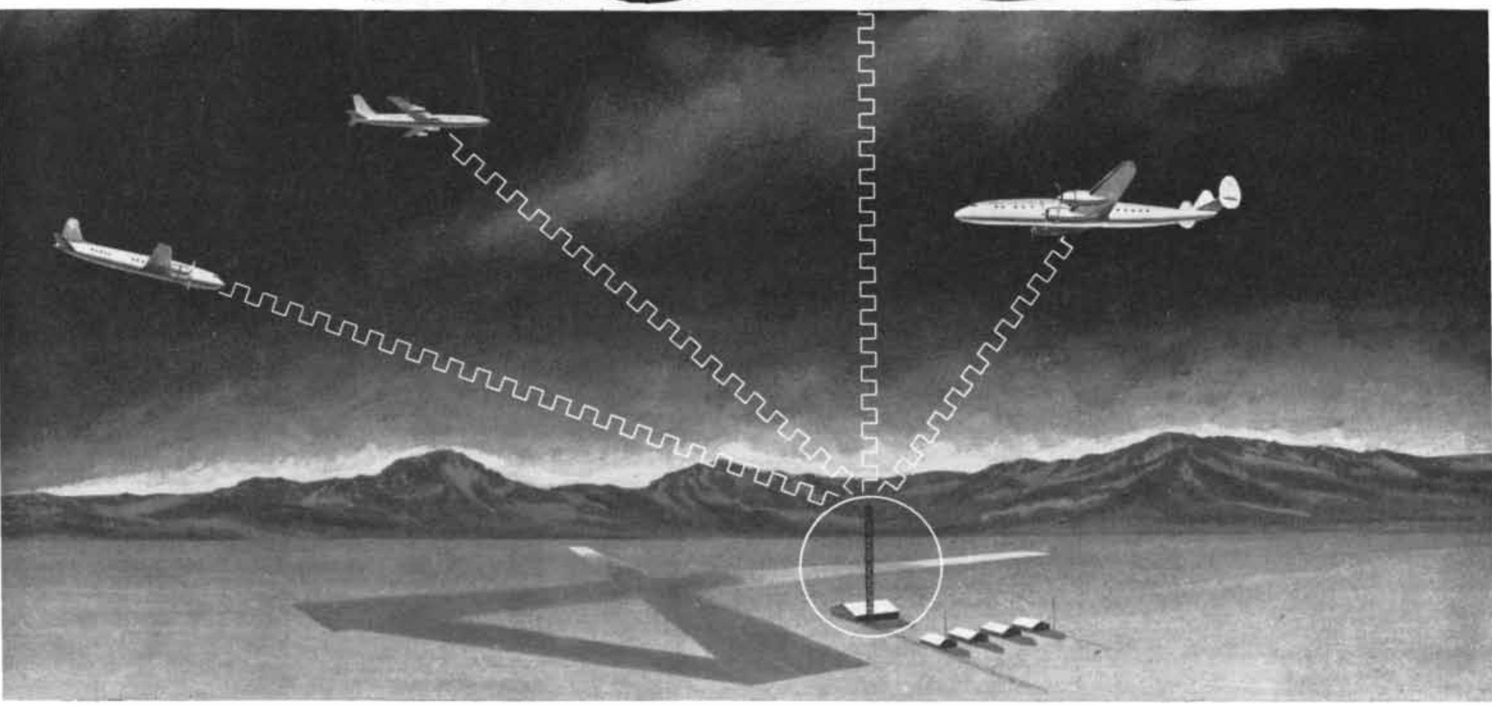
THE AUTHORS

ROBERT L. PLATZMAN ("What Is Ionizing Radiation?") recently became senior physicist at the Argonne National Laboratory, where he is forming a group of workers to study fundamental problems of the action of ionizing radiation. He is also chairman of the newly organized Subcommittee on Effects of Ionizing Radiations of the Committee on Nuclear Science, National Research Council. A native of Minneapolis, he received his Ph.D. in 1942 at the University of Chicago. He worked on the atomic-bomb project and after the war received two Guggenheim fellowships to study with Niels Bohr in Copenhagen. He was a professor of physics at Purdue University for 10 years. Platzman will spend the coming academic year as a Fulbright professor at the University of Paris.

JAMES R. ARNOLD and E. A. MARTELL ("The Circulation of Radioactive Isotopes") are radiochemists with, respectively, the University of California School of Science and Engineering at La Jolla, and the Air Force Cambridge Research Center. Arnold was born in 1923 in Metuchen, N. J., and earned his Ph.D. degree at Princeton in 1946, having been associated with the atomic-bomb project for two years. He then held fellowships at the Institute for Nuclear Studies of the University of Chicago and in the laboratory of George B. Kistiakowsky at Harvard University. In 1948 he returned to Chicago to work with Willard F. Libby on radiocarbon dating, and in 1949 he became an assistant professor at the Institute for Nuclear Studies. In 1955 he joined the chemistry faculty at Princeton University. His current post is associate professor of chemistry at La Jolla, where he is doing research on radioactive isotopes produced by cosmic rays, especially isotopes found in meteorites. Martell took a degree in civil engineering in 1942 from the United States Military Academy. He earned his M.S. degree in physical chemistry at the University of Chicago, and took a Ph.D. there in 1950 in radiochemistry. He also worked under Libby. From 1950 to 1954 he was with the Armed Forces Special Weapons Project, planning and directing experiments in nuclear radiation and in the fallout effects of atomic weapons. He directed experimental programs for several atomic- and hydrogen-bomb tests. Later he was the principal investigator at the *new wings for words*

AGACS

pronounced "AJAX"



AGACS, Experimental Automatic Ground/Air/Ground Communication System is a new concept in Air Traffic Control Communications to meet the accelerated pace of increased air traffic. Primary objectives are efficient usage of frequency spectrum, added safety through increased reliability and reduced burden to pilot and controller, and adaptability to all classes of aircraft. AGACS provides compatibility with existing ground and airborne communication equipment, selective addressing of information, and a minimum number of frequency changes during flight. The system utilizes two-way time division data transfer over existing ground and air communication links to provide an automatic, mutual exchange of information. The airborne facilities display to the pilot the last significant Air/Ground and Ground/Air message quantities, while the controller may recall from central memory-storage equipment the last Air/Ground and Ground/Air message quantities for display. The AGACS program is still in the developmental stage. In August, 1959, RCA provided initial models of both airborne and ground equipments for the Bureau of Research and Development of the Federal Aviation Agency for extensive experimentation and flight tests.

RCA

Tmk(s) ®

RADIO CORPORATION of AMERICA

DEFENSE ELECTRONIC PRODUCTS

CAMDEN, N. J.

Chicago "Sunshine" project, studying the world-wide distribution of strontium 90. He is now chief of the nuclear studies branch at the Air Force Cambridge Research Center, directing research on the geophysical aspects of world-wide fall-out and on the natural radioactivity of the atmosphere.

ALEXANDER HOLLAENDER and GEORGE E. STAPLETON ("Ionizing Radiation and the Living Cell") are, respectively, the director of and a biologist in the Biology Division of the Oak Ridge National Laboratory. Hollaender, a native of Germany, took his degrees at the University of Wisconsin, receiving a Ph.D. there in 1931 and remaining as a National Research Council fellow. He was an investigator for the Rockefeller Foundation in 1934, and then served for three years as investigator in charge of radiation work for a National Research Council project at Wisconsin. He joined the National Institutes of Health, working in biophysics, in 1937, and rose to the rank of head biophysicist, serving in that post from 1946 to 1950. He also became director of the Oak Ridge Biology Division in 1946. Other posts include the presidency of the Comité International de Photobiologie and chairmanship of the World Health Organization committee to study the effects of radiation on human genetics. Stapleton was born in Chicago in 1919 and attended school in Denver. He took his bachelor's degree at Regis College in Denver, and his master's degree (in 1943) at Saint Louis University. He then joined the atomic-bomb project and was sent to Oak Ridge, where he helped initiate a research program on the biological effects of nuclear radiations. He received his Ph.D. from the University of Tennessee in 1952. His chief research work is concerned with "the basic mechanisms involved in the lethal and mutagenic action of ionizing radiations."

JOHN F. LOUTIT ("Ionizing Radiation and the Whole Animal") has since 1947 been director of the British Medical Research Council Radiobiological Research Unit. He was born in Australia and educated at the University of Western Australia and the University of Melbourne. He was a Rhodes Scholar, and has received several degrees from the University of Oxford, including that of doctor of medicine. He also studied at the University of London. Loutit served as director of the Radiobiological Research Unit of the Atomic Energy Research Establishment at Harwell from 1947 to 1958. He was made a Fellow of the

SILICONE NEWS from Dow Corning

Cast Fine Detail Quickly

STRIP IT

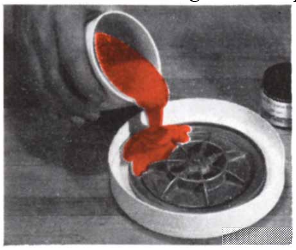
MOLTEN METAL

SILASTIC RTV
SILICONE RUBBER

flows in and around complex shapes; sets up in minutes

The incredibly life-like hand above was cast of rubber. It was made from a mold of the same material: Silastic RTV, the Dow Corning fluid silicone rubber that vulcanizes at room temperature.

The striking detail reproduced here — detail that would stir the heart of a Madame Tussaud — can be duplicated by you in your own plant. With ease. Simply pour liquid Silastic RTV into or around any object you wish reproduced. Wait a short time while the fluid sets up to form rubber. No heat-vulcanizing is needed. Now strip the rubber away and you have a mold for making exact reproductions. Into this you can pour a variety of casting materials including many plastics, molten metals . . . even more Silastic RTV.



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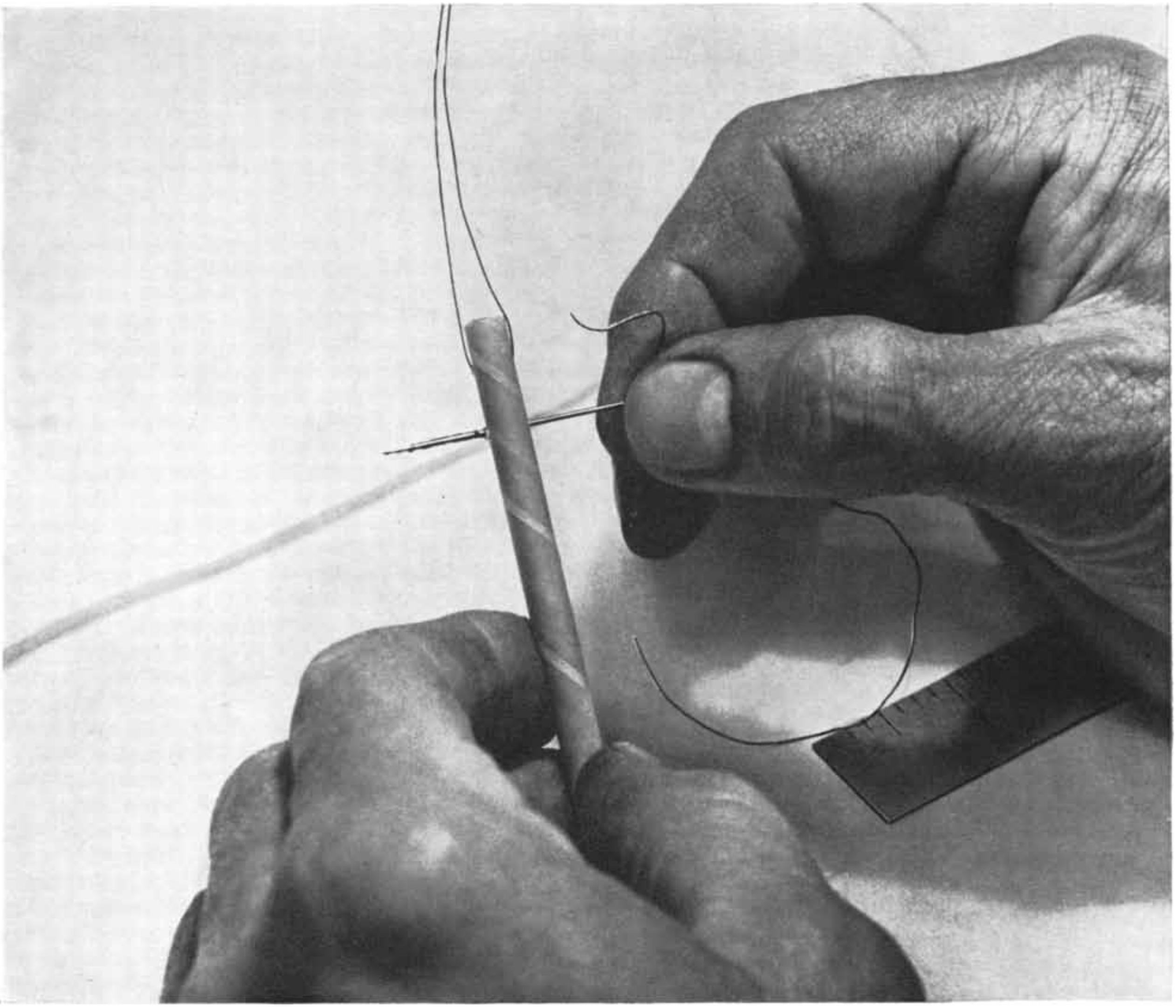
Royal College of Physicians in 1955, and a Commander of the Order of the British Empire in 1957.

JAMES F. CROW ("Ionizing Radiation and Evolution") is professor of genetics and chairman of the Department of Medical Genetics at the University of Wisconsin. He grew up in Kansas and attended Friends University at Wichita. "I started out to major in music, but discovered I wasn't talented enough, and shifted successively to physics, then to chemistry and finally to biology. I took a course in genetics . . . and decided that this was the most interesting of the biology courses and something that I would like to pursue." He took his Ph.D. in genetics at the University of Texas in 1941, and taught at Dartmouth College until he joined the Wisconsin faculty in 1948.

SHIELDS WARREN ("Ionizing Radiation and Medicine") is professor of pathology at the Harvard Medical School and scientific director of the Cancer Research Institute at the New England Deaconess Hospital. He is a graduate of Boston University, and took his M.D. degree at Harvard in 1923. He has been studying the effects of ionizing radiation for many years, and in 1945 was chief of the Navy's Medical Field Team in the Technical Commission to Japan. He served in 1946 as executive officer of the Naval Medical Research Section of the Bikini bomb test, and in 1947 as senior medical officer of the Atomic Casualty Investigation in Japan. He has helped direct and advise the Atomic Energy Commission Division of Biology and Medicine since 1947. In 1955 he became U. S. representative on the United Nations Scientific Committee on the Effects of Atomic Radiation. Since 1955 Warren has been chairman of the National Academy of Sciences Committee on Pathologic Effects of Atomic Radiation, and a member of the Committee on Genetic Effects of Atomic Radiation. He has also been chairman of the National Research Council Committee on Atomic Casualties.

A. CHARLESBY ("Ionizing Radiation and Organic Chemistry") is professor of physics at the Royal Military College of Science in England. He was born in London in 1915 and was educated there and on the Continent. He studied physics under Sir George Thomson at the Imperial College of Science and Technology, and subsequently taught and did research on electron diffraction and the structure of organic materials, particu-



How to Test a Solid Rocket Motor

In the early stages of research for new or improved propellants incongruous combinations of materials are often brought together in the chemistry laboratory—in this case, a common drinking straw, a strand of copper wire, a small batch of propellant and a sewing needle. The work shown here is a step in an experiment to test burning characteristics of a new high-energy propellant formula. The propellant, having been extruded into the straw, is threaded with a strand of copper wire. Later the "motor" is hooked into a specially designed apparatus that ignites the propellant and records and evaluates its performance.

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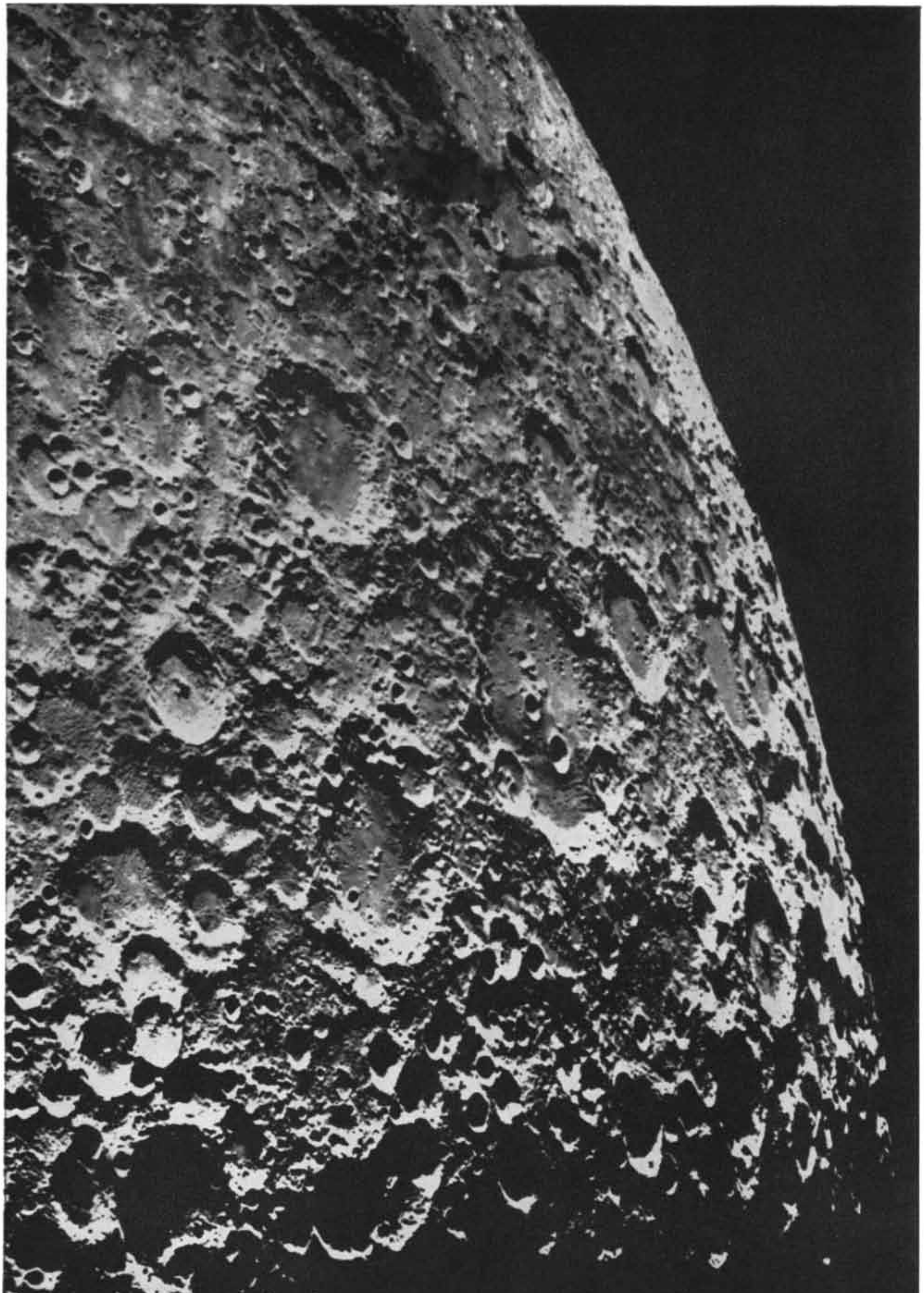

larly plastics. Charlesby was in charge of a group at Harwell studying radiation effects in materials, and in 1955 he joined the newly established research laboratory near Cambridge and set up the first industrial radiation research group in Great Britain.

DOUGLAS S. BILLINGTON ("Ionizing Radiation and Metals") has for a decade been director of the Solid State Division of the Oak Ridge National Laboratory. A native of Spearfish, S.D., he took his Ph.D. in chemistry at the University of Iowa in 1942. He was one of the small group of students interested in the solid state in the 1930's, and held several jobs in industrial laboratories, since most universities were not then active in this field. He was a metallurgist at the Naval Research Laboratory in Washington from 1946 to 1949, and also worked at Oak Ridge in that period.

GEORGE W. BEADLE ("Ionizing Radiation and the Citizen"), Nobel laureate for his work in biochemical genetics, is head of the division of biology at the California Institute of Technology. For the past year he has been Eastman Visiting Professor at the University of Oxford. He was born in 1903 in Wahoo, Neb., the son of a farmer. Beadle would probably have become a farmer himself but for the influence of a high-school science teacher, Mrs. J. C. Higgins, now of Jackson, Neb., who so fired his imagination that he determined to become a scientist. The late Professor Frank D. Keim at the University of Nebraska introduced him to genetics. After some time at Cal Tech, he went to Paris to work with Boris Ephrussi at the Institut de Biologie Physico-chimique. He returned for a year at Harvard University, and in 1937 went to Stanford University as a professor. There he worked with the chemist Edward L. Tatum. They decided to use the red bread-mold *Neurospora crassa* in genetic experiments, and it was for their work with this organism that they shared half the 1958 Nobel prize in medicine. In 1946 he succeeded Thomas Hunt Morgan, also a Nobel laureate, as head of the Cal Tech biology division.

ROBERT W. WHITE, who in this issue reviews *Psychoanalysis, Scientific Method and Philosophy*, edited by Sidney Hook, and Philip Rieff's *Freud: The Mind of the Moralist*, is professor of clinical psychology and chairman of the Department of Social Relations at Harvard University.

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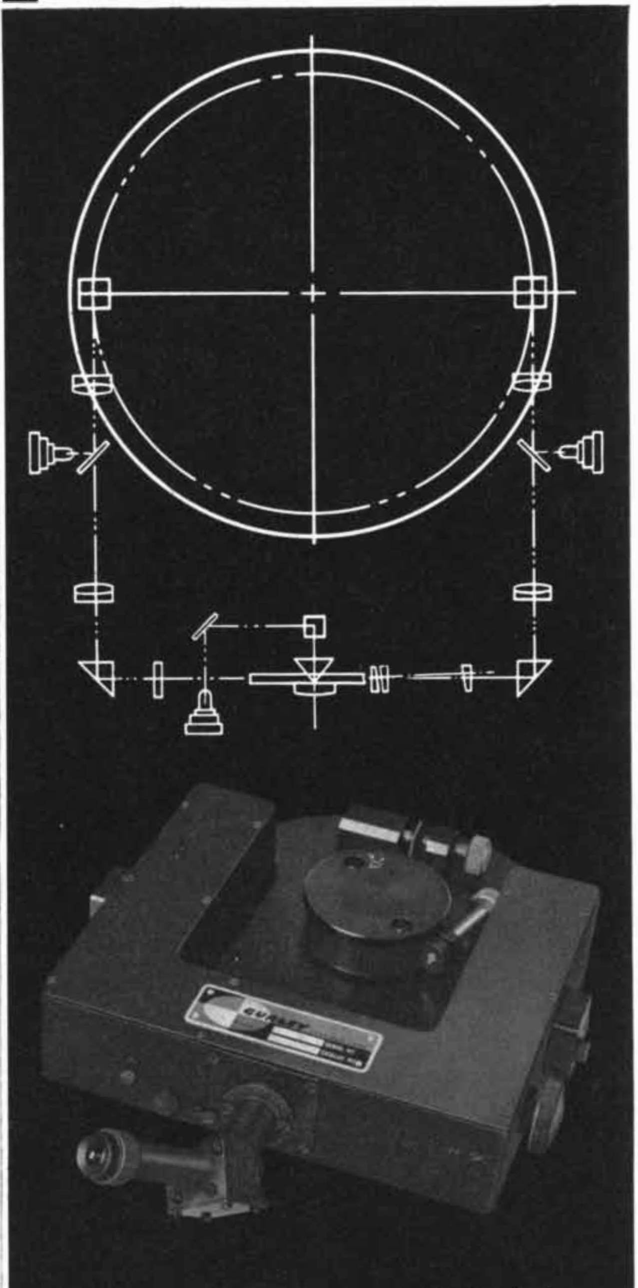

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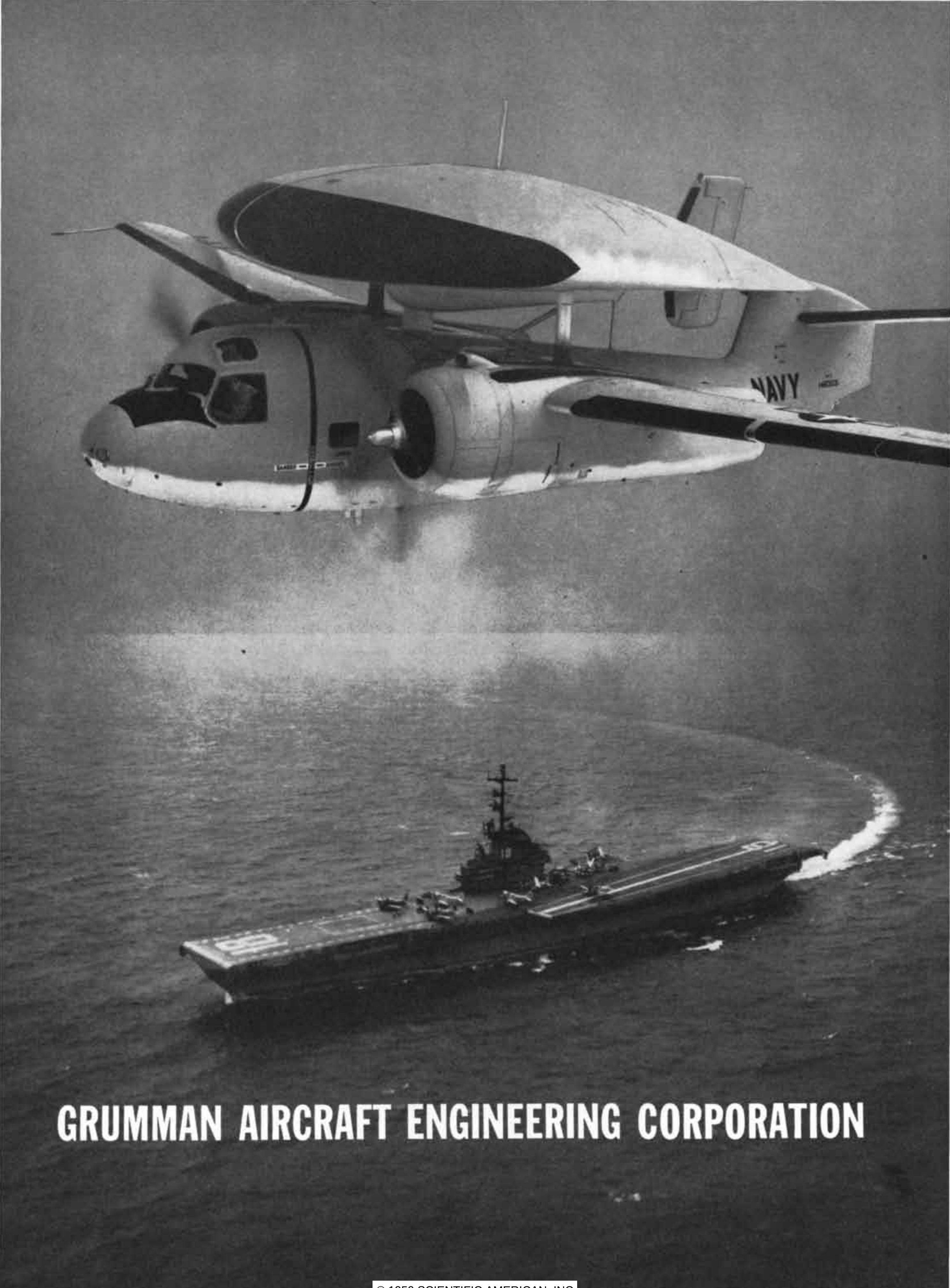
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Electronics Engineers, for career opportunities at Grumman Aircraft, see page 282.

Low-flying "enemy" aircraft or missiles are undetected by ground radar because, as the diagram shows, the range of ground-level radar extends no further than the horizon.

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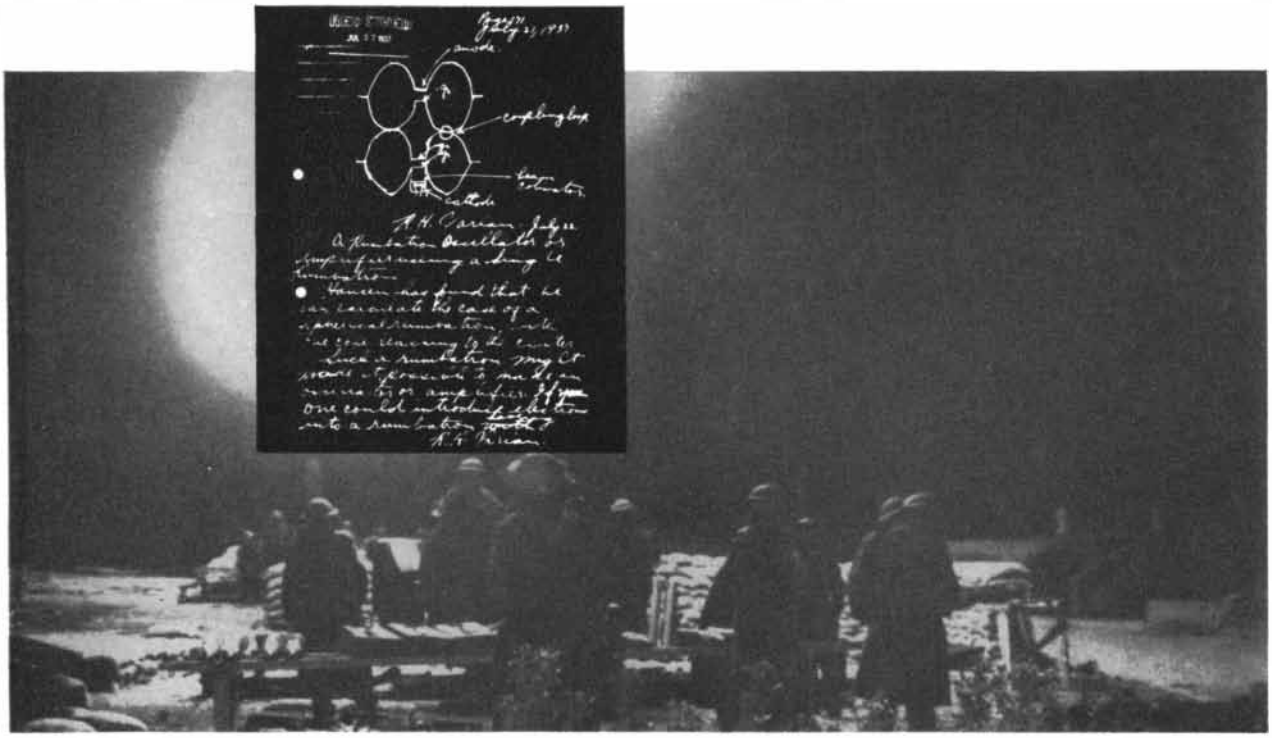
THE SKETCH THAT HELPED WIN A WAR



This sketch, drawn in 1937 by Dr. Russell Varian, Founder and Board Chairman of Varian Associates, led to the development of the klystron — and mobile radar. Dr. Varian's achievement played a vital role in the successful air defense of Great Britain and the ultimate air superiority of the Allies during World War II.

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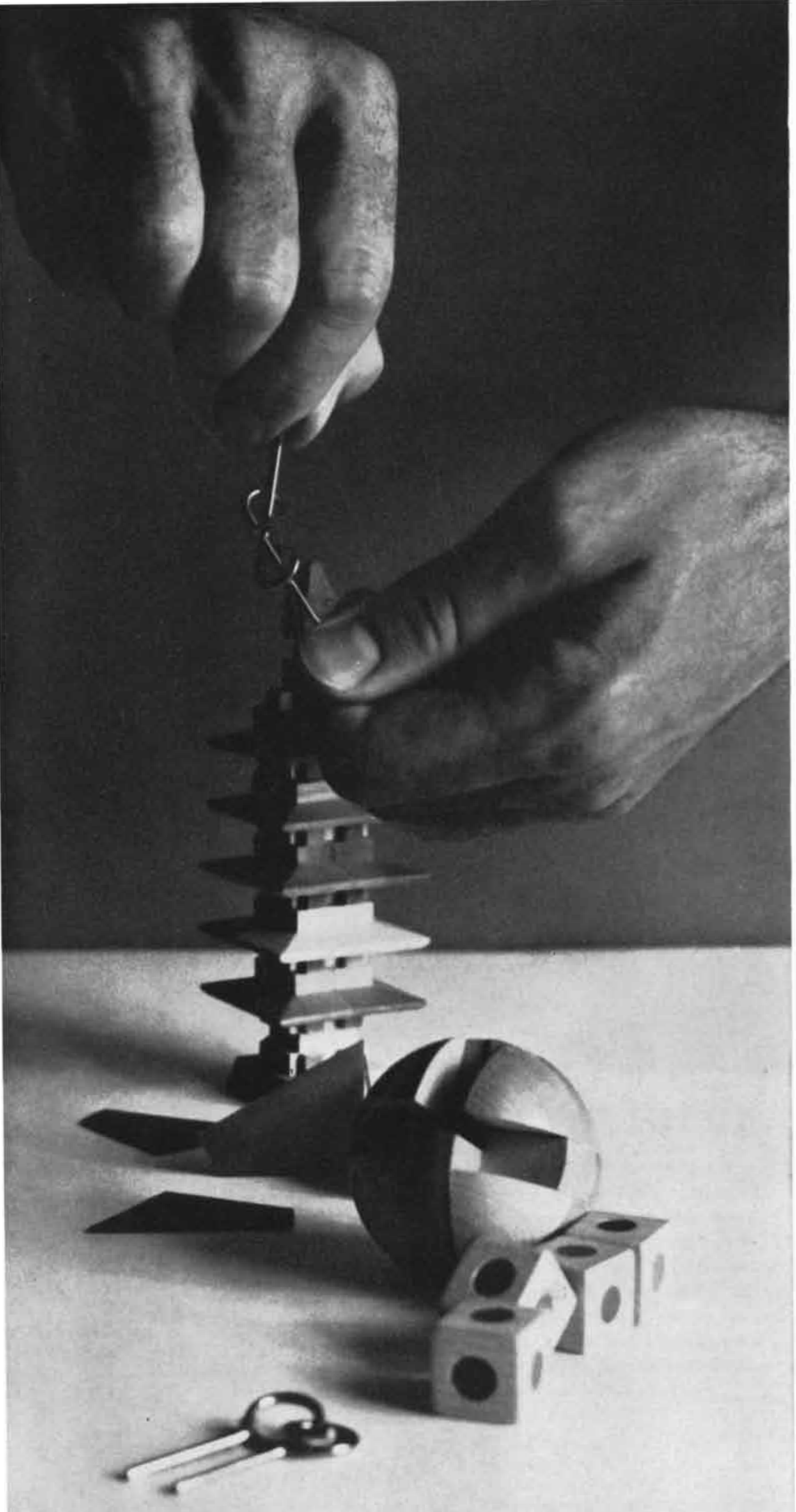

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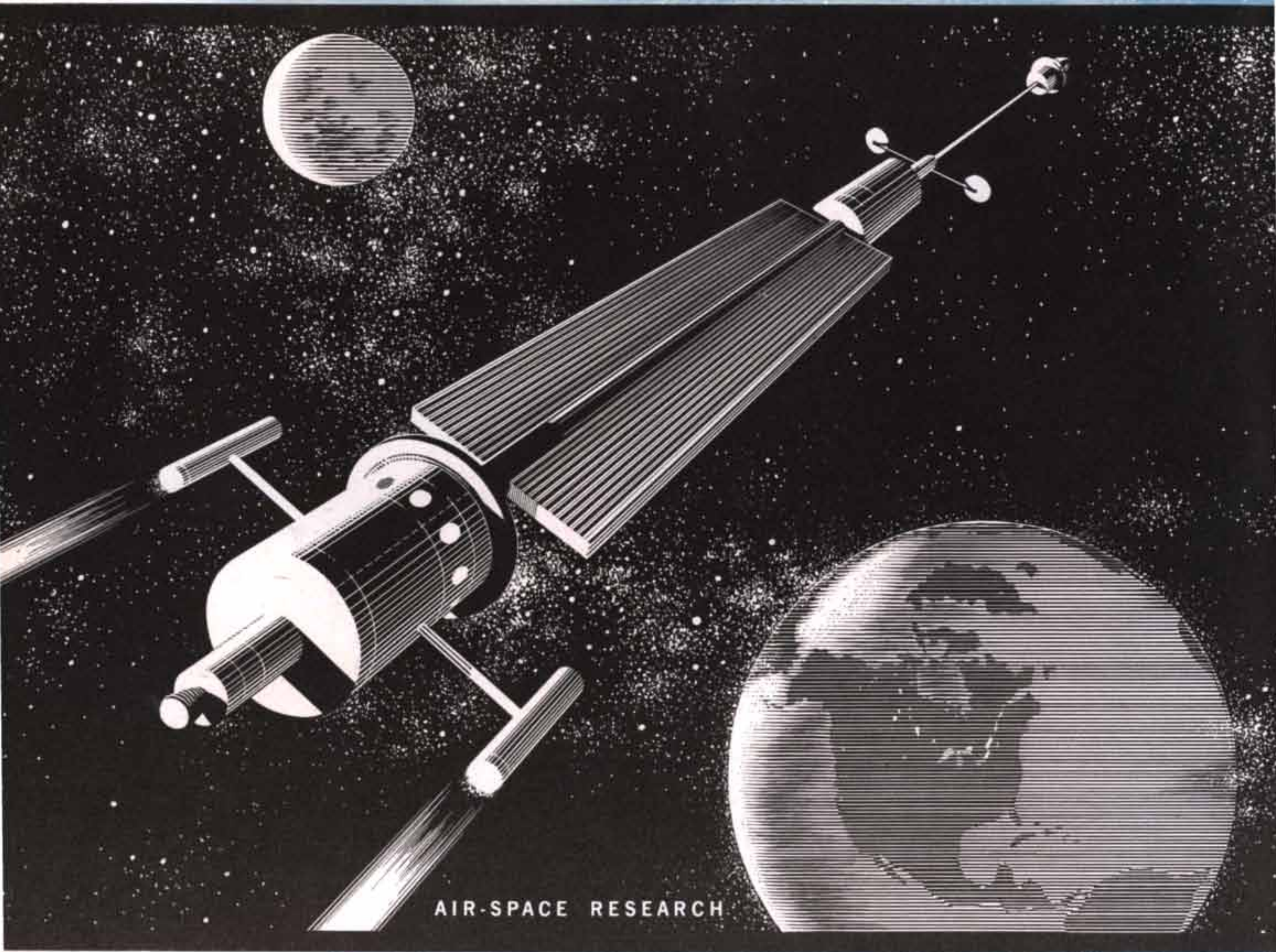
New Concepts for the Space Age Mark 15 Years of Progress by MARQUARDT

When founded in 1944, Marquardt was an organization devoted exclusively to research and development of the ramjet propulsion principle. Today, in its fifteenth year, the Corporation employs more than 5,000 in the creation and exploration of new concepts for the space age. Marquardt is now diversified, operating in five basic areas—all primarily related to the search for earlier and ever more effective solutions to space-age problems.



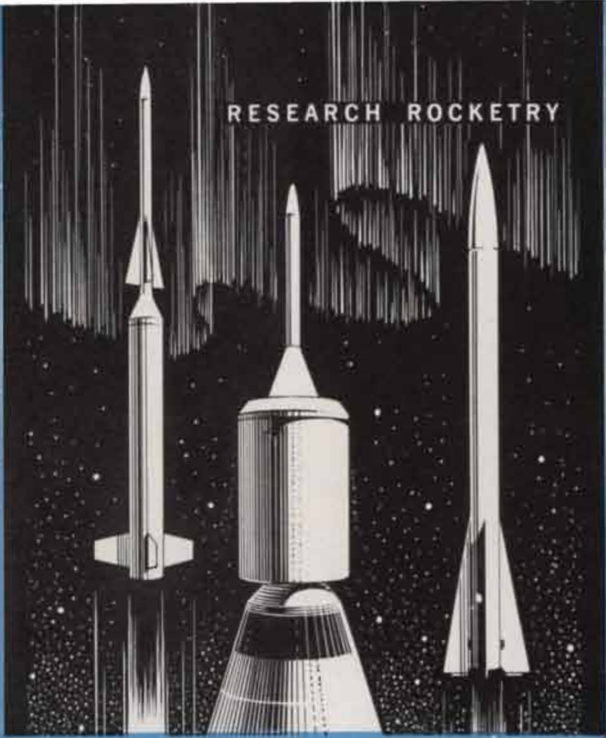
NEW CONCEPTS IN AIR-SPACE RESEARCH spring from ASTRO—Marquardt's Air-Space Travel Research Organization—where studies of an ionic rocket capable of powering future space vehicles are in progress. Other imaginative ASTRO studies span a broad spectrum including high-energy fuels, exotic materials, nuclear powerplants, advanced optics, cryogenics, space medicine, communications and guidance.

NEW CONCEPTS IN POWER SYSTEMS are in the making at Marquardt's Power Systems Group. Within the Group, Propulsion Division is engaged in continuing studies of a Hyperjet (rocket-ramjet) configuration capable of lifting future satellites from launch pad to upper atmosphere. Controls and Accessories Division is currently developing attitude controls for reconnaissance satellites, while Test Division is capable of ground-testing space-age hardware.

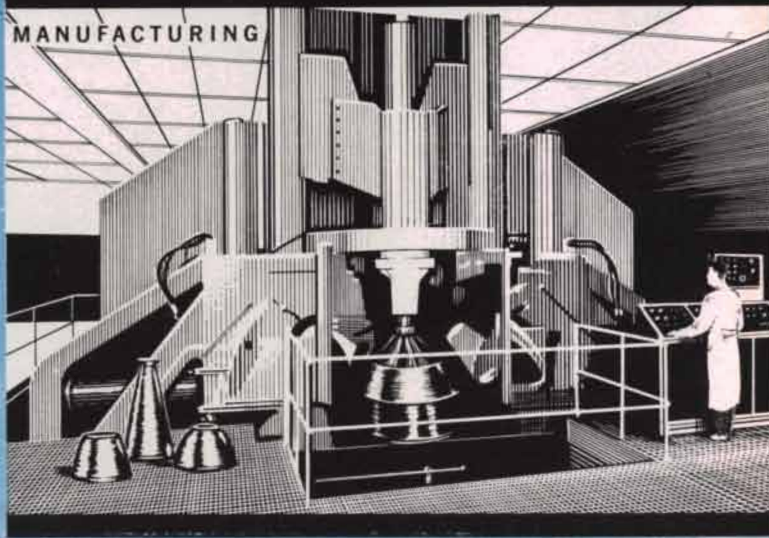
NEW CONCEPTS IN MANUFACTURING are typified by the first-of-its-kind Hufford Spin-Forge at Marquardt's Ogden Division. This 250-ton machine will contribute advances in space-age metal working state-of-the-art, while augmenting the Division's production of supersonic ramjet engines for the Boeing Bomarc IM-99.

NEW CONCEPTS IN SPACE-AGE TRAINING are an important product of Marquardt's Pomona Division—creators of a unique system which realistically simulates a 4,000 mile mission on an 8-foot map. The system will ground-train air and spacemen without risk and at great savings in cost.

NEW CONCEPTS IN RESEARCH ROCKETRY and instrumentation come from Cooper Development Corporation, a Marquardt subsidiary. Cooper has contributed to programs including Explorer and Sunflare projects, and Falling Sphere—is now at work on Project Mercury.


RESEARCH ROCKETRY


POWER SYSTEMS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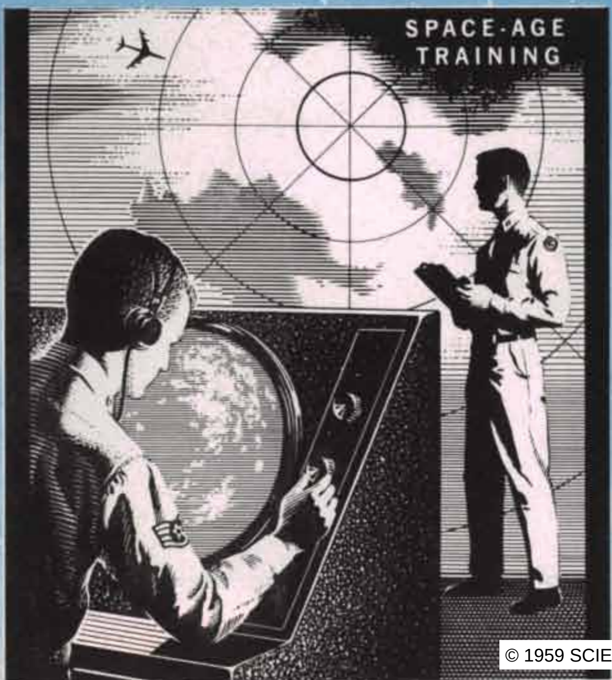

SPACE-AGE
TRAINING

Established 1845 **SCIENTIFIC AMERICAN** September, 1959 Volume 201 Number 3

Ionizing Radiation

This issue of SCIENTIFIC AMERICAN is devoted to the single topic of ionizing radiation.

Ionizing radiation consists of electromagnetic waves or material particles that have sufficient energy to ionize atoms or molecules (that is, to remove electrons from them), thereby radically modifying their chemical behavior. The molecules most sensitive to this action are those involved in the structure and function of living matter.

Life on earth has always been exposed to ionizing radiation. Most of this radiation comes from radioactive atoms occurring naturally in rock, soil, water and air and incorporated in the tissues of living organisms. But the intensity of radiation at the surface of the earth is relatively low. The ionizing radiation from the sun and other stars that flows through space is almost entirely filtered out by the earth's atmosphere. Were it not for this shelter, life processes could not go on.

Since the beginning of this century human activities have been increasing the volume of ionizing radiation on earth. Medical X-rays, which have done so much to conserve life, have increased the average exposure of much of the world population to as much as 100 per cent above the natural-background rate. With the advent of nuclear technology this exposure is increasing. Fallout from the testing of nuclear weapons has measurably increased the background of ionizing radiation in all parts of the world. Nuclear power-plants produce huge quantities of radioactive material, the containment and disposal of which raise serious technical problems, quite apart from the danger of accident. Some of this material is finding its way into science and technology as a source of ionizing radiation for new and diverse applications.

Men are concerned with this increase in ionizing radiation not only because it can affect the health and welfare of the living generation, but also because it deranges the hereditary mechanism and could blight the lives of their offspring through many generations to come. If nuclear weapons are ever used in war, ionizing radiation might well extinguish the human species.

How can men secure the benefits of ionizing radiation, and minimize the dangers? Such questions arise with every innovation in technology. But they raise compelling moral issues in connection with ionizing radiation because the consequences of its use or abuse may spread so widely in space and time, as has been demonstrated by the fallout of man-made radioactive isotopes.

To employ ionizing radiation wisely and safely men must know more about it. In this issue 11 investigators present a summary of the relevant knowledge. They also offer their judgments and recommendations under many headings. As the reader will find, they do not agree on all the facts nor do they arrive unanimously at the same conclusions. In the last analysis, with the interests of all men at stake, all must join in seeking to understand ionizing radiation and in making rational choices based upon that understanding.

COSMIC-RAY PARTICLES produced the dark tracks in this nuclear-emulsion photograph by ionizing silver bromide molecules in the emulsion. A cosmic ray enters the picture from the top; it collides with a nucleus in the emulsion and shatters into several fragments. The short tracks along the path of the primary particle were made by electrons. The photograph was made by Herman Yagoda of the Air Force Cambridge Research Center.

What Is Ionizing Radiation?

In their ability to penetrate matter and displace electrons in atoms and molecules, the various forms of this radiation have deep significance for science, technology and the future of man

by Robert L. Platzman

Ever since the discovery of X-rays in 1895 and of radioactivity in 1896, penetrating ionizing radiations have played a central role in the advance of modern physics and allied sciences. These versatile tools possess several novel attributes. One is their penetrating power: they can pass through matter, some of them for considerable distances and with little degradation of their energy. Another (not possessed by all of them) is their electric charge, which creates intense disturbances in the balance of the electrical forces that hold the constituents of atoms and molecules together. But the most salient property of ionizing radiations is their great energy, which permits the physicist to deal with single atomic particles. Nobody can observe a single atom in ordinary matter; for the most part physics and chemistry make their measurements on vast numbers of similar atoms. However, alpha particles, which are bare nuclei of helium atoms having enormous kinetic energy, are by virtue of that energy individually detectable. It is this incomparable delicacy that underlies many of the most celebrated discoveries in 20th-century physics.

The penetration of high-energy radiation into matter has two complementary aspects: the effects of the interaction upon the radiation and the effects upon matter. It is the first of these, which may be called radiation physics, that has received almost exclusive attention in the past. High-speed particles are, in a sense, probes that permit exploration of the inner structure of matter. Their deflection during penetration provides a measure of the forces to which they are subjected in the interior of atoms and molecules. Pioneering studies of electron penetration by Philipp Lenard and by J. J. Thomson late in the 19th century, and of alpha-particle penetration by Ernest Rutherford early in the 20th, led to a progressively deeper understanding of the structure of the atom, culminating with Rutherford's discovery in 1911 of the atomic nucleus. In the ensuing years refinements of the same mode of attack helped to establish the arrangement of electrons in atoms, of atoms in molecules and of atoms and molecules in liquids and solids. Similar techniques utilizing particles of greater energy later made it possible to examine the arrangement of neutrons and protons in the atomic nucleus and even the inner structure of the nuclear particles themselves. At the same time experiments on individual collisions between energetic particles or photons and atoms or molecules have been an invaluable proving ground for testing a host of different aspects of the quantum theory of physics.

Until comparatively recent years, on the other hand, the effects of ionizing radiations upon matter have been accorded far less attention. Scattered, conspicuous phenomena were recorded, and inquiry into their mechanisms was pursued by a handful of dedicated workers. But the fundamental problem attracted little in the way of vigorous and systematic attack until the sudden emergence of nuclear technology called serious attention to a lack of basic understanding. This new interest admittedly stems from pressing practical questions: physical ones, such as the modification of the mechanical, thermal and electrical properties of solid materials that are exposed to radiation; chemical ones, such as the potentialities for the use of radiation in industrial chemistry; and biological ones, such as the effects of radiation on human health. But the study of radiation action presents a multiplicity of novel and fundamental challenges and offers promise of providing new knowledge on the deepest levels. Thus the widespread current activity in research on radiation action, facilitated by the availability of radiation sources having unprecedented variety and intensity, is motivated by expectation of both practically useful and fundamentally important results.

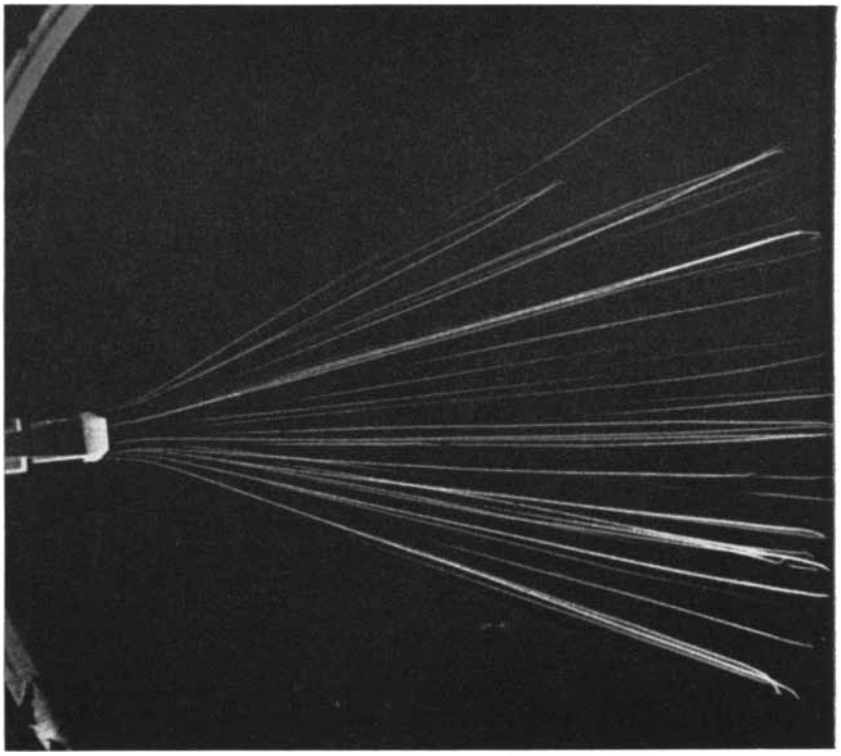
The varieties of ionizing radiation, whether corpuscular or electromagnetic [*see illustration on page 76*], produce in different ways the same sorts of ultimate effects on matter. They are called "ionizing" because a principal property—and often their most conspicuous one—is their ability to eject planetary electrons from atoms and molecules. The products of this reaction are ions: the negatively charged electron and the electron-deficient and thus positively charged atom or molecule. Ionizing radiation is often called high-energy radiation because its units have energies that are vastly greater than the binding energies of valence electrons in atoms or molecules, which are of the order of 10 electron volts (ev), and of atoms in molecules, which are about five ev. The high-speed atomic particles of corpuscular radiation ordinarily carry tremendous energies, most commonly from one to 10 million electron volts (Mev). Electromagnetic radiations are classed as ionizing radiation if their ultimate units (photons) have very high energy, and are then called X-rays or gamma rays. The photons of gamma rays from cobalt 60, for example, have energy of about one Mev. (Historically the term X-rays was reserved for photons from X-ray tubes and the term gamma rays for those from radioactive substances. This distinction is now obsolete, because the energy ranges of these two sources overlap broadly. There is no difference between X-rays and gamma rays in nature or behavior. In contemporary usage the term "X-ray" is more often applied loosely to photons below about .1 Mev, and "gamma ray" to photons of greater energy.)

Particles and photons of intermediate energy, say 20 to 100 ev, produce ionization and behave like high-energy radiations in many other respects. They have negligible penetrating power, however, and are entirely absorbed by the surface regions of liquids and solids. The photons of far-ultraviolet radiation from the sun are absorbed in the earth's upper atmosphere, maintaining there the electrified shells of the ionosphere that play such an important part in radio communication.

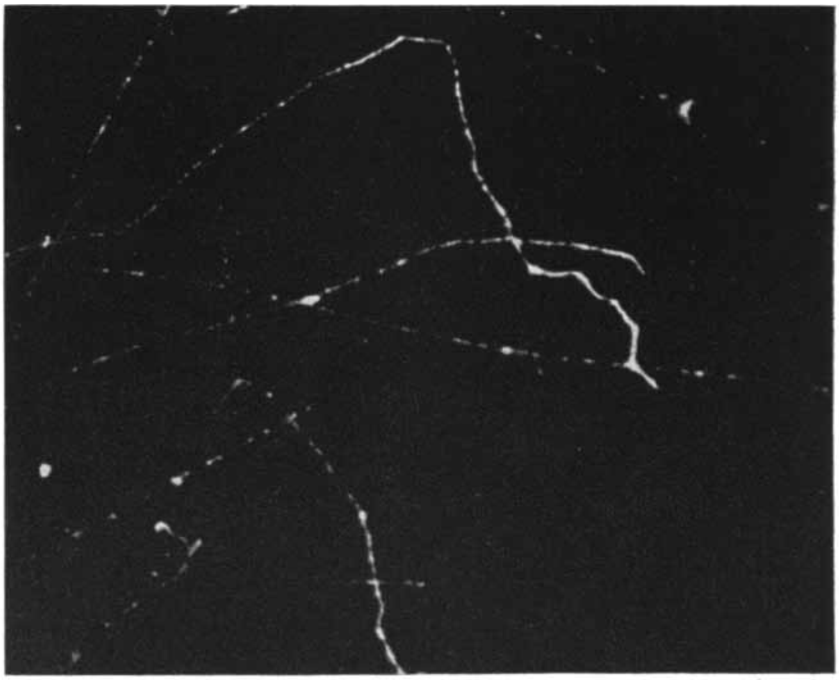
The interaction of each type of radiation with matter depends upon the mass and the charge, if any, of the radiation as well as upon its energy. Because high-energy neutrons, for example, have no electric charge, they interact feebly with atoms and therefore have great penetrating power. Eventually they give up their entire initial kinetic energy to the atomic nuclei that they happen to strike directly. In recoiling from these collisions the atoms lose one or several of their orbital electrons and themselves become charged particles.

Because X-rays also have no charge, they too have great penetrating power. They disappear in various absorption processes by which their energy is transformed into the kinetic energy of one or several electrons ejected from molecules of the penetrated medium. These energetic electrons, which again are electrically charged secondary particles, pursue their own paths through the medium, losing energy to it as would any electron of the same kinetic energy.

It is electrically charged particles that produce the overwhelming preponderance of the acts of energy-transfer which give ionizing radiations their significance in nature and technology. When a swiftly moving electron, alpha particle, proton or deuteron penetrates matter, the molecules near which it passes are subjected to an intense, transient electrical force. Since the binding of electrons in molecules is purely electrical in character, the new force is devastating. The organization of electrons within each molecule is disturbed, and many molecules along the path of the particle remain "excited" or ionized after the particle has passed. These two types of primary effect are very different in nature. In an excited molecule the acquired



ALPHA PARTICLES emitted by the source at left leave heavy tracks in a cloud chamber. Each track consists of a dense cylinder of ions on which water droplets have condensed. The alpha particles travel in straight lines and cease to ionize the gas after they have traveled a well-defined distance, called the range. The tracks of the particles are bent near the end as a result of collisions with atomic nuclei. Such collisions are more apparent at the end of a track because they are more likely when the alpha particle has been slowed down.



BETA PARTICLES, or high-speed electrons, originating at the left leave these tracks in a cloud chamber. The ions in the tracks are much farther apart than those in the tracks of alpha particles. As the electron slows down, its path becomes more erratic and the ions are formed closer together. At the very end of an electron track the proximity of the ions approximates that in an alpha-particle track. Both the alpha- and beta-particle photographs were made by J. K. Bøggild of the University Institute of Theoretical Physics in Copenhagen.

IONIZING RADIATION	SYMBOL	MASS	CHARGE
ELECTRON	∘	1	—
PROTON	●	1,836	+
NEUTRON	○	1,839	0
DEUTERON	●○	3,671	+
ALPHA PARTICLE	●○ ○●	7,296	+ +
X-RAY OR GAMMA RAY	⁓⁓>	0	0

PRINCIPAL FORMS of ionizing radiation are listed. All are particles of matter with the exception of X-rays and gamma rays, which are electromagnetic waves. The deuteron consists of a proton and a neutron; the alpha particle, of two protons and two neutrons. Some of the mass of the constituents of deuteron and alpha particle is transformed into the energy which binds them together.

energy alters the motion of the planetary electrons, whereas one of these electrons is actually released and wanders away from an ionized molecule. More energy is required to ionize a molecule than to excite it, but not a great deal more. On the average, some 10 to 20 ev of energy are transferred in each primary event, and the penetrating particle is thereby imperceptibly decelerated. Although the loss of kinetic energy occurs in discrete amounts, the changes are so minute compared to the total kinetic energy that the slowing-down can be considered, for most practical purposes, to be a continuous process. Eventually the particle is brought to rest and is no longer able to affect the medium.

From the excitation and ionization of large numbers of molecules flow a host of secondary consequences that are now attracting the interest of investigators both inside and outside the field of physics proper. Free ionized molecules have a high chemical reactivity which is powerfully disturbing in whatever milieu they appear. The excitation of a molecule, short of ionization, entails the reorganization of the electrons that hold its constituent atoms together. One or several of the weakened bonds tend to rupture, loosing stable and unstable fragments into the environment. These and the diverse sequences of events that follow may be triggered by any one of the various types of ionizing radiation. As William H. Bragg stated in 1912, "the forms of radiation differ in degree rather than in kind" in their effects on matter.

The observation of the primary effects of ionizing radiation gives us many of our most important methods for detecting and measuring the radiation itself. One of the most reliable is the ionization of gases, observed by Henri Becquerel a few months after his discovery of radioactivity. Since a single alpha particle from radium, for example, produces 137,000 positive ions and an equal number of electrons when it is completely absorbed in air, the consequent electric current can be measured with the aid of an amplifier. The ions formed in a gas (ions of nitrogen and oxygen molecules in the case of air) are usually exceedingly reactive; they often undergo chemical change during the time required to collect them at an electrode. The total electric charge, however, is not thereby altered. For this and numerous other reasons the ionization method of detection has proved remarkably trustworthy. Ionization chambers are widely employed to count energetic particles and to determine their individual energies.

A simpler device, the electrical counter invented by Rutherford and Hans Geiger in 1908, employs high voltages to break down the gas, once a passing particle has supplied an initial requirement of ions. Such a device yields a burst of current strong enough to be observed without amplification. Although useful for counting large numbers of ionizing particles, the electrical counter cannot determine their energies. The most common variety, the Geiger counter, has applications ranging from refined physical experiment to uranium prospecting, and can even be found in the Sears Roebuck catalogue.

The second basic method of detection rests upon the emission of light by excited molecules. When an isolated atom is excited, it must lose its excitation energy and return to its lowest energy-state by emitting one or several photons. Since few atoms exist in isolation, however, the excitation energy is usually dissipated by collisions with other atoms or molecules, and diverted to forms of energy other than light (*e.g.*, heat). When a molecule is excited, the initial conversion of energy can be internal; the bonds between atoms in the molecule are ruptured, and the excitation energy is converted into the chemical energy of the reactive molecular fragments. Indeed, very few molecules emit light when they are irradiated. There are, however, special substances in which the excitation energy is not degraded; they therefore emit light copiously under irradiation. Such substances can serve both to count energetic particles and to measure their energy. Inorganic crystals such as zinc sulfide have this property, and they find common use on the screens of television tubes. Electrons accelerated in the tube (which ordinarily have energies of some thousands of electron volts and are therefore typical ionizing radiation) impinge upon the screen and are absorbed; the resulting excitation leads to the emission of light.

An alpha particle impinging on zinc sulfide provokes the emission of a burst of photons, some 10,000 in number. Although this scintillation is very faint, it can be observed by the unaided (but dark-adapted) human eye. Most of the epochal discoveries of early nuclear physics, among them the discovery by Rutherford of the atomic nucleus and of the first nuclear transmutation, depended upon the visual observation of alpha-particle scintillations. In contemporary instruments either inorganic crystal phosphors such as zinc sulfide, or organic substances (usually mixtures of aromatic compounds), serve as scintillating media, and the human eye is replaced by an electrical device that converts the burst of light into an electrical signal.

Chemical reactions, engendered by both excitation and ionization, furnish a third important mode of observation and measurement. The blackening of photographic emulsion, a chemical effect that gave Wilhelm Conrad Roentgen the first clue to the existence of ionizing radiation, is still useful both for observing individual particles and for determining total amounts of radiation. The Fricke dosimeter, developed by the pioneer U. S. radiation chemist Hugo Fricke, depends upon another chemical reaction, the oxidation of ferrous sulfate dissolved in sulfuric acid, to give an accurate measure of absorbed energy.

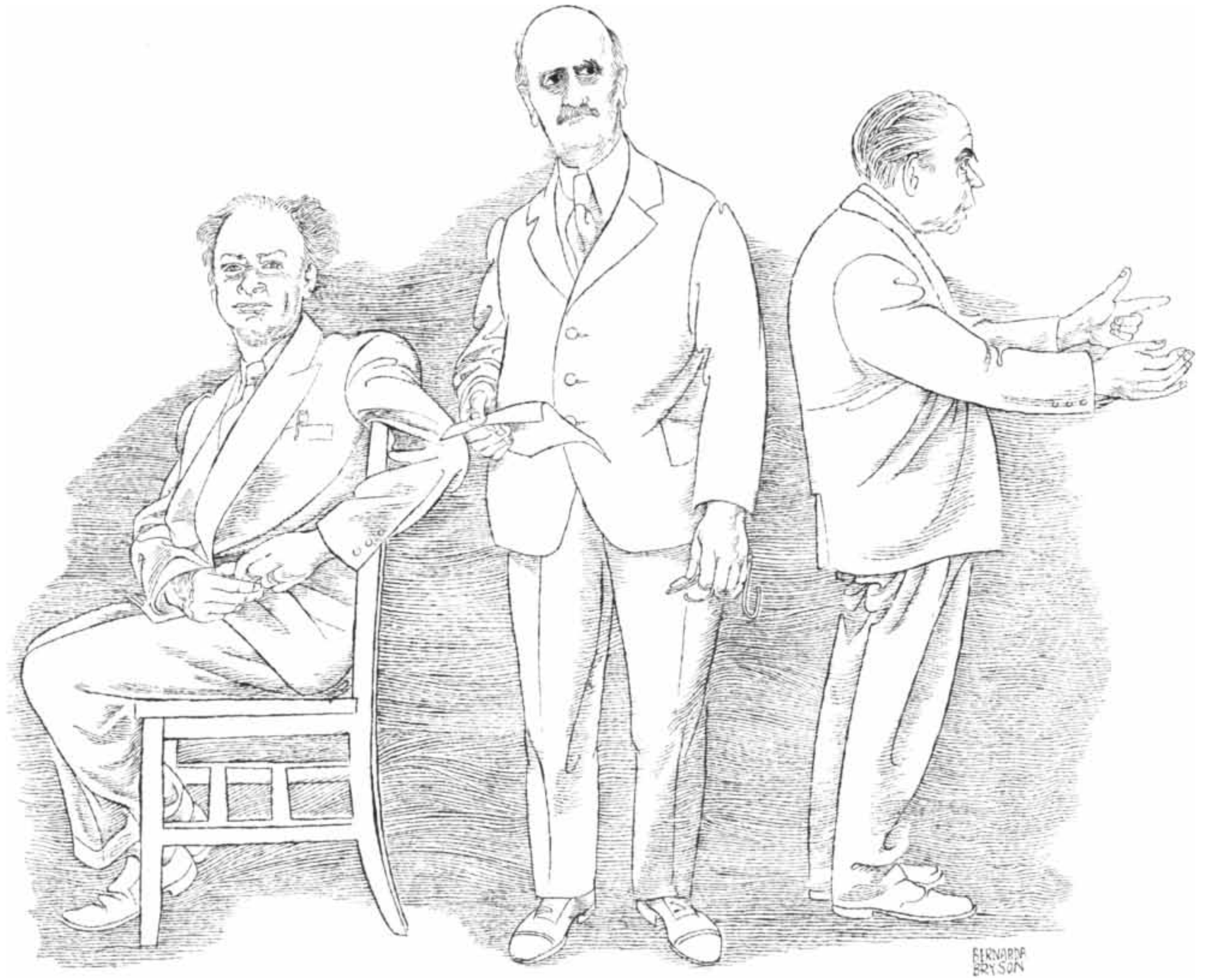
Radioactive substances and man-made machines provide the two most important sources of ionizing radiation. In radioactive disintegration the reorganization of the constituents of the atomic nucleus imparts great energy to the emitted particle or photon. In machines electrical power supplies this energy.

Naturally occurring radioactive substances emit three different kinds of radiation: alpha particles, beta particles (high-energy electrons) and gamma rays. Virtually exploding, the disintegrating nucleus hurls out the alpha particle or beta particle, and in some cases gamma rays as well. Some 30 different naturally occurring isotopes emit alpha particles, most of them with energies between five and 10 Mev, and a like number emit beta particles, with energies chiefly between .1 and 2 Mev.

Uranium and thorium, and their families of decay products, comprise the main source of natural radioactivity. As James R. Arnold and E. A. Martell explain in the article that follows, these elements are widely distributed throughout the crust of the earth, occurring highly concentrated in certain minerals and in very dilute form practically everywhere. Another ubiquitous source of natural radiation is the radioactive isotope potassium 40, an emitter of one-Mev beta particles which comprises one out of every 10,000 potassium atoms in all rocks, soils, waters and living things (including people). In addition to these elements, which have been here since the earth originated and will remain for billions of years, there exist other radioactive atoms, of lower abundance and usually of a more transient nature. Cosmic rays, to which the earth is constantly exposed, are themselves ionizing radiation of highly varied content. And the cosmic rays, in their passage through the earth's atmosphere, produce a quantity of atomic debris, part of which is radioactive.

To the natural abundance of radioactive isotopes man-made nuclear reactors, military and nonmilitary, have been adding steadily rising amounts of radioactive wastes, intentional and inadvertent. Radioactive isotopes can also be produced by bombarding stable isotopes with energetic atomic particles from an accelerator or a nuclear reactor. These artificially radioactive materials chiefly emit beta particles and gamma rays. Cobalt 60, for example, is manufactured by exposing rods of cobalt to the neutrons inside a reactor. It is a powerful and invaluable source of gamma radiation.

X-ray machines employ a high voltage to accelerate electrons boiled from a



"THREE B'S" of ionizing-radiation physics are the late Sir William Bragg (*center*), Niels Bohr (*right*) and Hans A. Bethe (*left*). Bragg laid the experimental foundations of knowledge of the penetration of ionizing radiations into matter. He discovered that alpha particles travel in straight paths, that they lose energy gradually and that they have a well-defined range. He made extensive measurements of the ionization of gases by various kinds of radiation. His findings were incorporated in his classic *Studies in Radioactivity*, published in 1912. Bohr published two celebrated papers in 1913 and 1915 which set forth the theoretical principles used to deal with the loss of energy by fast-moving charged particles. His *The Penetration of Atomic Particles through Matter*, published in 1948, is also a classic. Bethe wrote a monumental 76-page paper that applied the principles of modern quantum physics to the excitation and ionization of matter by energetic charged particles. The paper was published in 1930, when he was 24 years old.

hot cathode through a vacuum and into abrupt collision with a target plate. In this way part of the kinetic energy of the electrons is transformed into high-energy photons. Roentgen's original tube operated on 40,000 volts; X-ray machines in common use today operate on thousands to millions of volts. In general, the greater the voltage, the greater the energy of the X-ray photons and the greater their penetrating power.

Complex accelerators such as the cyclotron, the Van de Graaff generator and the linear accelerator, all now available commercially, can accelerate charged particles to energies up to many millions of electron volts. These engineering masterpieces employ electrical power to maintain elaborate electrical and magnetic fields, constraining the particles to move under acceleration by the electric field.

For the chemist and the biologist interest in ionizing radiations begins with the excited and ionized molecules produced by primary and secondary charged particles. The potency of ionizing radiation in chemistry and in life processes is a consequence of the extreme reactivity of these energy-rich, chemically activated molecules. If the energy absorbed by such molecules were merely degraded into heat, instead of augmenting their electronic energy, ionizing radiations would have little significance outside of physics.

An activated molecule may, but need not, lead to a permanent effect. The evolution of the action of radiation, from the primary exciting or ionizing event to the end product, is the most fascinating front now being explored by investigators. The sequence of events, which takes but a tiny fraction of a second, may be divided into three stages, with a fourth and far longer stage to follow in the case of living matter. In the first, or "physical," stage the incident radiations and their secondary particles impart energy to numerous molecules, yielding electrons and excited and ionized atoms and molecules as the primary products. The primary products are located near the particle paths and are therefore distributed nonuniformly in space. Cloud-chamber and nuclear-emulsion pictures make it possible to visualize these events, although these pictures reflect the situation in later stages of its evolution.

There follows instantly the "physicochemical" stage, in which the primary products undergo secondary reactions; the ions collide and react with normal molecules and the excited molecules spontaneously dissociate. Eventually, in the brief time-scale of the reactions, this stage yields a combination of stable molecules (some or all of which may be different from those originally present) and chemically unstable species (usually the molecular fragments known as free radicals).

The third, or "chemical," stage now ensues. The free radicals react with the milieu and with each other, ultimately producing the final chemical products. Elsewhere in this issue A. Charlesby reviews the interesting and potentially fruitful reactions that occur in this stage. Each of these stages is briefer in duration than the one that follows it. In water or biological tissue, for example, the physical stage requires only about 10^{-13} (.0000000000001) second; the physicochemical stage, about 10^{-11} second; the chemical stage, 10^{-6} second or somewhat more.

In biological systems there follows a fourth stage in which the organism, through its hierarchy of organizational levels, responds to the foreign chemical substances present at the conclusion of the chemical stage. The biological stage is usually protracted and can persist for days and even years, as the articles by Alexander Hollaender and George E. Stapleton and by John F. Loutit explain. Present-day understanding of the processes in the first, or physical stage, is advanced. But knowledge of what occurs in the other stages, including the biological, is inchoate.

Many of the phenomena induced by ionizing radiation are encountered with other forms of activation. For example, free radicals are produced as intermediates by the absorption of ultraviolet radiation and even in many ordinary chemical reactions. But the action of ionizing radiation has three distinctive characteristics. First, the excitation energy of the primary products is uniquely great. Free ionized molecules are virtually unknown to chemistry and biology except as the primary products of ionizing radiations. Second, the ionizing particle arrays the activated molecules in nonuniform spatial arrangement along its track. In activation by ultraviolet rays, chemical action or ultrasonic waves, the effects are randomly distributed in the medium. Finally, the individual acts

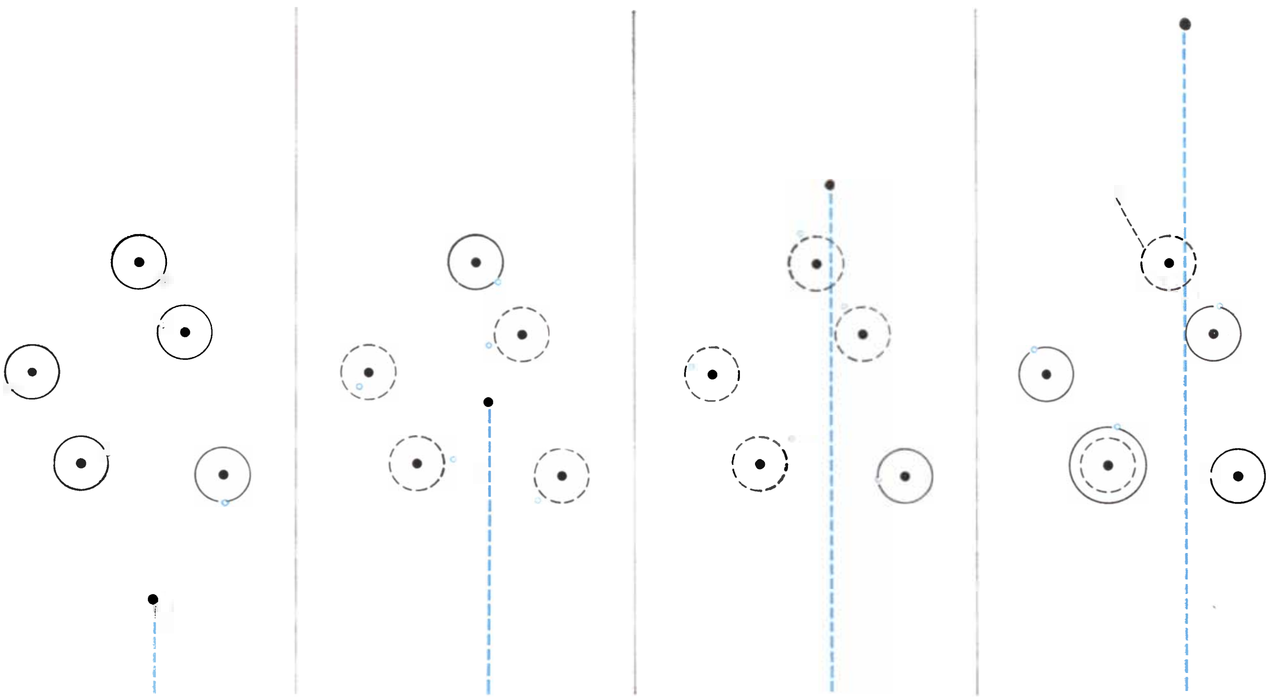
A Glossary of Ionizing-Radiation Units

Curie (*abbreviated c*): A measure of radioactivity in terms of the rate of atomic disintegrations. A piece of matter has an activity of one curie if 37 billion of its atoms disintegrate each second. This figure originated in the use of radium as a standard: One gram of radium has an activity of almost exactly one curie. Other substances disintegrate at different rates. Thus one gram of strontium 90 has an activity of 147 curies. Depending on the kind of atom, each disintegration results in the emission of an alpha particle or a beta particle and often gamma radiation as well. The effect of radioactivity on a neighboring substance depends on the type and energy of the emissions as well as on their rate.

Rad: The unit of radiation dose; defined in terms of the energy absorbed by irradiated material. An "absorbed dose" of one rad means that each gram of matter exposed to radiation absorbs 100 ergs of energy. To give some idea of the size of the unit, 420,000 rads would raise the temperature of water by one degree centigrade, assuming that all the absorbed energy is converted into heat.

Roentgen (*abbreviated r*): For many years the customary unit for amount of radiation, and used in several places in this issue. It is defined in terms of ionizing effect: one roentgen of radiation produces about two billion (or a total of precisely one electrostatic unit) each of positive and negative ions in one cubic centimeter of dry air at standard conditions (zero degrees centigrade and a pressure of 760 millimeters of mercury). The unit is useful only for X-rays and gamma rays of low or medium energy. One r of such rays to water or soft tissue administers an absorbed dose of very nearly one rad. For other types of radiation the relationship between the r and the rad is difficult to establish, and the rad is the superior unit.

Rem: A biological measure of dose that takes into account the comparative biological effectiveness of the type of radiation as well as the amount of absorbed energy. By definition one rad of X-rays, gamma rays or beta rays is equivalent to one rem. One rad of alpha rays, however, is equivalent to about 10 rem.



PRIMARY EFFECTS OF A CHARGED PARTICLE on a gas are schematically depicted. In the first drawing the particle approaches five gas molecules; the small colored circles represent only one electron in each. In the second drawing the particle disturbs the electrons in four of the molecules. In the third it has traversed the fifth molecule. In the fourth drawing it has receded, leaving one molecule ionized *(top)* and one in an excited state *(bottom left)*. The others have reverted to the original state.

of ionization along the track separate electric charges in the molecules with extreme suddenness. In substances such as water and proteins, where molecules are oriented by the unequal distribution of charge within them, this provokes a violent response.

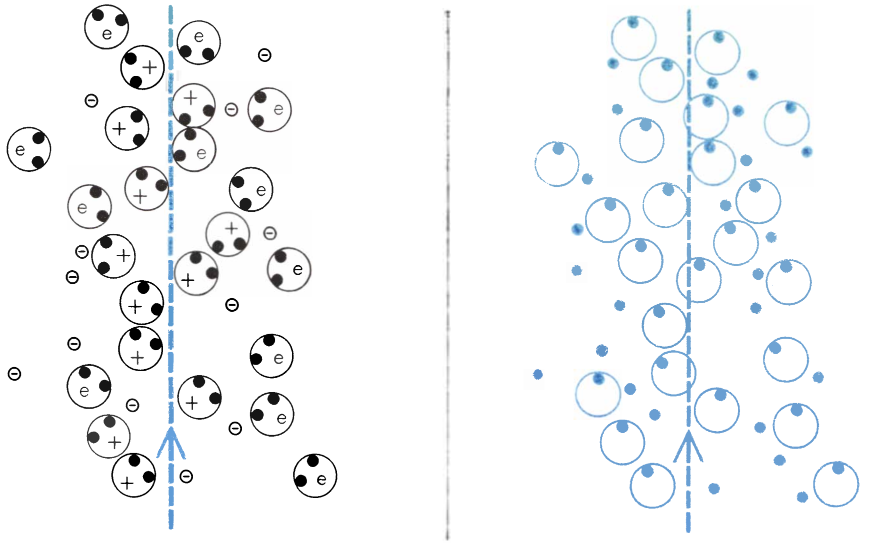
The rate at which a charged particle loses energy in matter during the physical stage depends very much upon certain of its qualities. When a charged particle interacts with a molecule, the degree to which the molecule is disturbed is determined by the electric force exerted by the particle upon electrons within the molecule. We should expect, therefore, that the greater the charge of the particle, the greater the probability of energy transfer. The force exerted is also inverse to the speed of the particle, because a slower particle exerts its force over a longer time. Theories devised by Niels Bohr and by Hans A. Bethe permit accurate prediction of the energy loss per unit distance of penetration—an important concept in radiation studies called stopping power or linear energy-transfer (abbreviated LET). The theories show that the LET is proportional to the square of the charge, and also, approximately, to the inverse square of the speed. Whether the charge is positive or negative is of no consequence. As a particle penetrates matter it gradually slows down; its LET therefore increases.

It is instructive to compare the LET of an alpha particle with that of an electron of comparable energy. Since the alpha particle has much greater mass, it must have much lower speed. In addition, its charge is twice as large. For both reasons the LET of an alpha particle is hundreds of times greater than that of a high-energy electron. On the other hand, the range of an alpha particle—the total distance it traverses before coming to rest—is correspondingly shorter. The alpha particles emitted by isotopes occurring in nature have ranges in air of a few inches; electrons of comparable energy travel more than 50 feet. In a liquid or solid the close packing of molecules, as compared to their wide separation in gases, drastically reduces both of these distances by a factor of roughly 1,000.

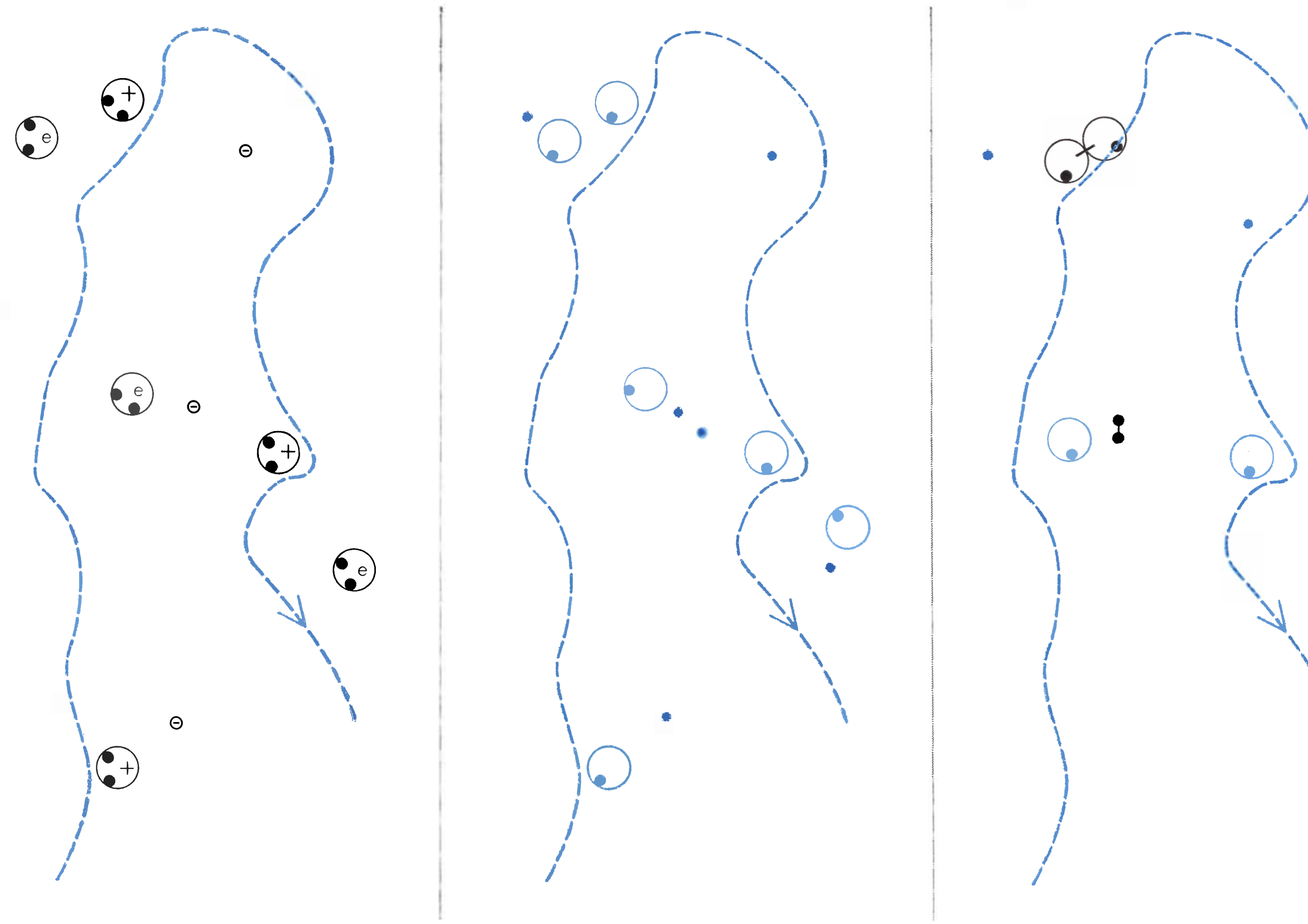
The geometries of particle paths also differ. Heavy projectiles such as alpha particles or protons are negligibly deflected when they transfer energy to the vastly lighter electrons. They therefore move in straight lines. But a penetrating electron, because of its small mass, is easily deflected; consequently it pursues an erratic course (particularly after it has been slowed down to an energy that is well below one Mev), as electron tracks in cloud chambers clearly show.

X-rays behave in an entirely different manner. A single photon passes unaltered by numerous molecules until, by chance, it interacts with a single molecular electron and transfers part or all of its energy. Thus the X-ray photon is not gradually absorbed, as charged particles are; rather, an X-ray beam is gradually attenuated as photons disappear from it. Complete attenuation is never attained; for example, a few inches of water reduce the intensity of a beam of one-Mev gamma rays by a factor of .5, eight inches by a factor of .25, 12 inches by a factor of .125, and so on. X-rays have far greater penetrating power than charged particles. The differences are illustrated by the compound radiation from radium. An ordinary piece of paper will absorb the alpha particles emitted by radium; a quarter-inch of glass is required for the beta particles; the gamma rays can be detected beyond several inches of lead.

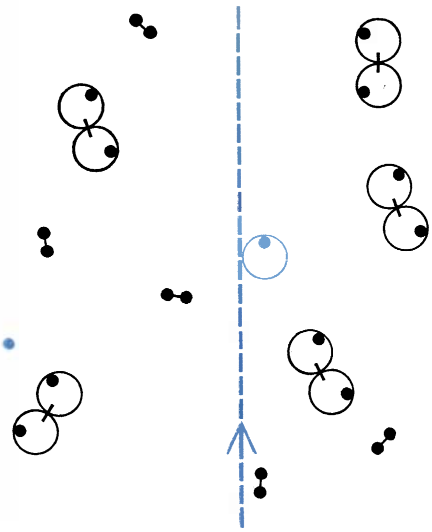
Although the spatial arrangement of activated molecules is decisively dependent upon the type of radiation, their nature and number are not. Some 10 or 15 ev are expended, on the average, for each activated molecule formed, and excitations and ionizations are nearly equal in number. In the physicochemi-



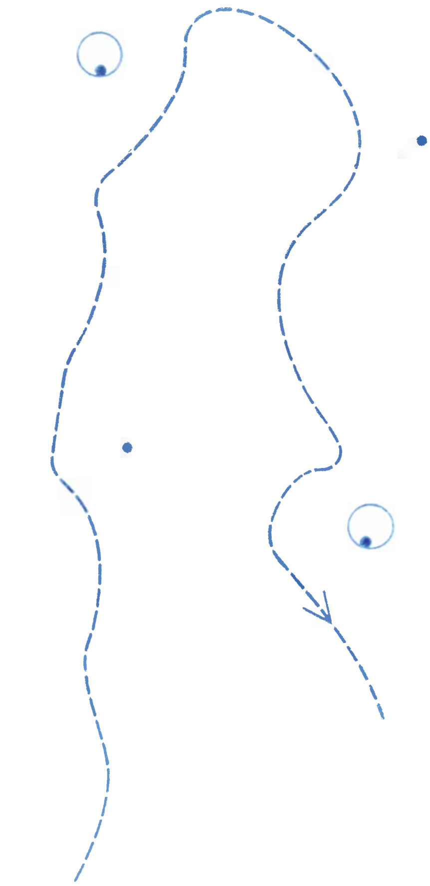
ALPHA PARTICLE with an energy of six million electron volts decomposes water according to this scheme. The first drawing depicts the end of the "physical" stage, lasting about 10^{-13} second. In the wake of the particle are excited water molecules (e), positive water ions (+) and electrons (—). Normal molecules are not shown. The second drawing depicts the end of the "physicochemical" stage, lasting about 10^{-11} second. Hydrogen atoms (*colored dots*) and hydroxyl radicals (*colored circles with dot inside*) are now in the wake. The third and fourth drawings depict the "chemical" stage, which may last 10^{-9} to 10^{-6} second. Some of the hydrogen



BETA PARTICLE OF 3,000 electron volts is unable to decompose pure water appreciably. The four stages shown here are the same as those for the alpha particle. However, because of the smaller electric charge and greater speed of the electron, the hydrogen atoms and hydroxyl radicals are not formed so close together. Hence fewer radicals unite to produce hydrogen and hydrogen per-



atoms and hydroxyl radicals have recombined into normal water molecules (*not shown*); others have formed hydrogen molecules (*paired dots*) and hydrogen peroxide molecules (*paired circles with dots inside*).



oxide molecules before diffusing away from track. Most of the molecules are destroyed by radicals that have escaped combination.

cal and chemical stages, however, the spatial proximity of primary products often has a potent influence. Such influence is termed a track effect, and it plays an important part in subsequent events. Track effects are the chief cause of differences in the chemical (and biological) effectiveness of various radiations. They are generally absent in gases but are often prominent in liquids and solids, in which the tracks tend to persist for far longer times. Thus alpha particles and beta particles are equally effective, for the same energy absorption, in causing the polymerization of gaseous acetylene; but alpha particles are very efficient in decomposing liquid water, whereas beta particles are virtually without influence.

We still know comparatively little about events in the physicochemical stage. Some information on the consequences of excitation is provided by photochemistry (the study of the chemical action of visible and ultraviolet radiation) and by the analysis of the spectrum of light absorbed by molecules. The absorption of light produces excited molecules, and does so under controlled conditions without the complicating formation of ions. An excited molecule will often break in two, and it will do so very quickly. The time required is only about 10^{-13} second for small molecules and somewhat longer for larger ones. The two fragments may, however, recombine and dissipate the energy of union as heat, particularly if the system is a liquid or solid, in which the fragments are hemmed in by other molecules and restrained from escaping.

Dissociation into free radicals is the most probable consequence of excitation in almost all inorganic molecules and most organic ones. Aromatic compounds, which are characterized by the six-carbon-atom benzene ring, are an exception. Most of them are able to convert electronic energy into heat, that is, into vibrational energy of their atoms. If the molecule can withstand this internal heating until the heat is able to flow away, it will survive primary excitation.

Ionized molecules have many interesting and curious traits, some of which have been revealed only recently. They are very reactive, often seizing upon a neighboring, neutral molecule and exchanging an atom or group of atoms with it. If they do not happen to have such an encounter, they may undergo drastic internal reorganization. For example, the molecule of the aromatic compound toluene is readily ionized by loss of a hydrogen atom from its methyl side group (CH_3); it thereupon incorporates the extra carbon atom from that side group in its hexagonal benzene ring to form a perfectly symmetrical seven-sided ring [*see illustration on page* 83]. Apparently the familiar prescriptions of chemical valence are disregarded by ions, perhaps more often than we yet appreciate.

Positively charged ions must eventually, of course, capture an electron—or a negative ion—and regain their electrical neutrality. But in many systems this process proceeds so slowly that it occurs long after ionic processes such as those just described have been completed. In all systems the physicochemical stage must be a complex one, with many different, and often violent, reactions proceeding simultaneously.

An exception to this general statement must be made with respect to the class of atomic solids, that is, metals, semiconductors and some insulating crystals. Electronic excitation and ionization have almost no permanent effect on these materials. The binding of electrons to the atoms in their structures is such that a disturbance in electronic motion is quickly dispelled. Nevertheless, some types of radiation cause marked alterations. Such effects arise from disordering of the local arrangement of atoms in the solid. Atoms can be displaced when struck by a penetrating particle with a mass of atomic magnitude, such as a proton or alpha particle, but not by an electron, which has so little mass. The observable effects in these solids, discussed in this issue by Douglas S. Billington are of great interest to students of the solid state.

The conclusion of the physicochemical stage leaves the system in a more subdued state, again at normal temperature, but strewn with molecular debris. The spatial distribution of the molecular fragments still reflects their origin near the linear tracks of energetic charged particles, although the initial compactness is now dispersed to a greater or lesser extent. In the chemical phase that follows, free radicals are the principal actors. These highly reactive molecular fragments diffuse away from the zones of high concentration, and concurrently react with one another or with such susceptible stable molecules as may be present. Since they live much longer than their precursors, free radicals are a vehicle for extending the influence of primary activation in both time and space. They can often attack a substance that is present in relatively small amount, small enough so that it does not itself become engaged in the physical or physicochemical stages. This indirect action is a common effect and in living systems is an imporant pathway to the ultimate biological consequences.

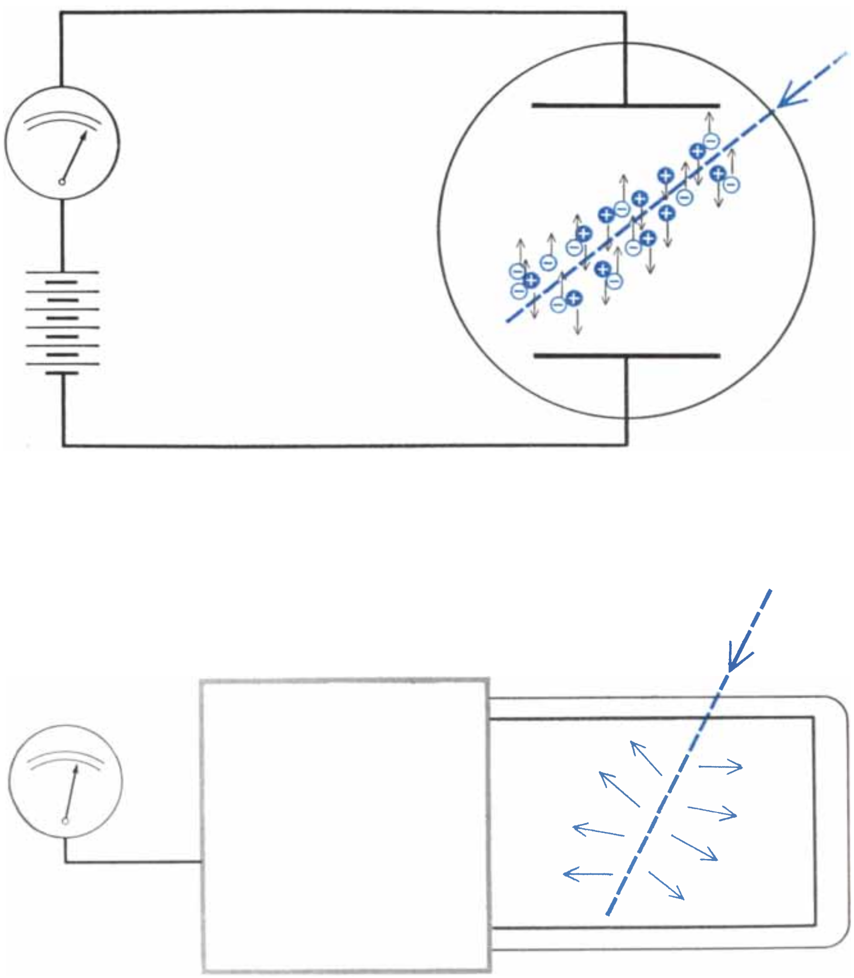
Free radicals are not peculiar to radiation action, most of them being known or surmised as intermediate species in photochemical or ordinary chemical reactions. Much of the present activity in radiation chemistry stems from the ready opportunity of generating large numbers of free radicals. In many chemical systems it is possible to measure the number of free radicals produced in irradiation. This is accomplished by adding a foreign substance, called a "scavenger," that reacts with radicals to form an observable product. Some scavengers that find common use are DPPH (diphenylpicrylhydrazyl), iodine, acrylamide, benzoquinone and oxygen.

Chemical changes caused by radiation from radioactive substances were noticed by the earliest investigators. Pierre and Marie Curie, for example, commented in 1899 that such radiation partially transforms oxygen into ozone. This reaction is a common one, being responsible for the oxidation of exposed metal surfaces and the deterioration of such materials as greases in the vicinity of a radiation source.

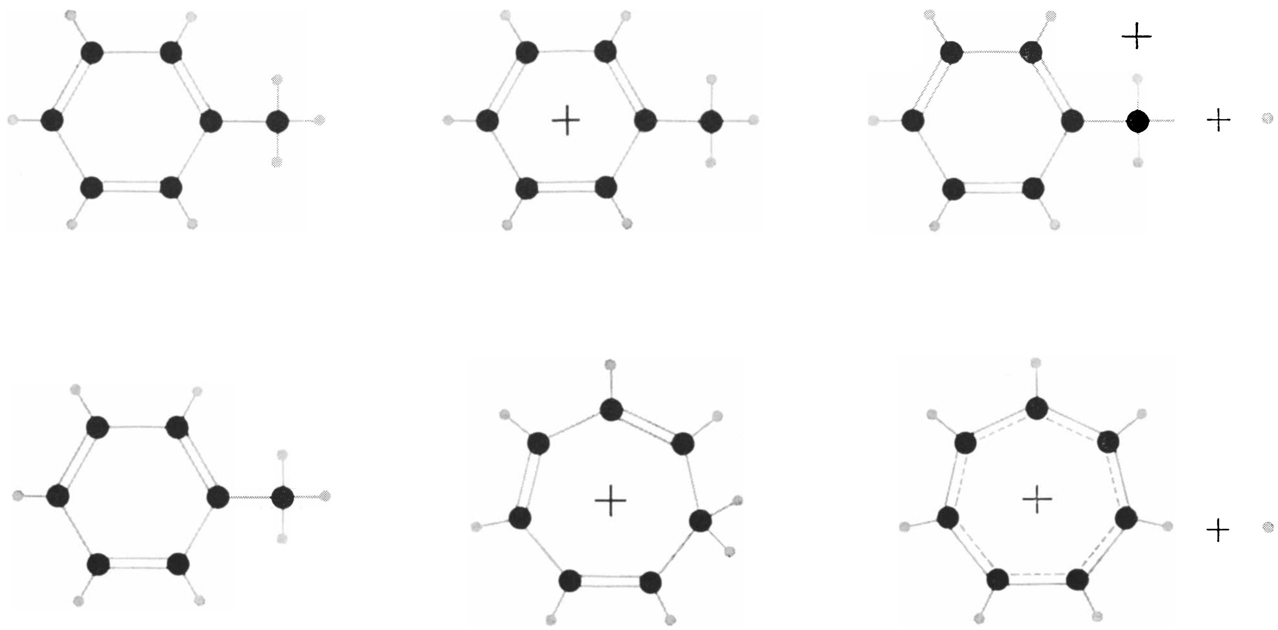
The radiation chemistry of gases has been investigated for six decades, for the past five under the leadership of S. C. Lind, now at the Oak Ridge National Laboratory. As a rule the number of molecules decomposed by radiation roughly equals the total number of primary products. The correspondence is inexact, however, because it is mediated by the complex processes of the physicochemical and chemical stages. It may even be effaced. Carbon dioxide (CO_2), for example, is hardly affected at all by radiation, presumably because reactions between free radicals lead to the reformation of CO_2 molecules. At the other extreme, a small dose of ionizing radiation will completely convert a mixture of hydrogen and chlorine into hydrogen chloride. This is the result of a chemical chain-reaction: A free hydrogen atom (H), formed by the dissociation of an excited hydrogen molecule (H_2), reacts with chlorine (Cl_2) to form HCl and a free Cl atom; the latter then reacts with an H_2 molecule to yield another HCl and a free H atom. Thus the H and Cl atoms function as catalysts and can unite vast numbers of H_2 and Cl_2 molecules. Ionizing radiation often breaks down inorganic gases into their elements. Gaseous organic compounds, on the other hand, react to irradiation in a more complex manner. The molecules of aliphatic hydrocarbons, for example, dissociate in a variety of ways, and the numerous fragments then react to yield a product that is a highly complex mixture, containing both smaller and larger molecules.

Because of the commercial possibilities inherent in the effort, the investigation of the action of radiation on organic liquids, especially petroleum products, now engages many laboratories. At the present time industrial application of radiation is slight. But there is widespread belief that another decade will see radiation in common use as a manufacturing tool. Organic radiation chemistry is, however, of great interest in its own right. It is an invaluable arena for investigating reactions of organic free radicals, and indeed provides information on many radicals, as well as excited and ionized molecules, that are not otherwise accessible to study.

All organic compounds evolve hydrogen upon irradiation. Part of this hydrogen is formed by dissociation at a carbon-hydrogen bond, resulting in a free H atom and a free radical. In many cases the H atom then proceeds to react with an intact molecule, yielding an H_2 molecule and a second free radical. The two radicals may then react with each other to form any of a variety of products, or they may combine to yield a molecule twice as large as the original one. This sort of doubling is very common among organic compounds. It is the prototype of cross-linking in giant organic molecules, which is technological-



IONIZING RADIATION IS MEASURED by two basic methods: ionization and excitation. At top is a schematic drawing of an ionization chamber. When an energetic charged particle traverses the chamber, it ionizes many molecules of gas. A voltage across the two plates sweeps positive ions to one plate and negative ions to the other. The resulting current is indicated on a meter. At bottom is a scintillation counter. When an energetic charged particle penetrates a special scintillating substance, the substance emits a flash of light. The light, trapped by a reflector, is converted into pulse of current by photomultiplier (*gray square*).



TOLUENE MOLECULE *(top left)* **behaves oddly when it is ionized. The carbon atoms in the molecule are represented by black balls; the hydrogen atoms, by gray. According to ordinary chemistry, the ionized molecule** *(top center)* **may lose a hydrogen atom but should still retain its basic six-sided ring structure** *(top right)*. **Seymour Meyerson and his collaborators have demonstrated, however, that the ionized toluene molecule forms a seven-sided ring, and that when it loses a hydrogen it is symmetrical** *(bottom)*.

ly the most promising development in the field.

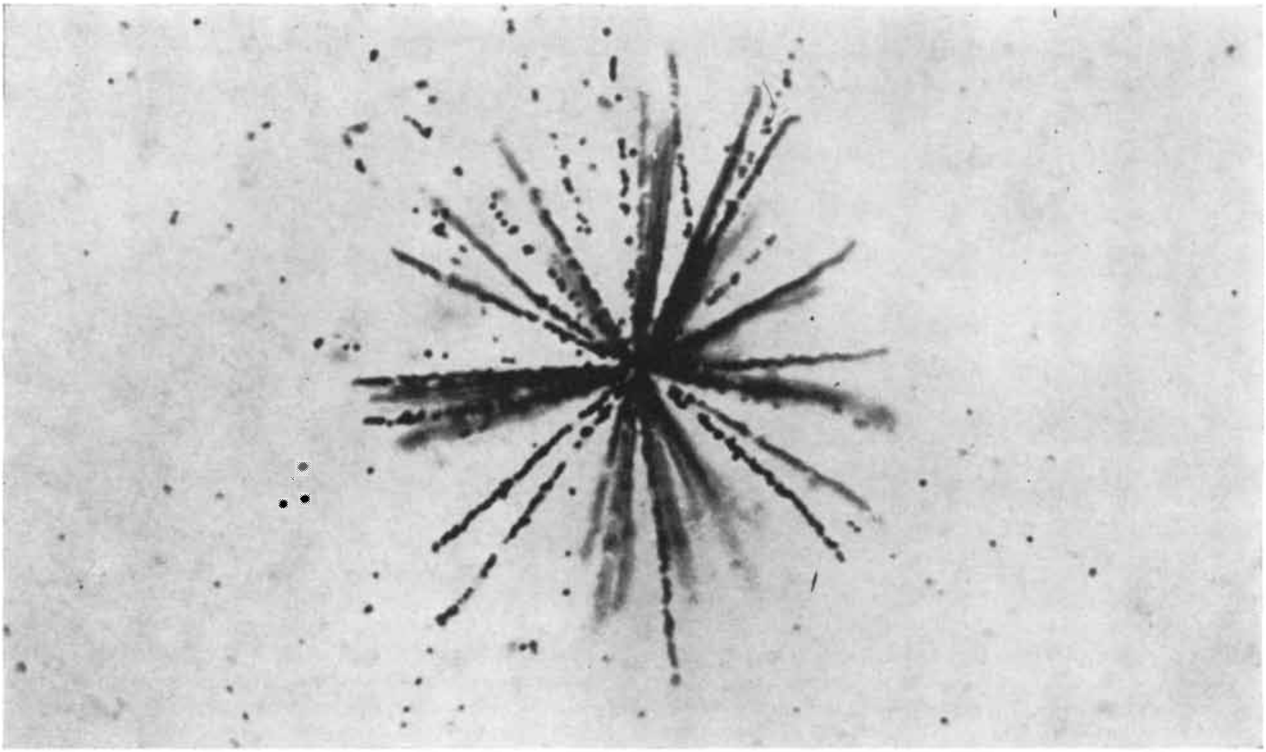
The breakdown of organic molecules invariably leads to a great number of different products. Paraffin hydrocarbons, especially, can fragment almost anywhere along their molecular chains, although there are preferred locations for the break. Most organic compounds have a normal radiosensitivity; that is, the number of molecules decomposed is approximately equal to the total number of primary excitations and ionizations produced by irradiation. Hence one molecule is decomposed for each 10 to 15 ev of energy absorbed. Aromatic substances, however, are more resistant to radiation. In contrast to the aliphatics they do not fragment but rather tend to form aggregates or multiples of the original ring structure.

Because water occupies a central role in inorganic chemistry, because it is vitally important in reactor technology and because it constitutes a major portion of the bulk of living matter, radiation chemists have given closer study to this simple substance than to any other. The events of the physicochemical stage are still quite unknown. But it has proved possible to devise consistent mechanisms for the chemical stage in a great variety of different dilute aqueous solutions on the basis of a simple hypothesis: that free H atoms and free hydroxyl (OH) radicals are the sole remaining products at the conclusion of the physicochemical stage. Presumably both excited and ionized H_2O molecules contribute to the formation of H and OH.

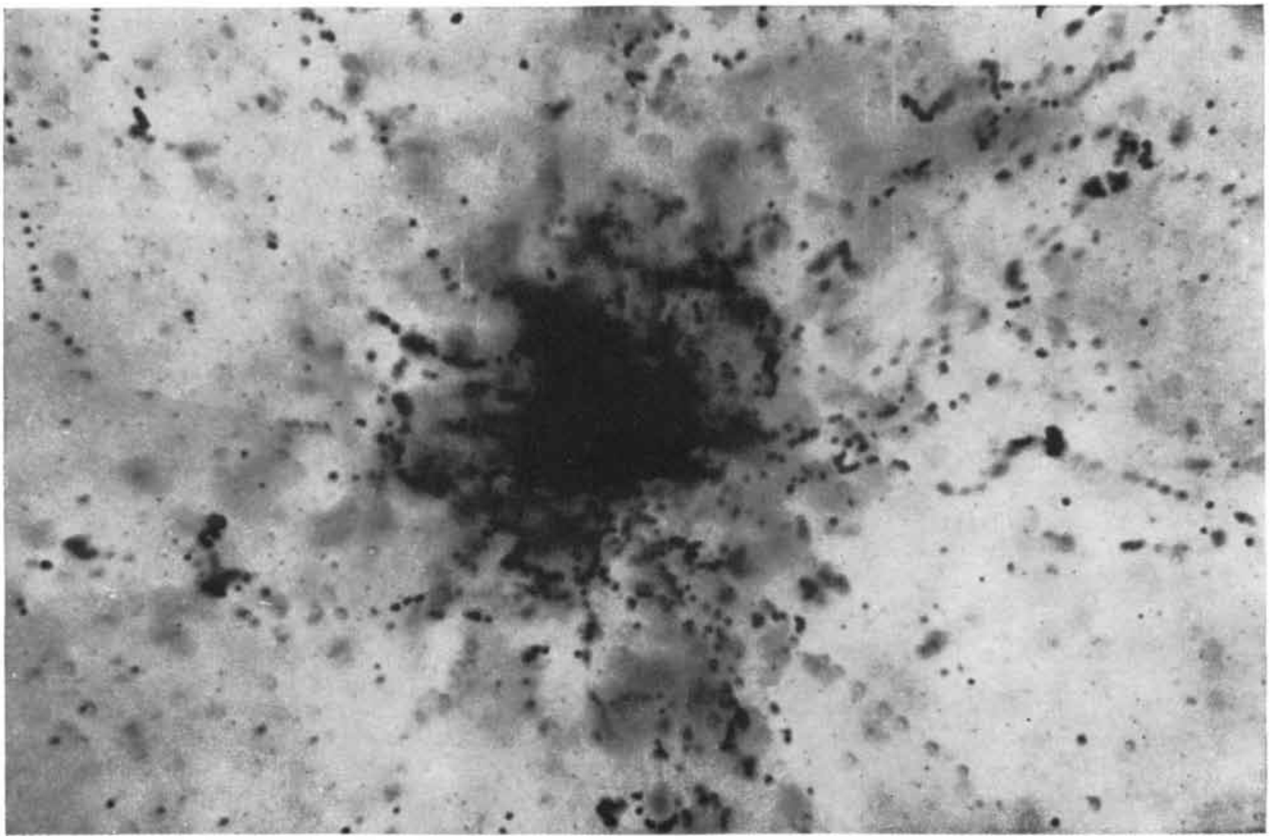
Track effects dominate the action of ionizing radiation on water. Under the action of beta rays or X-rays, which create no compact tracks, pure, air-free water remains stable. On the other hand, it decomposes readily into hydrogen and hydrogen peroxide under irradiation by particles with high LET, such as alpha particles. This gross difference in behavior finds ready interpretation in terms of the proximity of radicals along the track. The H atoms and OH radicals form principally within a narrow cylindrical region around an alpha-particle track, and in this region of extreme concentration they react rapidly. Roughly half of the H atoms encounter OH radicals and reform water, but the other half collide with H atoms and produce H_2. The OH radicals behave in like manner, combining with free hydrogen atoms to yield H_2O or with each other to form hydrogen peroxide (H_2O_2). Consequently about half of the water molecules decomposed initially by the radiation lead to final products, and very few radicals escape the reaction zone.

In the case of electron irradiation, which has a lower LET, few H atoms and OH radicals are formed in close enough proximity to react before they diffuse away into the body of the liquid. There they decompose such H_2 and H_2O_2 as may have been formed. If the water contains dissolved oxygen, its resistance to radiation of low LET vanishes. The H atoms react with O_2 to form the hydroperoxy radical HO_2, a much less reactive species, and this permits the decomposition of water to proceed unhindered. The hydroperoxy radical is implicated in many breakdown processes in which oxygen or air is present, as in biological systems.

Thus the action of ionizing radiation on matter always involves intricate mechanisms, notwithstanding the occasional superficial simplicity of its ultimate products. I hope that the reader may have savored the appeal of research in the field, and the challenges rooted in this very complexity. Among these challenges—it is almost a hallmark—is the diversity of scientific knowledge that the interpreter of radiation action must command. At the very least, mastery of many different branches of both physics and chemistry is exacted, and biological systems add a third dimension. The comfortable professional isolation of physicists, chemists and biologists is not respected by an alpha particle penetrating a living cell. Other articles in this issue will show many parts of the field in which valuable information has already accrued. One cannot divine what new horizons will be revealed.



NATURAL RADIOACTIVITY in the atmosphere is shown by this nuclear-emulsion photograph of tracks (enlarged 2,000 diameters) emitted by a grain of dust. The tracks are produced by alpha particles; their length identifies the dust as polonium, a decay product of uranium 238. The photographs on this page were made by Herman Yagoda of the Air Force Cambridge Research Center.



MAN-MADE RADIOACTIVITY in the atmosphere produced this second nuclear-emulsion photograph. The irregular tracery surrounding the dust particle is produced by beta particles. The character of these emissions identifies the substance as a fission product formed in a nuclear explosion, but poor definition makes precise identification impossible. The enlargement here is 1,200 diameters.

The Circulation of Radioactive Isotopes

Man's experiments with nuclear explosions have stimulated him to study the distribution of radioisotopes in his environment. These investigations have clarified many geophysical processes

by James R. Arnold and E. A. Martell

Life has evolved on earth in a haven relatively free of ionizing radiation. The fast-moving particles and hard electromagnetic radiation that impinge upon our planet from the sun and from elsewhere in our galaxy barely trickle through the sheltering atmosphere. Radiation from space accounts for only a quarter of the natural "background" radiation at the earth's surface. The balance comes from radioactive isotopes in rocks, soils, waters and the atmosphere.

The study of radioactivity in our environment has acquired new significance since man began to contribute measurable amounts to the total through his experiments with nuclear fission and fusion. Fortunately for us radioactive atoms are still rare, so that sensitive methods of detection are usually required. The high energy associated with nuclear processes makes it possible, however, to detect events on the scale of single nuclei. Moreover, the virtually unchangeable rate of decay (half-life) of each nuclear species allows high precision in the interpretation of data. Thus it has been possible to develop an increasingly reliable description of the world-wide transport and distribution, via the atmosphere and waters of the earth, of minute quantities of natural and man-made radioisotopes. These same studies have enhanced our understanding of the circulation of the atmosphere and the oceans.

Considerations of human welfare have prompted investigation of still a third major system of transport. This is the biosphere, with its intricate food chains that tie together the existence of living organisms. Radioactive zinc taken up in the sea by microscopic marine organisms may appear on the table in the tissues of a fish; radiostrontium from the soil of a meadow may similarly be present in a glass of milk.

Until 1932, when Frédéric and Irène Joliot-Curie produced the first artificial radioisotopes, the natural variety stood alone. Not until the first nuclear explosion in 1945 did man-made transmutations begin to influence the environment at large. Even today natural radioisotopes irradiate human beings far more intensely than man-made fallout.

Since radioisotopes are unstable by definition and thus are constantly decaying, why do they occur in nature at all? There can be only two reasons: either they were made long ago and their half-lives are long enough to permit them to persist, or they are still being made. Isotopes of both types in fact exist.

The long-lived "old" isotopes so far discovered range from neodymium 144, which has a half-life of about 5,000 trillion years, to uranium 235, which has a half-life of 710 million years. No radioisotope with a half-life of less than 710 million years occurs in this group. This fact, among others, enables us to date the formation of the earth's elements at between five and 10 billion years ago. More than a dozen long-lived natural radioisotopes have been discovered, and the list continues to grow as our methods for detecting them become more sensitive. However, three of them—uranium 238, thorium 232 and potassium 40—generate the overwhelming bulk of natural radiation in our environment.

The location of these isotopes within the earth depends not on their nuclear properties but on their chemistry. All three are easily oxidized metals. Their oxides are relatively low in density and thus occur in the crust of the earth rather than in its dense mantle and metallic core. Perhaps half of the radioactivity in the earth lies within 40 miles of the surface. This concentration significantly increases the radiation to which all living things are exposed—and makes uranium and thorium available to man's uses.

The radiation from isotopes in the crust is rapidly attenuated as it passes through rock and soil; most of the radiation that reaches living organisms originates less than six inches below the surface. The average surface radioactivity is on the order of two curies [*see glossary of terms on page 78*] per square mile, though values in different places vary by a factor as large as five. In general, the more acid rocks, such as granites, are more radioactive than the alkaline basalts; limestones show especially low radiation levels.

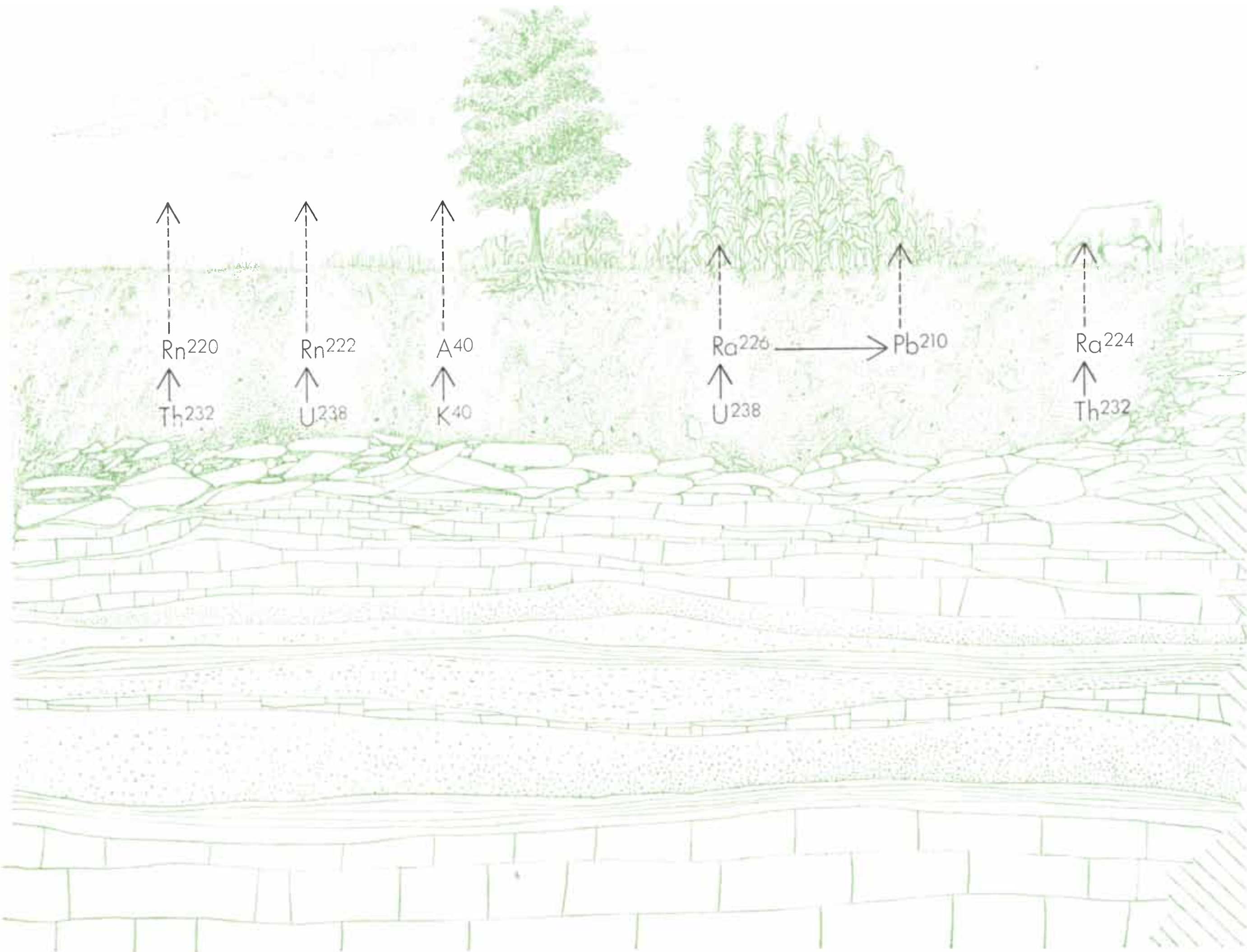
The radioactivity of potassium 40 ends with its transformation into stable calcium or argon. Uranium and thorium, however, decay into long series of radioactive "daughter" elements with half-lives ranging from several hundred thousand years down to microseconds. In impermeable rocks and other sealed reservoirs parents and daughters remain trapped together; their abundance with respect to one another dates the formation of the rock. Elsewhere they take different paths [*see illustration on next two pages*]. Thus radon, a gas, diffuses out of soils into the air. Its decay products constitute the chief natural source of atmospheric radioactivity. Radon itself has a four-day half-life and so reaches the upper atmosphere only in minute quantities. Its concentration at various altitudes tells us something about the rate at which air mixes.

As rocks weather away, some of the radioisotopes find their way in solution to the sea. Thorium quickly combines with constituents of sea water to form insoluble compounds that precipitate onto the ocean floor. Uranium precipitates far more slowly, so that its concentration in sea water reaches the comparatively high value of three parts per billion. Potassium also tends to be carried to the bottom; though virtually all of its compounds are soluble, its ions are adsorbed on particles of clay and other ion-exchange materials. This segregation of thorium and potassium lowers the already low concentration of radioisotopes in sea water; thus fishes suffer less external radiation than men.

In sea water the chemical transformations of decaying uranium lead to some unexpected effects. The second long-lived daughter of uranium 238 is thorium 230 (ionium). Its salts, like those of thorium 232, quickly precipitate into the constantly forming marine sediments. The precipitated ionium, however, eventually decays into radium, part of which dissolves out of the sediments and back into the bottom waters, whence it drifts upward. Its concentration in the ocean, like that of radon in the atmosphere, falls off from the bottom of the ocean to the top and provides an index of the slow mixing of the ocean waters.

Neither uranium 238 nor thorium 232 enters appreciably into the metabolic processes of living organisms, and neither do most of their descendants. The radiation that man receives from these elements is thus largely external. However, radium 226 and lead 210, of the uranium series, and radium 228, of the thorium series, can be taken up by plants and so travel eventually to man. In the human body they concentrate in bone and thus by themselves contribute about half as much radiation to the skeleton as do all their relatives put together. Potassium also enters into biological processes, and distributes itself through the soft tissues. It provides the bulk of the natural radiation that originates within the body.

Just after World War II Willard F. Libby at the University of Chicago opened up a whole new field of natural radioactivity. He began the study of radioisotopes produced by the most energetic radiations known: cosmic rays. These particles crash into the upper atmosphere and there shatter nuclei of nitrogen, oxygen and other atmospheric gases. On the average these collisions

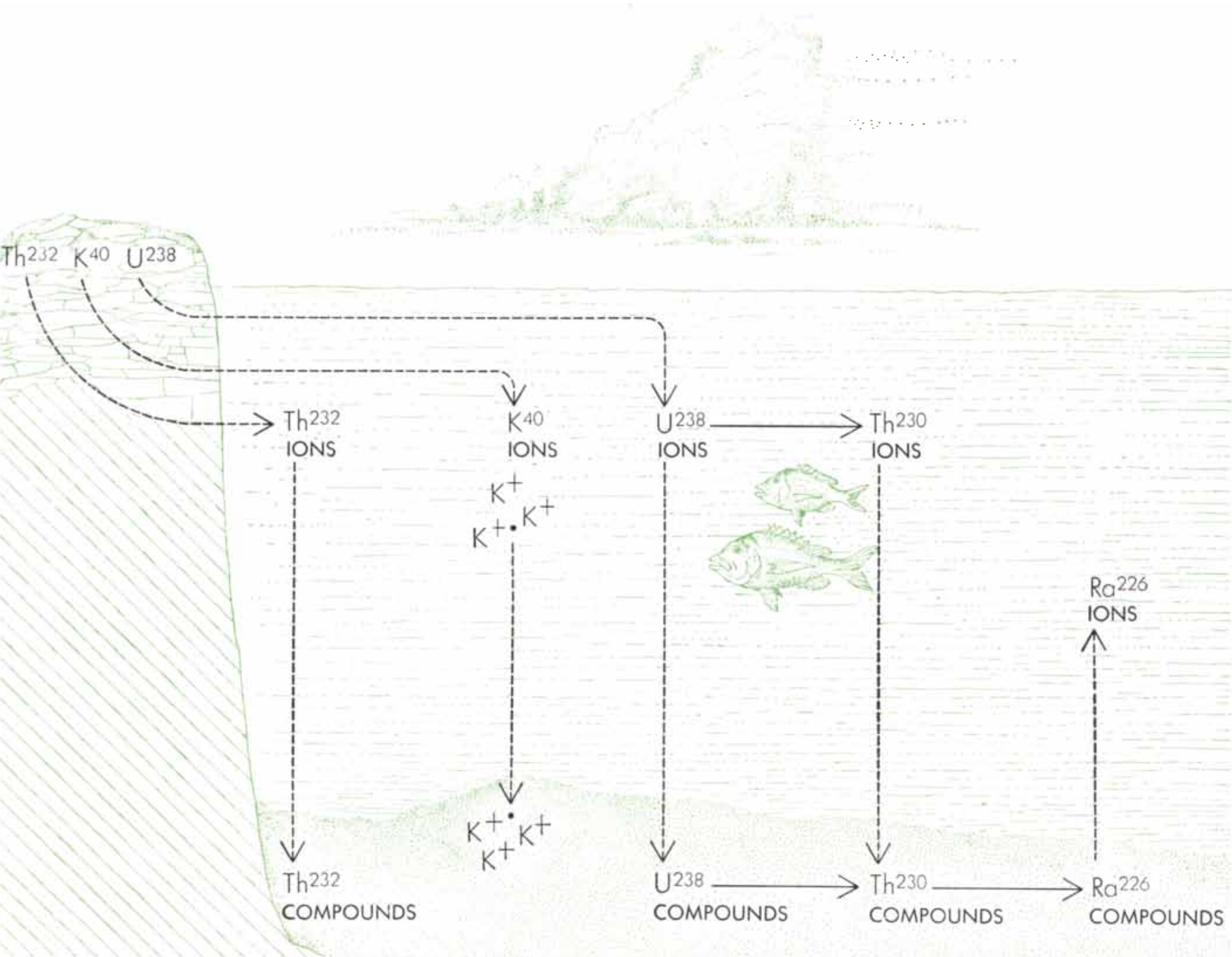


TRANSPORT OF RADIOISOTOPES from soil and rocks to atmosphere, living organisms and ocean is shown in this schematic diagram. Solid-line arrows indicate radioactive decay; broken-line arrows, physical transport of isotopes. Uranium 238 (U^{238}), thorium 232 (Th^{232}) and potassium 40 (K^{40}) are the three chief natural radioisotopes. In soils U^{238} and Th^{232} both release radon (Rn), a decay product, into the atmosphere; K^{40} releases traces of stable argon (A^{40}). Radium (Ra) and lead 210 (Pb^{210}), radio-

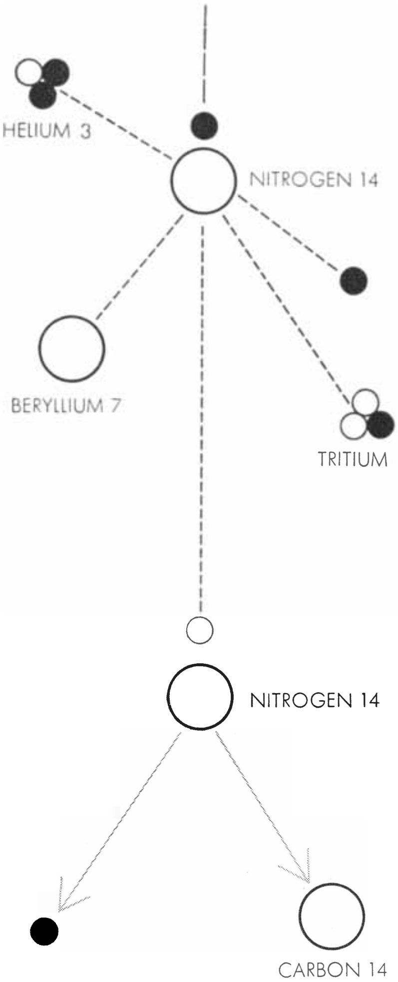
transmute about four atoms per gram of air per minute in the region between seven and 15 miles above the ground. Some of the new atoms are stable and so are indistinguishable from "old" atoms of the same nuclear species. Some, however, are radioactive and can be detected by sensitive methods. The most interesting of these is carbon 14, formed by the interaction of a secondary neutron and an atom of nitrogen [*see top illustration on next page*]. Because neutrons are common products of nuclear reactions, and nitrogen is the principal constituent of the atmosphere, carbon 14 is relatively abundant—perhaps we should say only slightly rare. The carbon 14 produced by cosmic rays accounts for about one atom of atmospheric carbon in a trillion.

The distribution of carbon 14 in the atmosphere and at the surface depends on its chemical properties, which are of course identical with those of ordinary carbon (carbon 12). Most carbon 14 exists in the form of carbon dioxide; thus it is carried in the turnover of carbon dioxide from the atmosphere into the oceans and through the biosphere. Delicate measurements of the differences in radioactive carbon dioxide in different places show that on the average a carbon dioxide molecule spends five years in the atmosphere, five years in the surface layers of the ocean and 1,200 years in the deep waters. Such calculations are made possible by the long half-life of carbon 14 (5,600 years) and the precision with which its concentration can be measured. If the time-scale of the turnover of carbon dioxide were extremely short with respect to the half-life of carbon 14, all parts of the atmosphere-ocean exchange system would maintain approximately the same ratio of carbon 14 to stable carbon 12. However, if carbon 14 atoms are "kept waiting" (as they are at the interface between the atmosphere and the oceans), some of them will decay in the air rather than in the water, giving atmospheric carbon dioxide a slightly higher radioactivity. Measurable differences of this sort actually exist; they enable us to plot the planetary circulation of carbon dioxide.

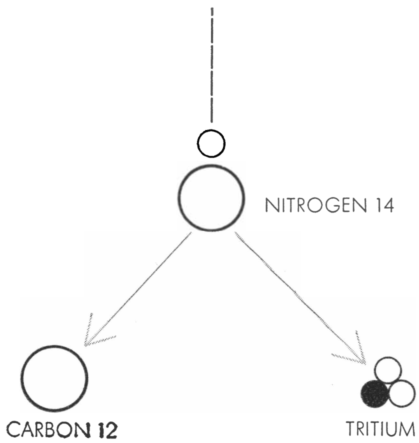
Since living organisms consist almost entirely of carbon compounds and water, carbon 14 is concentrated as it passes through the biosphere. Its internal emissions in human tissues amount to about 1 per cent of the background radiation.



active decay-products of uranium and thorium, can be absorbed by plants and then by animals. Thorium washed into the ocean rapidly precipitates as insoluble compounds. Potassium remains in solution, but some of its ions become attached to particles of clay (*black dots*) which fall to the bottom. Uranium precipitates more slowly than thorium. Its decay product, thorium 230, precipitates rapidly, but decays into radium, some of which dissolves back into the ocean. Diagram does not show all steps of the decay reactions.



CARBON 14 is formed in the atmosphere by a two-stage process. A high-energy proton (*black sphere*) from space shatters a nitrogen atom; one of the fragments, a neutron (*white sphere*), reacts with another nitrogen atom, yielding carbon 14 and a proton



TRITIUM (hydrogen 3) is produced by a similar process; in this case the reaction between the neutron and the nitrogen atom yields tritium and carbon 12. Tritium can also be produced by the shattering of a nitrogen atom, as shown in the drawing at top.

The relative abundance of carbon 14 in organic substances gives the archaeologist a technique for dating wood, bone and other old organic materials.

Man's consumption of fossil fuels during the past 50 years has been decreasing the radioactivity of atmospheric and biological carbon. Because the carbon 14 in coal and oil has long since decayed, the carbon dioxide from the combustion of these substances, amounting to about 15 per cent of the mass of atmospheric carbon dioxide, is nonradioactive and has diluted the carbon 14 content of the atmosphere. As the inert carbon dioxide has mixed into the oceans our consumption of fossil fuels has provided a sort of tracer experiment in reverse.

Another cosmic-ray product of great scientific interest is hydrogen 3 (tritium). Tritium is formed by a number of processes, most often by the transmutation of atmospheric nitrogen atoms. Only about 20 pounds of natural tritium exist on earth, the bulk of it in the oceans. Combining with oxygen to make water, it reaches the earth as rain or snow. With a half-life of only 12.5 years it does not travel nearly so far as carbon 14 before disintegrating. Water samples from different sources show marked differences in tritium content. Because of the vast quantity of normal water in the ocean, water evaporating from the ocean surface has a low tritium content; as the water moves upward in the atmosphere its activity is increased by tritium from above. Water evaporated from land, on the other hand, consists mainly of recent precipitation relatively rich in tritium. As an air mass moves across a continent it is enriched with tritium from below as well as above. The cycle is closed when the rain falls on the ocean, and its load of tritium mixes into the surface water. A significant amount of tritium is also carried into the deep ocean before it decays.

The tritium picture has been badly blurred in recent years by the relatively enormous quantities of the isotope released in the testing of thermonuclear bombs. Some puzzling recent measurements have suggested that even apart from bomb tests the earth contains much more tritium than can be accounted for by cosmic-ray production. Studies now under way may resolve this problem before long.

One does not use a grandfather clock to time a footrace, nor a stop watch to reckon the passing of the seasons. An isotope "clock" must likewise be chosen for its appropriateness to a particular scale of time. The best uranium measurements, for example, are accurate to no more than 20 million years—a small error in measuring the age of the earth but hopelessly too large to resolve the comparatively recent onset of the Ice Age. As our list of cosmic-ray-produced isotopes expands, we are finding that nature has been remarkably accommodating in providing clocks suitable for a variety of measurements. Thus beryllium 10, with a half-life of 2.5 million years, promises to help fill the gap between uranium and carbon-14 dates. Silicon 32, with a half-life of 700 years, may enable us to time processes of oceanic mixing for which the carbon-14 clock is too slow and the tritium clock too fast. Phosphorus 32, beryllium 7 and sulfur 35, with half-lives of a few weeks, serve to clock the much faster processes of atmospheric circulation. Certain man-made isotopes, principally those generated in nuclear explosions, are beginning to be used for the same purpose.

Starting with the first thermonuclear explosions in 1952, the testing of nuclear weapons has been radically altering the relative abundance of radioactive isotopes in the environment. The energy yield of all the tests conducted by the three nuclear powers prior to the tacit agreement to suspend tests in November, 1958, had added up to 174 megatons (equivalent to the yield from 174 million tons of TNT), of which 92 megatons came from the fission of heavy nuclei and 82 megatons from the fusion of light nuclei. From these tests, as their principal radioactive by-product, came more than 4.5 tons of fission products: the direct offspring of the fission of uranium and plutonium, which are produced at the rate of roughly 100 pounds per megaton of fission yield. Thermonuclear explosions in addition yield tritium as a direct product of the fusion reaction; the total output to date is estimated at 100 pounds, about five times the amount of natural tritium. Other isotopes arise as secondary products of the interaction of neutrons with the materials of the bomb and the gases of the atmosphere, and with the substances in the soil and sea if the burst is at the surface. Among these isotopes the most abundant is carbon 14.

Produced at a considerably higher rate over the past seven years than the natural product of cosmic-ray neutrons, the man-made carbon 14 now in circulation around the earth amounts to about one ton and equals about 1 per cent of the total natural abundance. Most of it is still in the atmosphere compounded in carbon dioxide. In living organisms it has raised the carbon-14 content as much as 10 per cent above normal, a situation that may confuse future archaeologists.

The fission products liberated by the nuclear explosion would be cause for greater concern than they have aroused were it not for the fact that most of them are so short-lived. Roughly speaking, the radioactivity of the fission-product mixture decreases by 90 per cent for each seven-fold increase in time following the explosion that produced it. Thus the level of activity seven hours after the explosions is about a tenth the level after one hour; two weeks (about 7^3 hours) later the activity has dropped to about a thousandth the one-hour figure.

Of the more than 90 different radioisotopes identified among the fission products, two have figured at the center of scientific and public concern: strontium 90 and cesium 137. Both are produced in substantial quantities by nuclear fission, both have relatively long half-lives (about 25 and 30 years respectively) and both become engaged in the metabolism of the human body. Neither element is a normal constituent of biological processes. But the chemistry of strontium resembles that of calcium. Like calcium it concentrates in the bone, where its radioactivity may give rise to leukemia and bone tumors. Strontium 89, a short-lived fission product, follows the same metabolic pathway. Cesium, on the other hand, somewhat resembles potassium and its radioisotope concentrates in the soft tissues of the body, with particular hazard to the genes.

Tests so far have produced about 140 pounds of strontium 90, with a total radioactivity of nearly 9.2 million curies. By the end of 1958 decay had reduced these figures to about 130 pounds and 8.5 million curies; cesium 137 radioactivity at the same time amounted to 15 million curies.

Two other isotopes, iodine 131 and barium 140, have recently attracted attention. Barium, like strontium, concentrates in the skeleton; iodine, in the thyroid gland. Because they have short half-lives, radioiodine and radiobarium have been at near-zero levels since early this year. Other bomb products, such as radioisotopes of zinc and cobalt, may play a minor role in marine ecology, because some oceanic organisms concentrate relatively enormous quantities of these elements in their tissues. However, only minute quantities of these isotopes are likely to reach human beings.

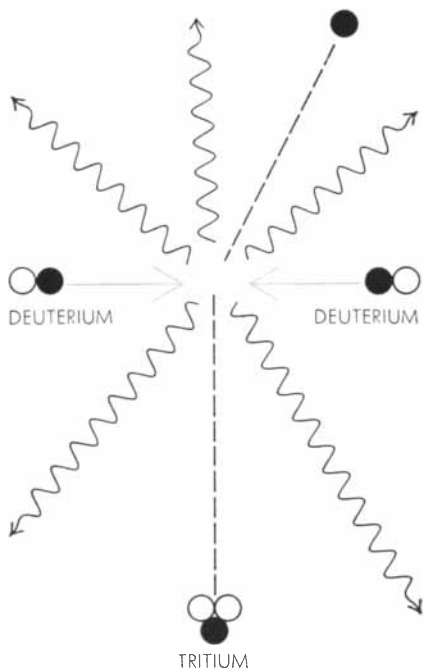
The distribution of strontium 90 and other fission products, and hence their effects on man, depend largely on the type and location of the explosion that produced them. Surface explosions over land vaporize and irradiate great quantities of soil and so yield a heavy local fallout; 80 per cent of it comes down in a matter of hours, spreading downwind from the site of the explosion in an irregular elliptical pattern. Over water the close-in fallout drops to as low as 20 per cent of the total. Although contamination of areas adjacent to testing sites has occurred, local fallout has played only a small role in human affairs. In war, however, local fallout from a megaton weapon would deliver lethal external gamma radiation to unsheltered people in areas of thousands of square miles, and the strontium 90 would render soils unfit for agriculture over even larger areas for generations afterward.

Detonations of 100- to 200-kiloton yield at or near the surface propel their fission products no higher than the troposphere, the turbulent lower layer of the atmosphere. Convection currents in the troposphere rapidly mix air from various altitudes, so that tropospheric fallout comes down in a few months at most. Most of it is scavenged by rain or snow, with the larger particles simply drifting to earth. Since tropospheric winds rarely cross the Equator, most tropospheric fallout remains in the hemisphere where it originated. It accounts for only a small percentage of the fallout from weapons tests.

High-yield nuclear tests thrust their radioactive clouds into the stratosphere, where vertical mixing of air is slow and precipitation nil. The tiny radioactive particles (less than 1/10,000 inch in diameter) remain aloft for periods ranging from months to years, and are spread over large parts of the earth's surface by high-altitude winds. Stratospheric fallout, which accounts for about two thirds of total fallout, is the dominant source of artificial radioactivity that weapons tests have introduced into the environment.

The first observations of stratospheric fallout indicated that it remained aloft for five to 10 years—long enough to become evenly distributed between the Northern and Southern hemispheres. This comported with the idea that the stratosphere was a continuous, stable envelope enclosing the turbulent air masses of the lower atmosphere. Recently, however, the record revealed that the fallout has tended to concentrate in the North Temperate Zone and to come down at a maximum rate in the spring. Some investigators proposed that seasonal and latitudinal variations in the transport of air from stratosphere to troposphere might be responsible. However, this hypothesis did not explain the absence of comparable concentrations in the Southern Hemisphere.

By measuring the ratios of long-lived to short-lived fallout isotopes in rainwater, investigators have been able to establish the time and place of the explosions that generated the fallout. Since the initial proportion of one fission product to another is about the same in each nuclear explosion, such measurements make it possible to extrapolate backward from the observed ratios and thus to estimate the dates of the original explosions. Recent interpretations of these measurements have revealed the existence of stratospheric fallout much "younger" than five years. During the summer of 1958, a separate study of rainfall from the tropical air masses that move up over the U. S. from the Gulf of Mexico showed that the extrapolated time of origin of the fallout delivered by this rainfall matched the dates of certain U. S. medium-yield tests conducted several months previously. Fallout in rains from "polar" air masses during the same period had apparently originated in high-yield Soviet tests conducted a

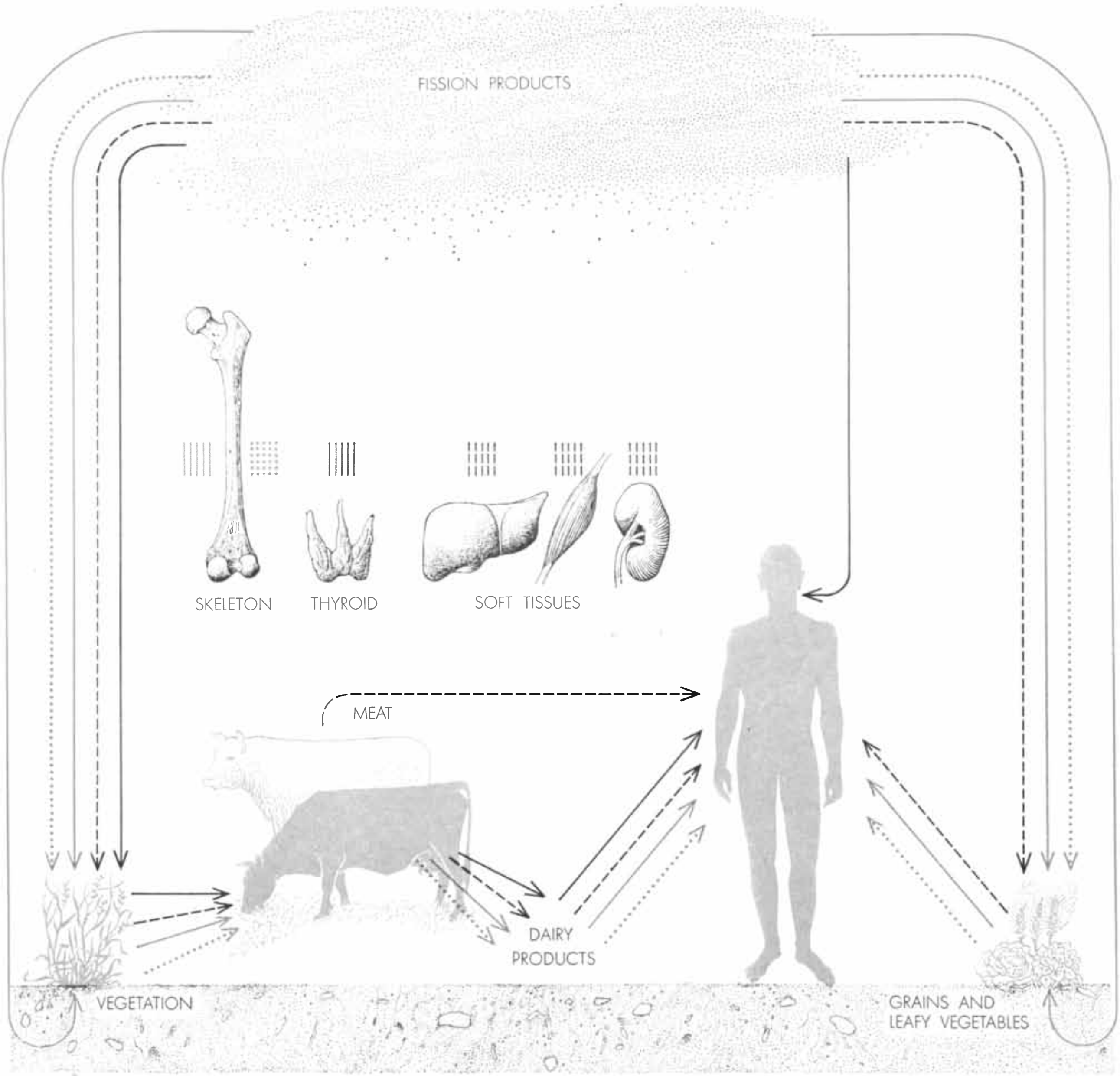


MAN-MADE TRITIUM is a by-product of some thermonuclear (fusion) reactions, such as that between two deuterium (hydrogen 2) atoms; proton (*black sphere*) is another by-product. The reaction also yields energy in the form of gamma rays (*wavy arrows*).

little earlier. The highest concentrations of strontium 90 were invariably associated with the Soviet tests.

The unexpected rapidity of the stratospheric fallout from Soviet tests focused attention on a peculiarity of the tropopause, the boundary between stratosphere and troposphere. Over the Equator, the tropopause lies about 10 miles up. Over the middle latitudes it dips sharply to about six miles. Here the jet streams—high-altitude winds that blow from west to east parallel to this dip—create a gap in the tropopause. Several meteorologists had already called attention to the possibility that the stratosphere and the troposphere exchange air through the gap.

A little calculation showed that Soviet fallout injected into the lower stratosphere could have been carried by the movement of stratospheric air through the tropopause gap into the troposphere, where vertical mixing would bring it fairly rapidly to earth [*see illustration on page 93*]. Fallout from U. S. and British high-yield tests, all of which have taken place near the Equator, has been evenly distributed over the world. Soviet tests, on the other hand, have been carried out north of a latitude of 50 degrees. Substantially all the fallout they have



PATHS OF ENTRY by which fallout reaches human beings are shown schematically for the five fission products of greatest biological importance. Strontium 89 and 90 (*solid colored arrows*) reach man through the soil and, more directly, by contaminating surfaces of plants. Cesium 137 (*broken black arrows*) forms insoluble compounds in soil and thus reaches us only by the more direct paths. Iodine 131 (*solid black arrows*) and barium 140 (*dotted arrows*), because of their short half-lives, reach man only as surface contaminants and (in the case of iodine) by inhalation. Once absorbed, the isotopes concentrate in different parts of the body.

produced has remained in the Northern Hemisphere. Most of it has reached or will reach the ground in the densely populated North Temperate Zone. The spring peaks in fallout evidently stem from the timing of the Soviet tests, which have been conducted in the autumn and winter.

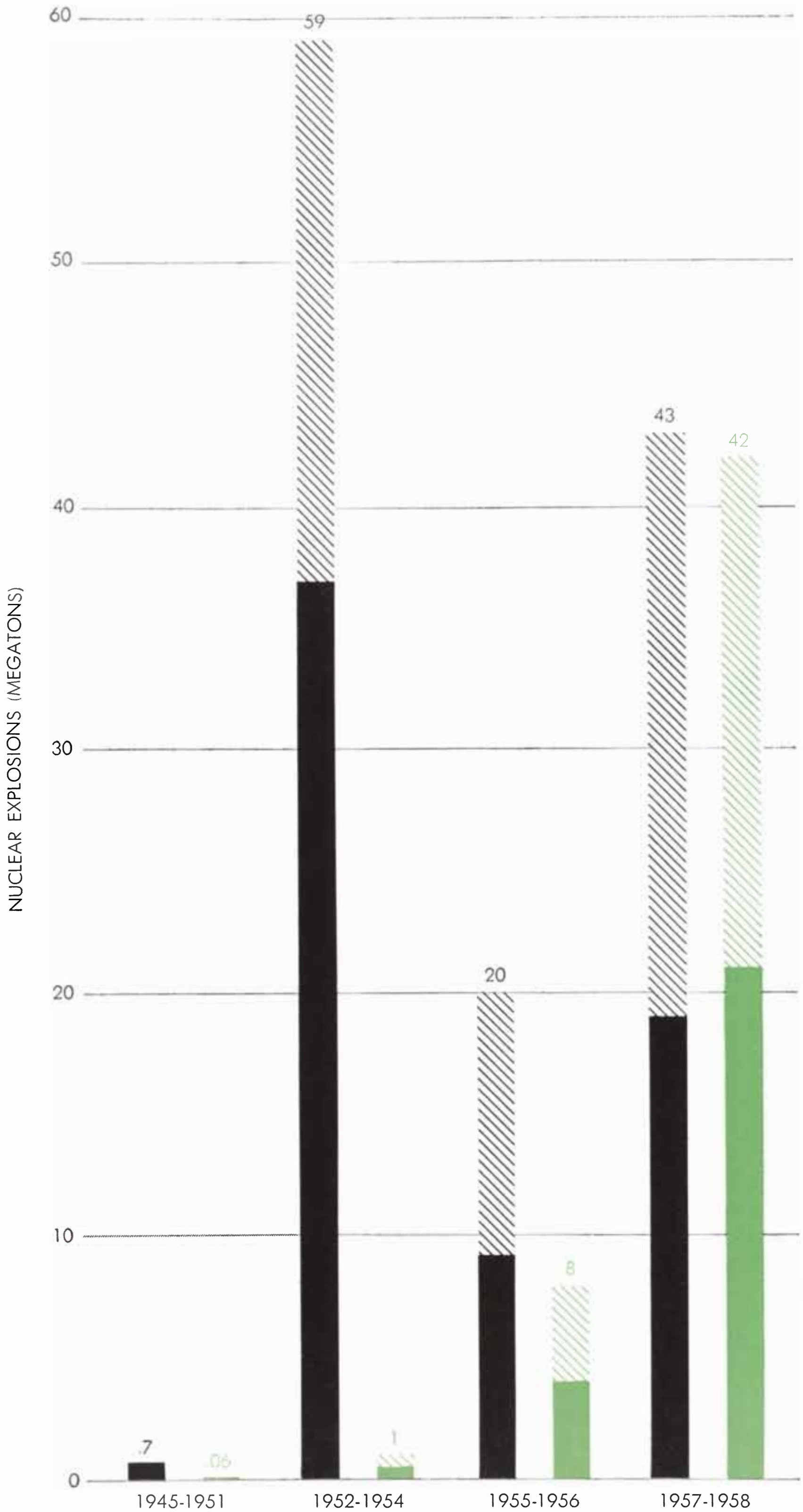
The tests in the U.S.S.R. last October gave strong confirmation to this theory: they produced a record peak in the fallout of strontium 90 over the Northern Hemisphere this past spring. Short-lived fission products appeared in this fallout in high concentrations, while throughout the Southern Hemisphere they remained near zero.

These findings with respect to man-made fallout suggest that a similar pattern may be found in the distribution of "fallout" from cosmic-ray action. Because the magnetic field of the earth funnels cosmic rays toward the poles, the major production of natural radioisotopes occurs in those latitudes and would presumably come to the surface via the gap in the tropopause.

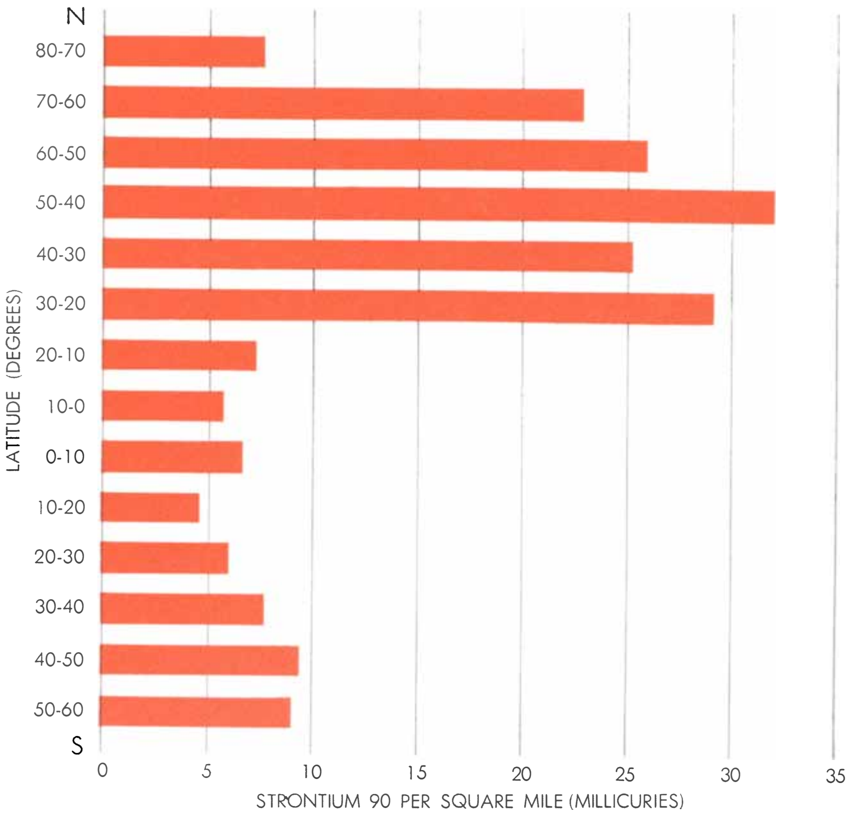
The revised picture of atmospheric circulation makes it possible to forecast with some assurance the present and future distribution of strontium 90. From the nine million curies of this isotope produced to date, local fallout on U. S. and British test sites or in the Pacific Ocean subtracted three million curies at the outset. The Soviet tests produced little local fallout, since few or none of them were surface shots. Thus essentially all the remaining six million curies were injected into the stratosphere.

On the basis of a recent world-wide survey of strontium in soils, made by L. T. Alexander of the U. S. Department of Agriculture, it appears that 3.2 million of these six million curies had already come down to earth by October, 1958: 2.4 million in the Northern Hemisphere and .8 million in the Southern. The strontium reached a peak concentration, averaging about 33 millicuries per square mile, between 40 and 50 degrees north latitude. As for the 2.8-million-curie balance still in the stratosphere, the atmospheric circulation data indicate that most of it will have fallen out by 1965. Coming down in the same geographic pattern, it will approximately double the radioactivity of the soil produced by strontium 90 as of October, 1958. The fallout of cesium 137 should follow a similar pattern, and will contribute a somewhat higher radioactivity to the soil.

So long as these man-made radioisotopes remain on the ground, their



INCREASE IN NUCLEAR EXPLOSIONS since 1945 is depicted in this chart. Black bars indicate U. S.-British explosions; colored bars, Soviet tests. Fission explosions, indicated by solid parts of the bars, are the chief source of man-made environmental radioactivity, yielding about 100 pounds of fission products per megaton. Fusion reactions, shown by hatching, produce almost no fallout. The proportion of fission to fusion in Soviet tests is estimated.



CONCENTRATION OF FALLOUT in the Northern Hemisphere is shown on this chart, based on a world-wide study of strontium in soils by L. T. Alexander of the U. S. Department of Agriculture. The concentration results from the peculiarities of atmospheric circulation shown on the opposite page. Fallout still aloft will roughly double these figures by 1965.

activity constitutes only a small addition to the external background-radiation to which living things are exposed. But once they are entrained in the chemistry of the biosphere their effective activity is heightened by concentration, and they irradiate living cells and tissues from within. Not many fission products find a place in biochemistry. The few that do follow various pathways in the food chain and some of them ultimately arrive in the tissues of human beings.

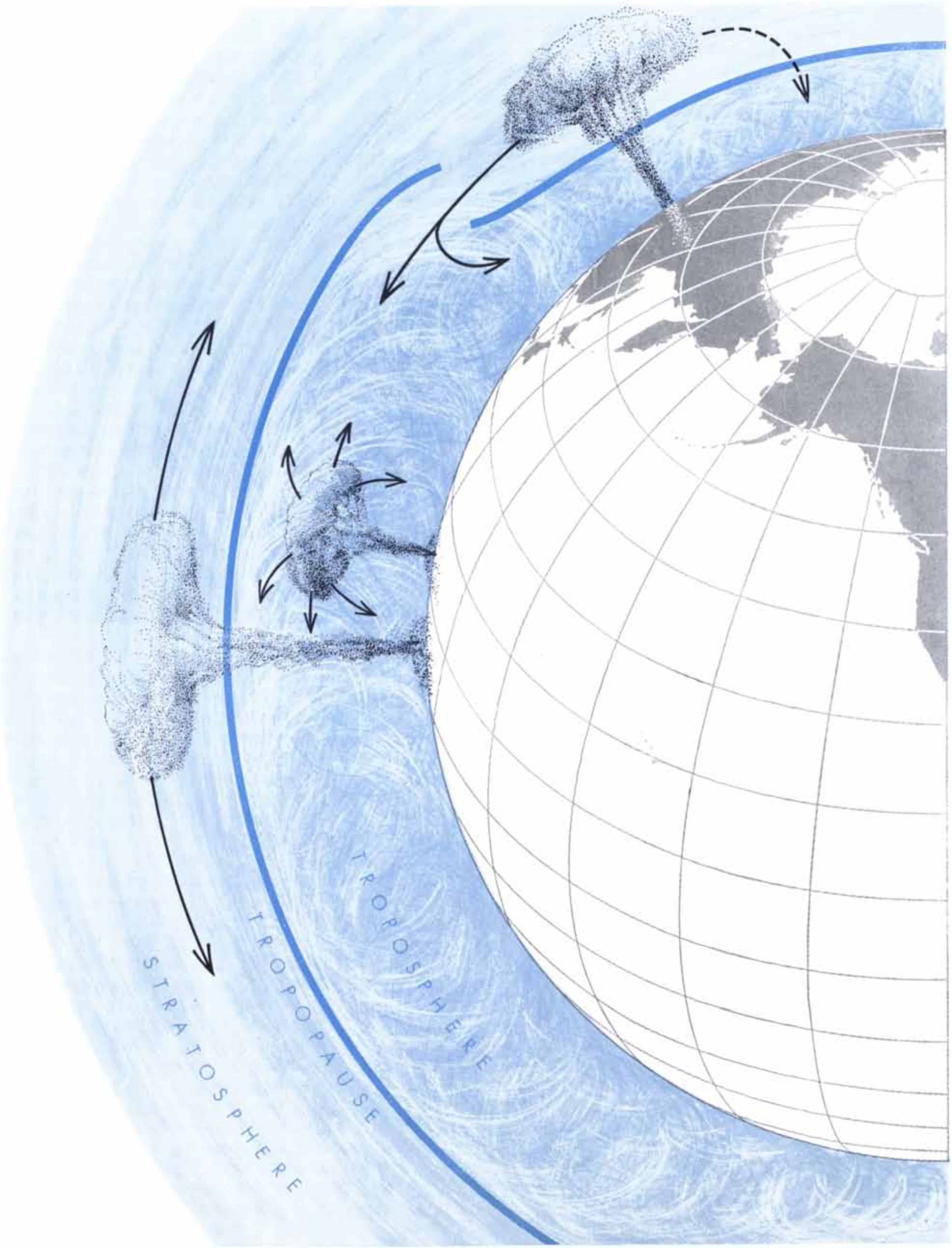
Strontium 90, for example, can be picked up from the soil in the metabolism of a plant, ingested by a dairy cow and delivered to the table in milk or butter. It may, however, skip one or more of these links in the food chain and arrive as a mere surface contaminant adhering to leafy vegetables and grain. Cesium 137, on the other hand, tends to form insoluble compounds in the soil and thus does not enter into plant metabolism. It is, however, ingested by beef or dairy cattle as a contaminant of grasses and passed on in meat or milk.

At each stage in the food chain the nutritional processes of the plant or animal tend to discriminate against strontium 90 in favor of its chemical analogue, calcium. Thus the ratio of radiostrontium to calcium will decrease as the two move together up the chain. At the first stage it seems that the strontium-calcium ratio in the plant varies not only with the ratio in the soil, but also with the character of the soil and ground cover, the method of cultivation and the type of plant. For example, in a soil matted with roots the radiostrontium coming down from above will not be so quickly diluted with calcium and so will be absorbed by the plant in a higher ratio to calcium. In animals, according to C. L. Comar of Cornell University, the chemical balance of metabolism regulates the strontium-calcium ratio more rigorously; the animal preferentially incorporates calcium into its tissues and rejects strontium. The ratio in a cow's milk is about 11 per cent of the ratio in the animal's fodder. In the human body the ratio diminishes still further; Comar estimates that the overall decline in the ratio from plant to man will be 90 per cent in the case of the average U. S. citizen, who obtains most of his calcium from dairy products. Where people live on a cereal diet and get most of their calcium from plants, without the intervening discrimination by animal metabolism, the drop is smaller. In any case the introduction of the radioisotopes into the tissues raises the effective biological activity far above the contribution that the same quantity of radioisotopes makes to external background radiation. Clearly the subject of biological transport of fallout requires much more research.

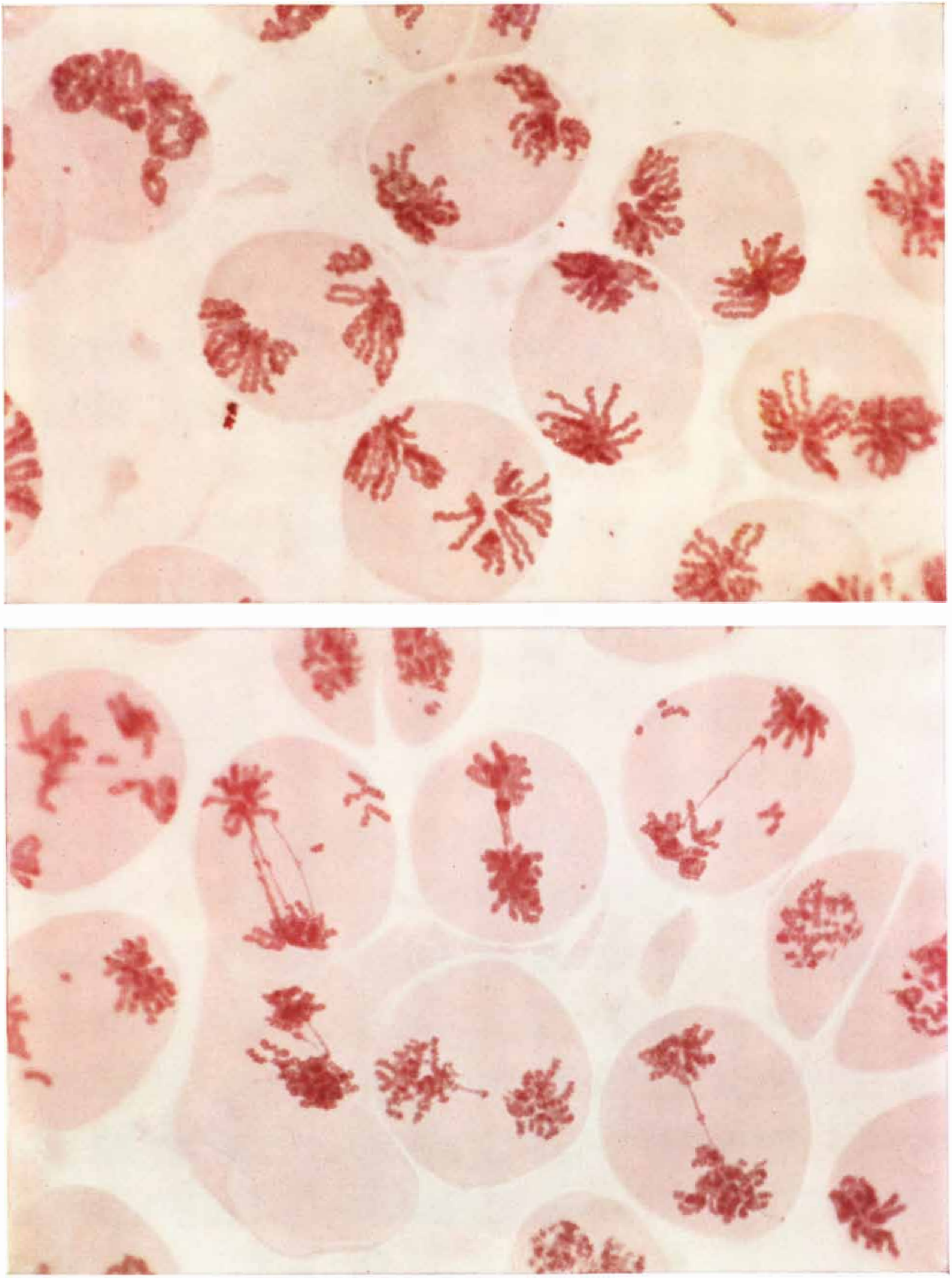
Some recent tracer experiments promise to refine our knowledge of the fallout of natural and man-made radioactivity and of its ultimate distribution over the earth. During the U. S. nuclear tests of last summer, rhodium and tungsten were incorporated into some of the bombs. Neutrons from the explosions partially transformed them into the radioisotopes tungsten 185 and rhodium 102. The travel of these isotopes in the atmosphere can be followed easily. Tungsten 185, with a half-life of 74 days, was injected by several medium-yield explosions into the lower stratosphere. Several laboratories are sampling stratospheric and surface air and analyzing precipitation at a number of points in order to follow its history; the findings of this study should be published by the end of this year. Rhodium 102, with a longer half-life of 210 days, was chosen to study the longer-term processes at higher altitudes, and so was injected chiefly into the upper stratosphere. By comparing its history with that of the tungsten we should obtain some useful measurements of the effect of altitude on residence time and distribution of fallout.

The waste products of nuclear reactors constitute an additional source of man-made radioisotopes. These wastes, mainly fission products, pose many of the same biological problems as bomb debris. Indeed in the long run—barring a nuclear war—radioactive wastes will far outweigh the products of nuclear explosions. Fortunately man can decide within wide limits when and where he will release these substances into the environment. Our expanding knowledge of the atmosphere and ocean should enable us to do so in such a way as to minimize their effect on living organisms.

As this article is written, international discussions of a ban on the testing of nuclear weapons are continuing at Geneva. Such a ban would bring an end to this peculiar form of atmospheric contamination. As a consequence it would certainly improve our opportunity to investigate the fallout of both natural and artificial radioactivity and thus to learn more about the circulation of the oceans and the atmosphere.



DISTRIBUTION OF FALLOUT depends on the size and location of the original explosion. High-yield test near the Equator (*left*) thrusts its fission products into the stratosphere, where horizontal circulation slowly spreads it over both hemispheres. Low-yield test (*left center*) does not reach the stratosphere; vertical mixing in the troposphere brings down its debris into one hemisphere in a matter of weeks. Debris from high-yield Soviet test at high latitudes (*top*) will be carried by horizontal circulation through tropopause gap and to some extent through the tropopause itself at higher latitudes (*broken arrow*). Most of it will come down over the North Temperate Zone. The scale of the atmosphere and the explosions is greatly exaggerated for purposes of clarity.



EFFECT OF RADIATION ON CHROMOSOMES is depicted in these photomicrographs made by Arnold H. Sparrow and Robert F. Smith of the Brookhaven National Laboratory. At top are cells from the wake-robin plant (*Trillium erectum*); their threadlike chromosomes have been stained with acetocarmine. At bottom are cells in same stage of division that had earlier been exposed to 50 r of X-rays. In many of these cells are fragments of chromosomes and chromosome bridges. The cells are enlarged about 1,000 diameters.

Ionizing Radiation and the Living Cell

The primary site of the biological effects of radiation is in the cell. The specialized structures of the cell, including the genes, are damaged not only by direct hits but also by the chemical products of radiation

by Alexander Hollaender and George E. Stapleton

The processes of life involve a relatively low turnover of energy and a high degree of self-regulating harmony. In contrast, ionizing radiation conveys huge packets of energy and, upon interaction with living matter, provokes anarchy. The consequences may run, in extreme circumstances, to the derangement of the hereditary mechanism or to the death of the organism. In every case the ultimate damage arises from the injury done to individual cells. But injury to the cell must itself be understood in terms of the events that occur in the substance of the cell along the path of the ionizing ray or particle. Like the ionizations that mark the track of a particle in a cloud chamber, these are discrete and specific events in which particular molecules are involved. The biological outcome thus depends not so much on the amount of energy impinging on the cell as on the energy absorbed by the molecules caught in the track of ionization.

As Robert L. Platzman has observed elsewhere in this issue [see "What Is Ionizing Radiation?," page 74], free ionized molecules are uncommon in biology except as the primary products of ionizing radiation. These may be otherwise intact molecules, with one or more electrons stripped from them, or the ionized fragments of larger molecules. In their highly reactive state they enter almost instantly into reactions with one another and with neighboring molecules, producing as their end products new substances strange to the chemistry of the cell. The unstable secondary products, notably free radicals and peroxides, relay the disturbance in turn to other molecules in the cell, enlarging the area and scope of the injury. It is in the secondary, chemical phase of this process that the biologist begins his studies. Recent investigations have indicated that a limited portion of the damage is amenable to experimental modification. Experiments on this line have begun to elucidate the steps between the primary physical event and the biological expression of its impact upon the cell.

Many years ago radiobiologists first noted that the number of cells inactivated by a given exposure to radiation is a simple function of the number of living cells present. In other words, the fraction of cells damaged per unit dose is constant. Investigators also observed that the number of cells in which genetic mutation occurs follows the same rule. Thus the biological effects show up in accord with the randomness of events along the paths of ionizing particles. J. A. Crowther of the University of Cambridge therefore postulated about 35 years ago that the death or inactivation of a cell results from a "hit" on a sensitive spot. Implicit in the hit theory was the assumption, later confirmed by experiment, that certain biological consequences may follow from the passage of a single particle or from the ionization of a single molecule or cellular structure. Crowther's hit theory was duly amended by the "target" theory, which postulates that the incidence of hits is related to the size of the sensitive structure or molecule: the fewer the hits required to inactivate the cell, the larger the structure must be.

Radiobiologists thus found themselves in possession of a technique for determining the size, shape and structure of key submicroscopic parts of the single cell. In order to ensure that the effect under investigation is the direct result of the primary ionization, the technique requires the removal of water and other molecules that aid in the transfer of energy from the primary event. Although the effects observed on dehydrated cells are not necessarily comparable to the effects on cells in their natural state, such investigations have yielded important information. Inactivation studies using particles of various energies have provided the basis for constructing models of virus particles and bacterial spores which in some cases have shown a close resemblance to the structures later observed by electron microscopy. Since high-speed electrons have a low probability of hit, as Platzman explains in his article, they are used to measure the volume in which a collision will produce inactivation. For example, the three-dimensional structure of bacterial spores was plotted with electron beams of various energies, from a beam that was barely able to penetrate the spore coat to one that could permeate the sensitive material within the spore. On the other hand, the high probability that an alpha particle will interact with molecules in its path makes it possible to use these particles to find the cross-sectional area of the structure under investigation. The same technique has even been applied to the determination of the shape and size of individual biological molecules.

In the opinion of some biologists, however, the dehydration necessary for these studies removes precisely those complicating indirect and secondary reactions that are of significance in the intact living cell. Since the cell is 75 per cent water, it is apparent on the basis of abundance alone that more energy is absorbed by the water molecule than by any other molecule in the cell. The peroxides and free radicals that result from the ionization of water are among the most important toxic agents involved in the ultimate inactivation. By diffusing through the water in the cell these agents may act directly on the target molecule or indirectly via the reactive products of their action on other molecules.

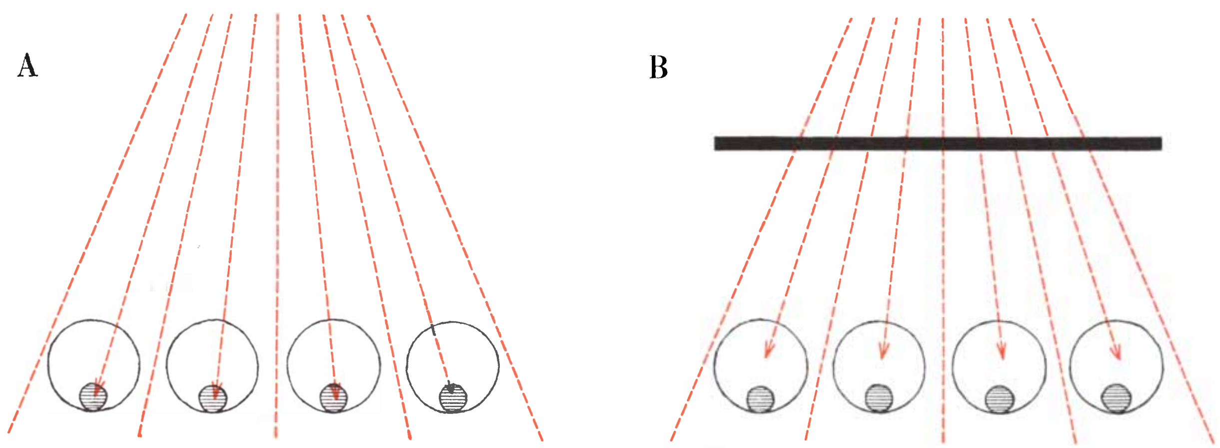
C. A. Tobias of the University of California and Raymond E. Zirkle of the University of Chicago have proposed a working model for such indirect effects in the inactivation of yeast cells. They visualize the target molecule as surrounded by a liquid medium; the target can be considered "hit" if it interacts with activated molecules or free radicals diffusing to it from the medium. As a picture of the usual course of events in the cell, this model is sustained by experiments in which yeast, bacteria and other cells are exposed in the frozen state to ionizing radiation. The cells prove to be remarkably insensitive in this condition, undoubtedly because freezing curtails the process of diffusion. The same line of reasoning suggests that compounds which react with the oxidizing agents produced by irradiation should be able to intercept these agents before they interact with sensitive material. Such reducing compounds, especially the mercaptoalkylamines, have proved to be fine protective agents, reducing the radiation sensitivity of some bacteria as much as freezing or dehydration does.

Franklin Hutchinson of Yale University has recently shown that the mean diffusing distance of the reactive intermediates produced by radiation is in the neighborhood of 30 angstrom units (an angstrom unit is a hundred millionth of a centimeter). In other words, the indirect effects occur close to the track of the ionizing particle. Hutchinson bases this determination on his measurement of the relative sensitivity of two enzymes and a coenzyme in normal and dried yeast cells. His data also show that in the normal cell indirect inactivation is of greater importance for smaller molecules, and conversely that inactivation by direct hits is more likely for large molecules. In the case of an enzyme isolated from the cell, Walter M. Dale of the University of Manchester has shown that the proportion of effect due to indirect action increases as the enzyme is diluted and the ratio of water molecules to enzyme molecules is increased.

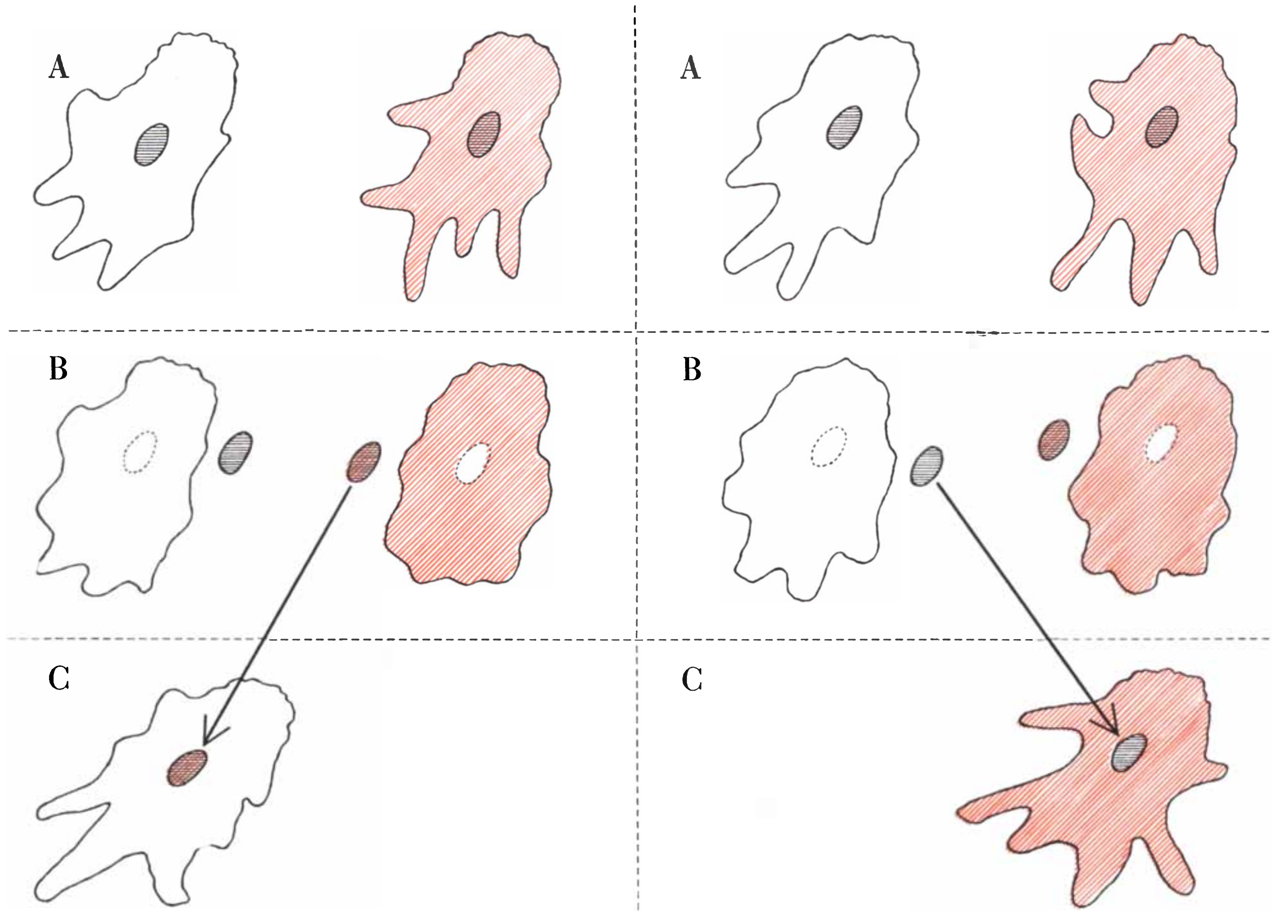
The passage of energy from molecule to molecule seems to be enhanced if the two are joined in some fashion. For example, when the enzyme hyaluronidase is irradiated dry in the presence of hyaluronic acid (its substrate, or the substance upon which it acts), it is inactivated by a single ionization anywhere in the enzyme-substrate complex, indicating that energy migrates from one molecule to the other. On the other hand, no energy passes between individual protein molecules in a pure enzyme preparation. When low-voltage electrons with limited range are allowed to impinge on dried preparations of the enzyme invertase, only the molecules actually struck by the particles are inactivated. It may be that the binding of the molecules in the enzyme-substrate complex is sufficient to permit migration, whereas energy cannot migrate in molecules not bound to one another.

As one might expect, the structure in the cell that proves to be most sensitive to ionizing radiation is the nucleus—the coordinating and directing center of the cell and the bearer of its genetic plan. Zirkle made this finding almost 30 years ago in what is now regarded as a classic experiment. He used fern spores that have an eccentric nucleus, the location of which is marked by an easily recognized spot on the coat of the spore. Zirkle could thus selectively expose the nucleus or the cytoplasm (that part of the cell which lies outside the nucleus) to a beam of alpha particles [*see illustration below*]. He observed that irradiation of the cytoplasm inhibited certain processes of germination—cracking of the spore coat, production of chlorophyll, cell division—but that irradiation of the nucleus inhibited these processes at much lower doses. More recently R. C. von Borstel has performed similar experiments at the Oak Ridge National Laboratory; he employed the egg of the wasp *Habrobracon*, which also has an eccentric nucleus. Von Borstel found that, on the average, a single alpha particle traversing the nucleus of the wasp egg prevents hatching, whereas it takes a million alpha particles traversing the cytoplasm of the egg to produce the same quantitative effect. Extremely narrow beams of radiation are now widely used in such studies, and the investigator is able to observe directly the effects of the irradiation on the structure and function of the cell under the microscope and to record his observations by microcinematography.

J. F. Danielli and Muriel Ord of Kings College in London, and Daniel C. Mazia and Henry I. Hirshfield, who were then at the University of Missouri, carried this line of investigation further, employing the delicate technique of microsurgery to transplant the nucleus of the single-celled amoeba to another amoeba. They found that the transplanting of an irradiated nucleus to an unirradiated cell



FERN SPORES (*large circles*) lined up with their nuclei (*small hatched circles*) at one side were exposed to alpha particles by Raymond E. Zirkle of the University of Chicago. When the cells were exposed without an absorbing filter (*left*), the particles penetrated both the cytoplasm (*open area*) and the nucleus. When they were exposed with a filter (*right*), the particles could only penetrate the cytoplasm. Because certain germination processes of the cells exposed without a filter were inhibited by smaller doses of radiation than cells exposed with a filter, Zirkle concluded that the nucleus was more sensitive to radiation than the cytoplasm.



TRANSPLANTATION OF NUCLEI in the amoeba by several workers also demonstrated that the nucleus was more sensitive than the cytoplasm. At left the nucleus of an irradiated amoeba (*colored*) is transplanted to an unirradiated amoeba; the latter survives about three days. At right the nucleus of the unirradiated amoeba is transplanted to irradiated one; latter survives some three weeks.

is significantly more often lethal than the transplanting of a healthy nucleus to an irradiated cell. Cells with an irradiated nucleus usually died within three days; an amoeba with an irradiated cytoplasm was slow in dividing but could survive for three weeks or more. The irradiated cytoplasm actually relayed the ionization damage to the unirradiated nucleus; when the nucleus was transplanted again to a cell with unirradiated cytoplasm, this also behaved abnormally.

The greater resistance of the cytoplasm to injury by radiation is probably related to the fact that it contains many multiples of each of its important structures; the nucleus, in contrast, rarely possesses more than one or two sets of chromosomes, its most important components. The spores of some fungi, however, contain various numbers of identical nuclei. When these are irradiated, the number of spores killed by a given exposure is in inverse proportion to the number of nuclei present. The cell dies only after the last nucleus is inactivated. Similarly, in certain yeast cells that have one, two, three, four or more identical sets of chromosomes, much less radiation is needed to inactivate cells that have only one set.

Among the enzymes in the cytoplasm that conduct the principal energy-exchange functions of the cell, the ones that contain sulfhydryl groups (SH) are perhaps the most sensitive to ionizing radiation. Relatively small doses of ionizing radiation markedly reduce their biological activity. The inactivation apparently results from the oxidation of the sulfhydryl groups [*see illustration on next page*]. These enzymes, in consequence, are prey especially to the reactive intermediates liberated by the irradiation of the water in the cell, and the rate of inactivation is higher in dilute solutions. Characteristically the sulfhydryl groups appear in two places in the structure of an enzyme, either enclosed in the folds of the molecule or exposed in external active centers. The latter are of course more accessible to the effects of oxidizing agents. But by the same token they should also be accessible to reducing agents that can effect a reversal of the oxidation. Experiments by the late E. S. Guzman Barron of the University of Chicago showed that enzymes containing exposed sulfhydryl groups can indeed be reactivated in this way.

Some cell damage can also be explained on the basis of changes induced by radiation in the permeability of the cell membranes. Such membranes not only envelop the cell itself but also divide the nucleus from the cytoplasm and provide containers within the cytoplasm that enclose enzymes with their proper substrates and separate them from other materials of the cell on which they might act. According to Z. Bacq of the University of Liège and Peter Alexander of the Chester Beatty Research Institute in London, irradiation may damage the membranes and permit enzymes to leak out. Increases in enzymatic activity often observed after irradiation of cells might be a result of this mechanism. A change in membrane permeability might also be a factor in enzyme inactivation; a released enzyme might inactivate other enzymes with which it normally does not make contact.

Ionizing radiation may thus kill or injure the living cell in a variety of ways. But radiation also has far-reaching effects upon the most intricate of all life processes: the genetic mechanism by which the cell transmits its hereditary plan to its daughter cells. This plan is encoded in the genes contained in the chromosomes of the nucleus. The loss of some genes, damage to their structure or changes in the order in which they appear on the chromosome can have significant effects on the daughter cells if, indeed, the daughter cells are capable of life. The remainder of the nuclear material seems to be set aside for constructing the elaborate mitotic apparatus which ensures the equal distribution of the genetic material when the cell divides. Damage to the nucleus shows up in several ways: in "stickiness" of the chromosomes early in mitosis, in breakage or deformity of the chromosomes, in hereditary differences in the daughter cells. Radiation often causes damage that can be seen under the microscope: aberrations resulting from the breakage of two or more chromosomes and the subsequent rejoining of the broken ends. Fragments of different chromosomes may end up connected to one another, and one of these combinations may then lack the special structure called the centromere which is needed if the chromosome is to take part in mitosis and to be passed on to daughter cells. When the cell divides, the piece without a centromere is lost, and the daughter cell usually dies because it cannot survive lacking such a large number of genes. Broken chromosomes can form many other combinations, but a large proportion of the aberrations produced are lethal.

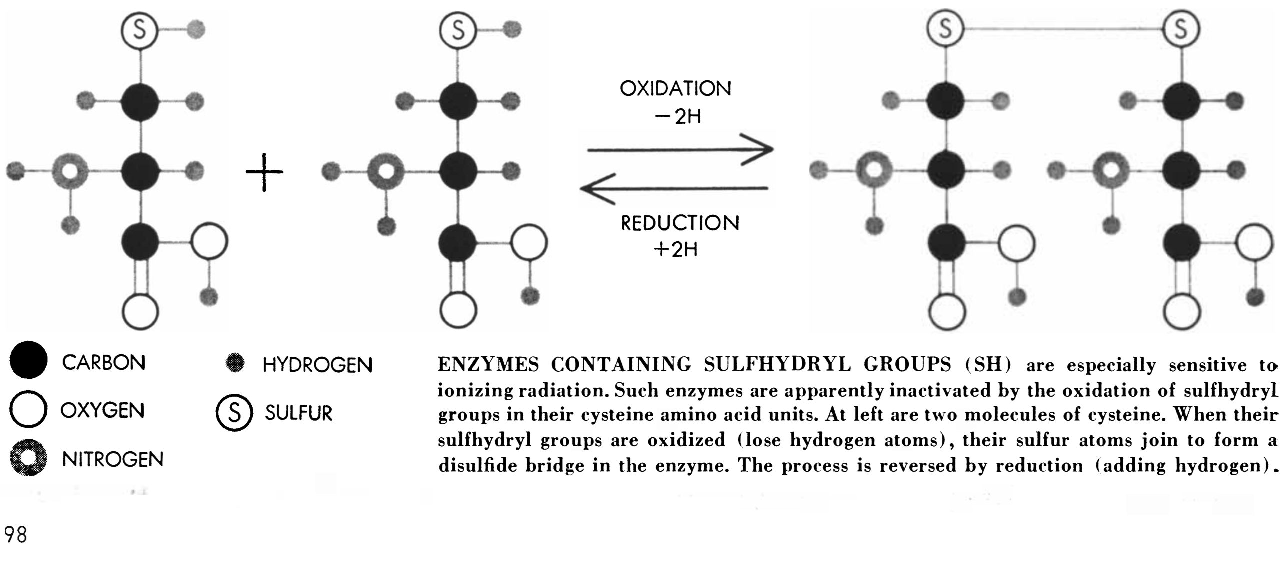
Chromosome breakage can be caused not only by direct hits but also indirectly by reactive substances produced in the water surrounding the chromosomes. J. M. Thoday and John Read at the University of Sheffield found some years ago that many more chromosomal aberrations are produced in the root cells of the broad bean (*Vicia faba*) when the cells are exposed to X-rays in the presence of atmospheric oxygen than in its absence. At the Oak Ridge National Laboratory Sheldon Wolff and his associates have recently demonstrated that there are several intermediate steps between the absorption of energy and the final observable effect; the cell must be actively metabolizing and, particularly, synthesizing protein before the breaks can rejoin.

As James F. Crow and George W. Beadle demonstrate elsewhere in this issue, radiation-induced changes in the individual genes are perhaps more important than gross structural changes in the chromosomes. Charlotte Auerbach of the University of Edinburgh found that several chemical agents can produce gene mutations similar to those induced by ionizing radiation, suggesting that mutations might be a secondary result of radiation. In support of this interpretation a number of investigators have discovered that the observed frequency of mutations varies with the concentration of oxygen in the medium during irradiation. L. J. Stadler of the University of Missouri, who discovered that radiation induces gene mutations in plants, found some years ago that more mutations appear in plant cells when they are irradiated wet.

Investigators are now engaged in radiation experiments on the genetic substance itself, deoxyribonucleic acid (DNA), separated from the chromosomes of the cell. When the material is isolated together with the protein with which it is normally associated, the preparation has a gel-like quality indicating a degree of polymerization and hence an organized structure consistent with its function. Under extremely small doses of radiation the nucleoprotein is depolymerized and loses its gel-like quality. But Berwind P. Kaufmann with M. H. Bernstein at the Carnegie Institution of Washington prepared a synthetic combination of DNA and protein by mixing DNA and cattle serum albumin, and found that this preparation depolymerizes more easily under the influence of X-rays than does either of its constituents.

DNA can be isolated from one strain of a microorganism and then used to confer hereditary characteristics of this strain on another strain of the same species. Exposure of the isolated DNA before it is reacted with the recipient strain makes it possible to detect loss of biological activity as a consequence of radiation. Such a test is more sensitive than the observation of gross physicochemical changes. Raymond Latarjet of the Institut du Radium in Paris and other workers have performed experiments of this kind. They find that the capacity of DNA to transfer hereditary characteristics is destroyed by small doses of ultraviolet radiation or X-rays or by peroxides at low concentrations. Even a minor alteration in the DNA molecule can drastically affect the rest of the cell, since DNA bears the information required for the synthesis of other key cell constituents.

A number of experiments suggest that the inhibition of the synthesis of DNA is even more important than the degradation of existing DNA. If DNA syn-

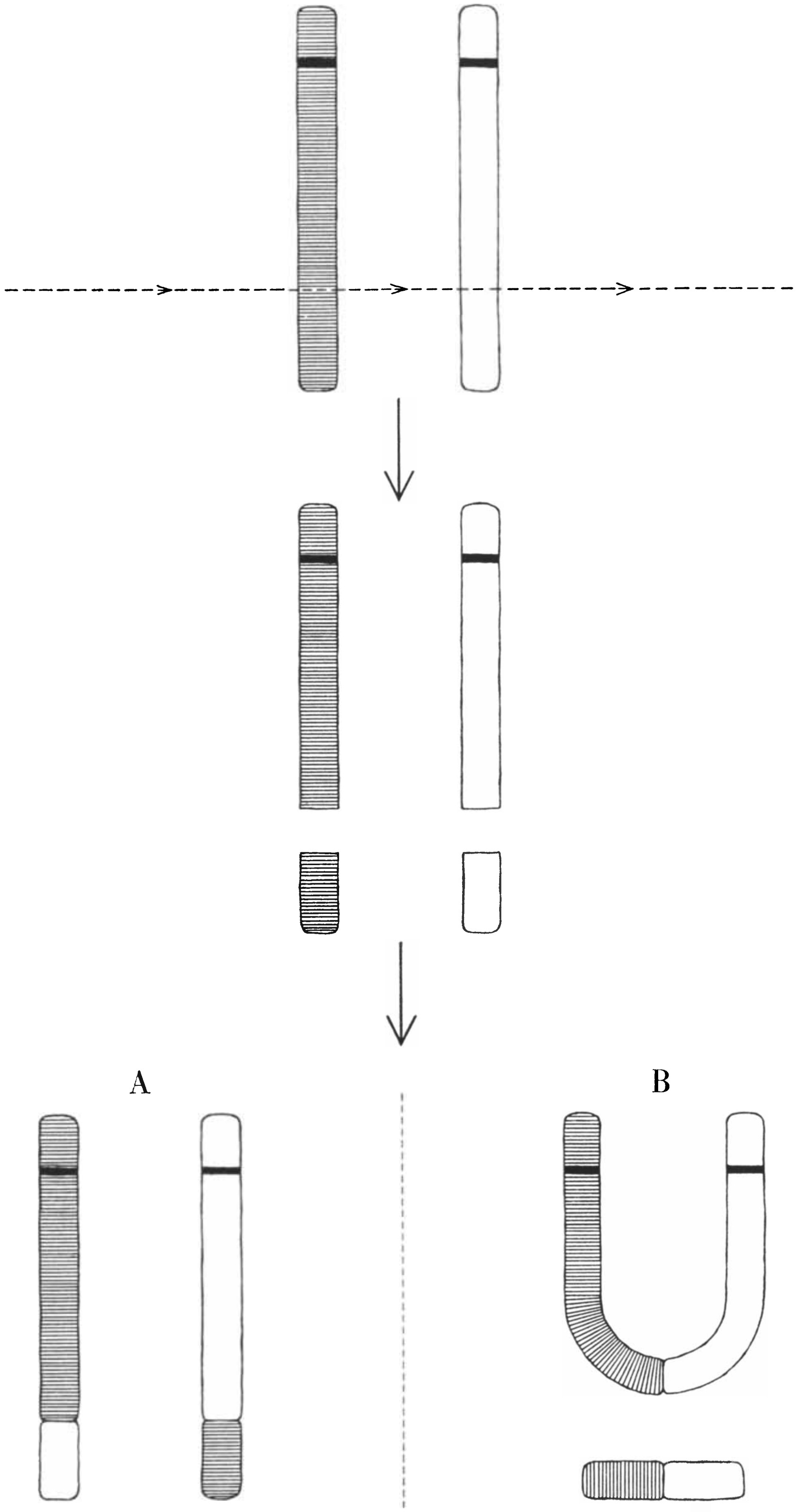


ENZYMES CONTAINING SULFHYDRYL GROUPS (SH) are especially sensitive to ionizing radiation. Such enzymes are apparently inactivated by the oxidation of sulfhydryl groups in their cysteine amino acid units. At left are two molecules of cysteine. When their sulfhydryl groups are oxidized (lose hydrogen atoms), their sulfur atoms join to form a disulfide bridge in the enzyme. The process is reversed by reduction (adding hydrogen).

thesis is inhibited, the cell cannot divide, even though growth processes continue and the mass of the cell increases. This phenomenon has also been observed in cells that have been chemically treated to incorporate abnormal molecular subunits into their DNA.

Irradiation thus sets off a chain of reactions, at each step increasing the extent of damage several-fold. The first step is the direct action of the ionizing radiation which may itself strike an important target. In the next instant the ionized and excited molecules in the path of the ionization embroil neighboring molecules in reactions producing a variety of unstable and reactive end-products that spread the damage to target molecules untouched by the primary event itself. T. Alper of the Hammersmith Hospital in London has suggested that an ionized or activated molecule may react with a variety of molecules in its immediate vicinity for a period of about a millionth of a second, the molecules being brought together by diffusion through the water within the cell. Certain molecules apparently remain in the activated state longer than others, and can continue to degrade or inactivate a target substance for hours after the actual exposure to radiation. This effect, which is not yet fully understood, is seen in the inactivation of DNA, of enzymes or of virus particles and even of whole bacterial cells held in the presence of hydrogen peroxide after irradiation. The reaction is stopped or prevented only by a substance capable of decomposing the peroxide. The final phase of damage results from the deranged metabolic performance of injured cell structures, and is expressed in the inhibition of cell division, in inactivation and death, or in the distortion of the genetic process.

The ultimate effects of irradiation on the living cell may be greatly affected by the physiological state of the cell and by treatment after irradiation. Cells in the "resting" stage between divisions are much less sensitive to radiation than are cells in the act of dividing. Investigators at Oak Ridge have observed that beta-mercaptoethylamine, a sulfhydryl compound, can protect bacteria and fungi against radiation-induced mutations. Such varied postirradiation treatments as starvation, inhibition of protein synthesis with antibiotics or by nitrogen starvation, lowered temperature or the addition of certain nutritional factors to the growth medium can lower the death rate in certain cell populations. It is especially significant that in certain types of living cell the same postirradiation



BREAKAGE OF TWO CHROMOSOMES by a single ionizing particle can have various effects. At top the particle (*broken line*) passes through the two chromosomes. The black segment near the top of each chromosome represents the centromere, the point at which two opposing threads of the mitotic apparatus pull the daughters of each chromosome apart during cell division. The broken chromosomes (*middle*) may simply reconstitute themselves. They may also exchange fragments as shown at A; in this case they can divide normally. Finally they may exchange fragments as shown at B; one of new chromosomes lacks a centromere and cannot divide. Thus the daughter cells lack this chromosomal material and die.

treatments that reduce the rate of cell deaths also reduce the number of observable mutations. These studies suggest that the mutation-inducing or lethal damage does not become established in living cells until some time after irradiation, and that the abnormal or inadequate metabolic processes resulting from the injury must intervene to fix it irreversibly.

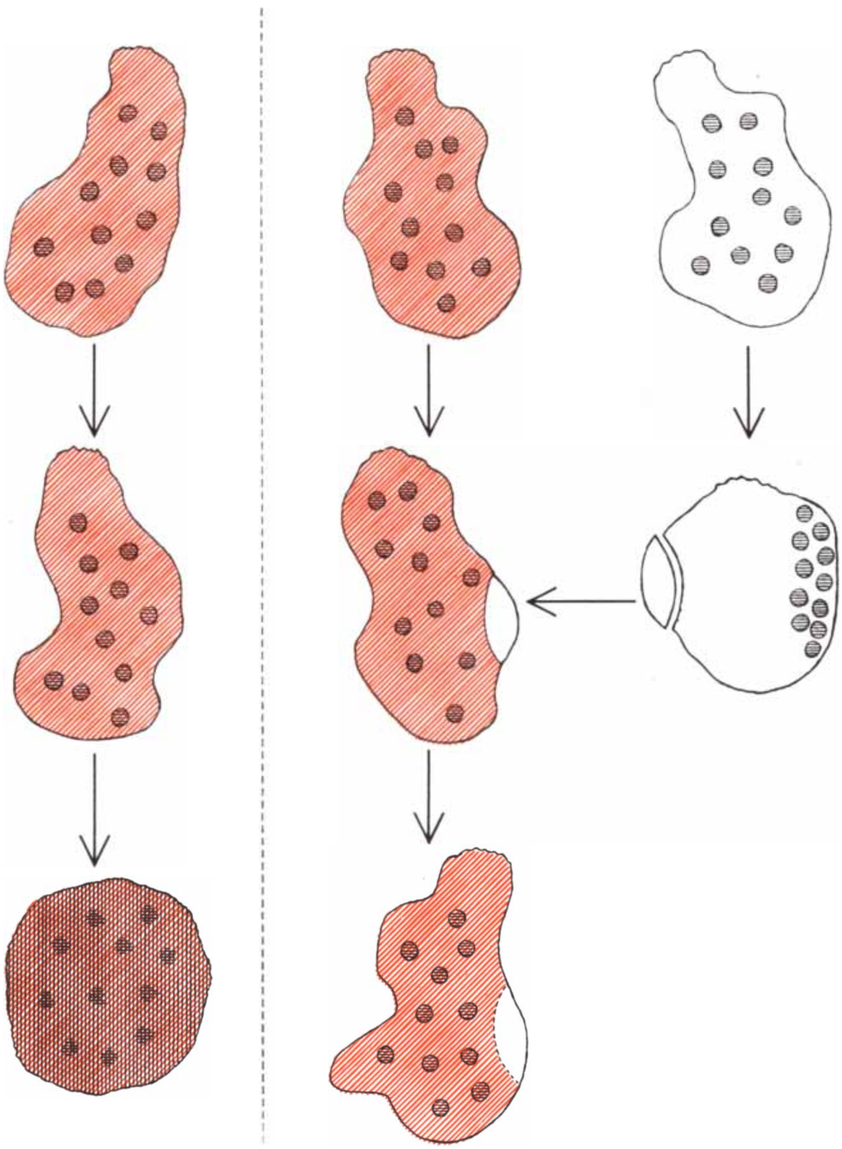
It is not to be inferred that all radiation damage is significantly amenable to pre- or post-irradiation treatment. There must also be a portion of the damage, especially that produced by direct energy absorption in key molecules, that is not responsive to treatment at all. This undoubtedly represents a considerable portion of the effects observed, and explains why even the smallest dose of radiation seems to do some irreversible harm to the cell.

Certain experiments indicate that some cells have a capacity for spontaneous repair. Working with the amoeboid protozoon *Pelomyxa*, E. W. Daniels of the Argonne National Laboratory has demonstrated that processes in the cytoplasm can enable the cell to recover after irradiation. When Pelomyxa is irradiated, it is slow to divide. But when Daniels injected a bit of cytoplasm from an unirradiated Pelomyxa into an irradiated one, the irradiated protozoon proceeded to divide at its normal pace. This work does not necessarily imply that cytoplasmic injection can repair nuclear damage; here the critical damage may have been restricted to the cytoplasm.

There is some evidence that if the rate of irradiation is low enough, repair mechanisms can operate during the irradiation and reduce permanent damage to the cell. W. L. Russell of Oak Ridge has recently shown that the frequency of radiation-induced mutations in the precursors of the sperm and egg cells of the mouse depends on the rate at which the radiation is administered. The mutations are more numerous if the precursor cells are subjected to a given amount of radiation over a short period than if they are exposed to the same amount of radiation spread out over a longer period. Only the immature sex cells of the mouse, however, demonstrated this variability of response to the dose rate. The mature sex cells exposed to radiation showed no corresponding change in the incidence of mutations.

What are the implications of all this experimental work for higher forms of life, including man? It is difficult to extrapolate findings from the single cell to the human organism. From what we know about the vulnerability of the cell during division and about the sensitivity of the cell nucleus, however, we can predict that the tissues most vulnerable to radiation will be those containing cells with relatively little cytoplasm and those multiplying most rapidly: the blood-forming tissue of the bone marrow, the tissues of the reproductive organs and embryonic tissues. We know that the whole animal can recover spontaneously even from what might appear to be lethal damage. The mechanism of this recovery is difficult to examine in detail. Probably undamaged cells provide materials for the recovery of damaged ones, multiply to replace those lost and neutralize the toxic substances. Many important cell systems can repair themselves after relatively low doses of radiation. When they are destroyed by larger doses, it is sometimes possible to replace them by transplantation. These and related matters are discussed in greater detail in the article that follows.

In sum, cell studies have served to elucidate the basic mechanism by which ionizing radiation damages the living organism. They have provided no evidence that there is a true threshold of dosage below which ionizing radiation produces no harmful effects; even at low dosages the effects are still appreciable. But cell studies have also demonstrated that it is possible to modify, at least to some extent, the most important effects of radiation.



CYTOPLASM WAS TRANSFERRED from an unirradiated *Pelomyxa* to an irradiated one by E. W. Daniels of the Argonne National Laboratory. When Pelomyxa, which has several nuclei, is irradiated, it dies or is slow to divide (*left*). When an unirradiated Pelomyxa is centrifuged so that its nuclei are at one side, a bit of its cytoplasm can be transferred to an irradiated one (*right middle*). Irradiated cell then survives and divides at its normal pace.

Kodak reports on:

why the radiologists, cardiologists, urologists, internists, laryngologists, and neurosurgeons got together... new life for the old telescope or copying camera... a method for forecasting titanic stress in fine detail

Cinefluorography

On the other side of town, on November 14 and 15 of last year, there was held the First Annual Symposium on Cinefluorography of the University of Rochester School of Medicine and Dentistry.

To the masses, many of whom may live longer or at least enjoy themselves more than if this conclave had never convened, it would have been mildly interesting to know that x-ray movies of the innards in action had so far advanced from a stunt (for TV science programs) to a diagnostic routine as to make it a subject for a convention. Very mildly interesting, on a November Saturday which already offered the intellectual challenge of picking point spreads for the football games.

To the 150-odd ambitious, cleareyed radiologists, cardiologists, urologists, internists, laryngologists, and neurosurgeons who came from all over, it was far, far more than a chance to flee the daily hurly-burly for an unequivocally tax-deductible weekend. At this time and place began the process of shaping into standard working technique all the individual improvisations, frustrations, and foolish pioneer feelings experienced late at night in deserted laboratories by medical men coping with electronics, optics, photographic sensitometry, and random fluctuations at the quantum level.

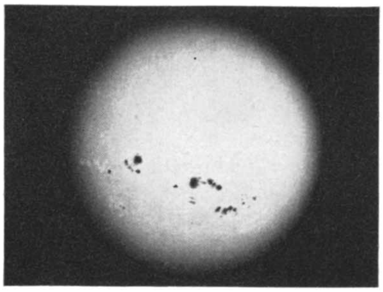
To certain elements of the electronics industry the symposium brought visions of a well-bred market for advanced merchandise, quite free of the fearful dependence on military spending and of the fearful perils of appliance merchandising. If the electronics boys in 1953 hadn't brought out image amplifiers that multiply fluoroscope image intensity a thousandfold or more so that film can be exposed without frying patients, there would have been no symposium. Their emissaries sat unabashed among the M.D.'s.

To the University of Rochester it was a chance to become the national cinefluorographic capital. It had become involved with the subject as early as 1929. To have one member of its radiology department such an expert on motion picture quality that he had produced Poe's "The Fall of the House of Usher" to supra-professional cinematic standards had helped enormously. We helped, too.

To us, doomed by our charter to the endless pursuit of monetary gain, the symposium was important for stimulating sales of *Kodak Cineflure Film*, a product which uniquely combines extreme speed to green light with very high contrast. It is obtainable from most x-ray dealers.

To Charles C Thomas, Publisher, Springfield, Ill., the symposium provided a title he is publishing this month, Cinefluorography. *It contains all 19 papers and the discussion thereof. For a free copy of a bibliography of cinefluorography, write Eastman Kodak Company, Medical Division, Rochester 4, N. Y.*

De orbe... de urbe



This picture of the solar disk with sunspots and bright faculae was taken on *Kodak Autopositive PB Film* at the prime focus of a 6-inch *f*/15 reflecting telescope at 1/100 second without a filter or any interposed optics. The ¾″ negative image can stand a lot more enlargement. Alas, there is no room for that here, or for an explanation of why this particular film was chosen. To read all about it, send for a preprint of "Photographing the Sun" to Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y. If you've made a reflecting telescope and sometimes wonder why, you may find a soul-satisfying answer in that article.

The space here must serve more pressing needs having to do with another product called "Autopositive," the new *Kodagraph Autopositive Projection Paper*. This paper you put in an enlarger or copying camera and use for reproducing drawings or documents at any desired magnification or minification. Black photographs black, and white photographs white. The negative-to-positive jazz is avoided, and even the conventional hypo fixing bath is replaced by a jet of plain water. For information on where to buy it and how to use it, write Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y.

Photoelasticity by the slice

Westinghouse, long known as a hotbed of photoelastic activity, has been nice enough to cast upon the waters of industrial co-prosperity a piece of technique that could help sell more *Kodak Contour Projectors*. No time must be lost in spreading the word. Too long have we touted photoelastic stress analysis with no brighter prospect of gainful return than seeing a little film put to good use in recording the pretty patterns.

Westinghouse took one of these projectors of ours, a non-photographic optical-mechanical device intended for the checking of dimensions on enlarged images of mechanical parts, and they turned it into a magnifying polariscope. This they did in the interest of reaching reasonable decisions on the mechanical design details to enable a nuclear reactor pressure vessel to withstand the titanic stresses that it must bear.

Scale models were built out of a certain transparent epoxy resin which not only exhibits the well known differential retardation between light polarized parallel and perpendicular to the stresses, but can retain the effect "frozen in" after the pressure is released and the model is literally sliced up in various planes of interest to the stress analysts. Instead of yielding average values of stress over the areas where electrical resistance strain gages happen to be bonded, this method shows how the stress pattern builds up to ominous levels at points suspected or not. The *Kodak Contour Projector* is what brings the stress analyst in close, past the gross structure of the pattern, to the all-important fine details where structural failure starts.

Don't bother Westinghouse for a description of the optical, mechanical, and electrical additions they've made to the projector. It's enough that they are publishing a full description of the analytical method (Proceedings of the Society for Experimental Stress Analysis, *17*, No. 1). *They're not interested in selling projectors. Eastman Kodak Company, Special Products Division, Rochester 4, N. Y., is.*

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

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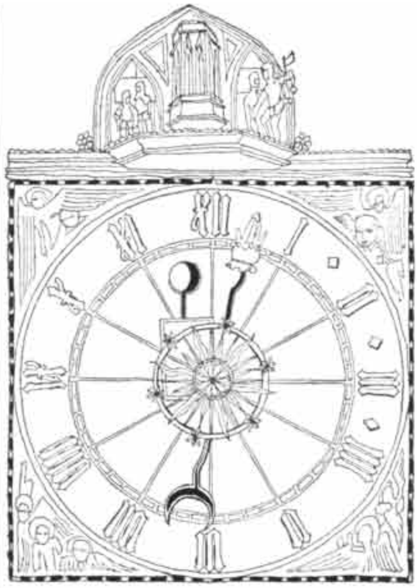
SCIENCE AND



International Medical Institute

President Eisenhower's call in his State of the Union message two years ago for U. S. support of medical research abroad is about to bear fruit. Early in August the House Subcommittee on Health and Safety concluded hearings on a bill to set up an agency to encourage international cooperation in medical research and to provide U. S. grants to foreign investigators. The bill was passed by the Senate by a 63-17 vote in May. Completion of House action is expected at the present or next session of Congress.

The agency would be known as the National Institute for International Medical Research and would become another of the U. S. Public Health Service's numerous National Institutes of Health. The new institute would be authorized to spend up to $50 million annually for training personnel and planning and conducting research on disease and rehabilitation of the physically and mentally handicapped. Studies could be conducted in the U. S. or abroad. A National Advisory Council for International Medical Research would be organized to advise the Surgeon General on the activities of the institute and to review financial grants.

The President called for U. S. aid to foreign medical research as part of a wider program of aid to science abroad and for increasing scientific and cultural contacts between the U. S. and the U.S.S.R. and the countries of eastern Europe. The international medical institute bill was introduced in the Senate soon afterward by Lister Hill of Alabama, a Senator with a strong interest in health legislation. When Senator Hill reintroduced the measure last January in the new Congress, it bore the names of 63 members of the Senate as co-sponsors. During six days of Senate hearings, no witness appeared against the bill, and it was enthusiastically endorsed by a list of organizations and individuals taking in nearly the whole of the fields of medicine and public health.

Rocket-Age Projects

Contracts have been awarded by the National Aeronautics and Space Administration for a start on two much-discussed rocket-age projects. Atomic clocks, to be placed aboard earth satellites as a means of testing parts of the special and general theories of relativity, are to be designed and built by the National Bureau of Standards, Massachusetts Institute of Technology and Hughes Aircraft Company. A small seismograph, rugged enough to withstand launching in a rocket and subsequent landing upon the moon, is to be developed by Columbia University's Lamont Geological Observatory and the California Institute of Technology.

Even before the launching of the first artificial satellite it was widely suggested that the clock paradox of special relativity—the slowing-down of a moving clock—might be tested by putting an atomic clock into orbit and comparing the frequency of the clock's "ticks" (the radio waves the clock generates) with the frequency of a similar clock on earth. More recently it has been pointed out that an orbiting clock can also provide a check upon one of the predictions of the general theory of relativity—a hypothesis hitherto difficult to test because many of the effects it forecasts are too small to be observed. General relativity predicts an increase in the energy of radiation falling through a gravitational field, for example, in the radiation falling upon the earth from a source at some distance from the earth. In the case of radiation from a constant-frequency source—such as the radio waves from an atomic clock—the increase in energy would result in an increase in frequency (the so-called gravitational blue shift); *i.e.*, the clock would appear to run fast [see "Artificial Satellites and

THE CITIZEN

the Theory of Relativity," by V. L. Ginzburg; SCIENTIFIC AMERICAN, May].

Atomic clocks can be made to measure time with an accuracy approaching one second per 1,000 years—precision enough to allow detection of both the special-relativity "slow-time" and general-relativity "fast-time" effects. More than one clock is likely to be put into orbit, because the slow-time effect should be most evident in satellites below 2,000 miles of altitude, while the fast-time effect is expected to be strongest at altitudes above 2,000 miles.

The lunar seismograph to be designed at Columbia and Cal Tech will weigh between 10 and 20 pounds and is to detect crustal movements resulting either from internal activity of the moon or from the impact of meteorites on the moon's surface. Information on such movements, telemetered back to earth, will provide clues to the moon's internal and surface composition, as well as data on the size and velocity of meteoric particles in space. Several types of lunar seismograph, varying in sensitivity, frequency response and other characteristics, will probably be developed. Target date for the landing of the first seismograph on the moon is 1964 or 1965.

Test-Ban Developments

A group of experts from the U.S.S.R., Great Britain and the U. S. last month recommended the use of satellites for detecting high-altitude nuclear explosions. Their report to the Geneva conference stated that five or six vehicles, weighing several thousand pounds each and traveling at altitudes of more than 18,000 miles, could survey the entire earth and the space around it. The necessary instruments for satellites and associated ground stations were said to require no fundamental advances in technology. However, the experts acknowledged that the system would be very expensive and technically difficult to achieve. They also proposed less ambitious schemes with orbits only 300 to 450 miles above the earth. These would leave some gaps in surveillance at lower altitudes.

As the talks at Geneva continued, the U. S. Atomic Energy Commission was reported by *The New York Times* to be "quietly preparing for immediate resumption of nuclear testing if the negotiations with the Soviet Union for a ban collapse." The preparations include the digging of tunnels in Nevada for underground explosions and maintenance work on the Eniwetok proving grounds.

The voluntary one-year moratorium on U. S. tests, which began with the Geneva talks, expires on October 31. At a recent committee hearing in the House of Representatives AEC chairman John A. McCone said he "would not continue this present type of ban" if negotiations extended beyond that date. "I would think," he continued, "that at the end of the year this policy should be very carefully reconsidered. I feel that we have been extremely patient in those negotiations and I do not think that we should find ourselves in a position of stopping testing just for the purpose of sitting at a conference table."

U.S.S.R. Census

The first results of a census taken last January reveal that the population of the U.S.S.R. has the extraordinarily high ratio of 55 females for every 45 males. Virtually the entire deficit of men is in persons over the age of 32, and is due to losses of men in World War II. Usually estimated at three to seven million, these losses may actually have been very much larger.

A preliminary report on the Soviet census, translated from *Izvestia*, is published in the July issue of the *Population Bulletin*. The report discloses numerous striking changes in the population of the U.S.S.R. since the last census was taken in 1939.

Present-day Russia has moved far from the predominantly rural nation of World War I. Almost 100 million of the U.S.S.R.'s 208.8 million people live in cities. Cities with a population of 200,000 or more number 72. Urban growth has been especially rapid since 1956. In that period more than 200 new cities have been established and the urban population has risen by 16 million. Despite the emphasis upon the development of Siberia, however, only 30 per cent of the population—urban and rural—lives in and beyond the Urals, as compared with 25 per cent before World War II.

The natural increase (excess of births over deaths) of the Soviet population is currently about 3.5 million annually. Births number more than 25 per 1,000 of population per year, or more than five million per year. Deaths total 1.5 million annually, for a crude death rate of 7.5 per 1,000 per year. The latter is one of the world's lowest crude death rates

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HEAT SEMICONDUCTIVITY

Pyrographite shows the greatest anisotropy of heat conduction of any known substance, for it conducts heat 500 times better in one of its planes than the other. Along the surface, its plane of conduction, pyrographite has the highest thermal conductivity of any substance yet discovered—30% higher than copper. Pyrographite has a destruction temperature of 6600° F.

In the longitudinal plane of the monatomic carbon molecules that form the hexagonal crystals of pyrographite, atoms are spaced at 1.42 Angstrom units; the spacing between the longitudinal planes is of the order of 3.40 Angstrom units. The unique heat transport characteristics result from the high degree of orientation of the longitudinal layer planes.

Pyrographite, which has a high strength-to-weight ratio, can be used for re-entry bodies and rocket nozzles where it has excellent erosion resistance at temperatures up to 6000° F. It also has application in nuclear reactors.

The study of pyrographite and similar materials by such men as R. J. Russell, S. F. D'Urso and E. F. Keon is representative of the basic research at Raytheon—where scientific imagination is broadening man's knowledge.

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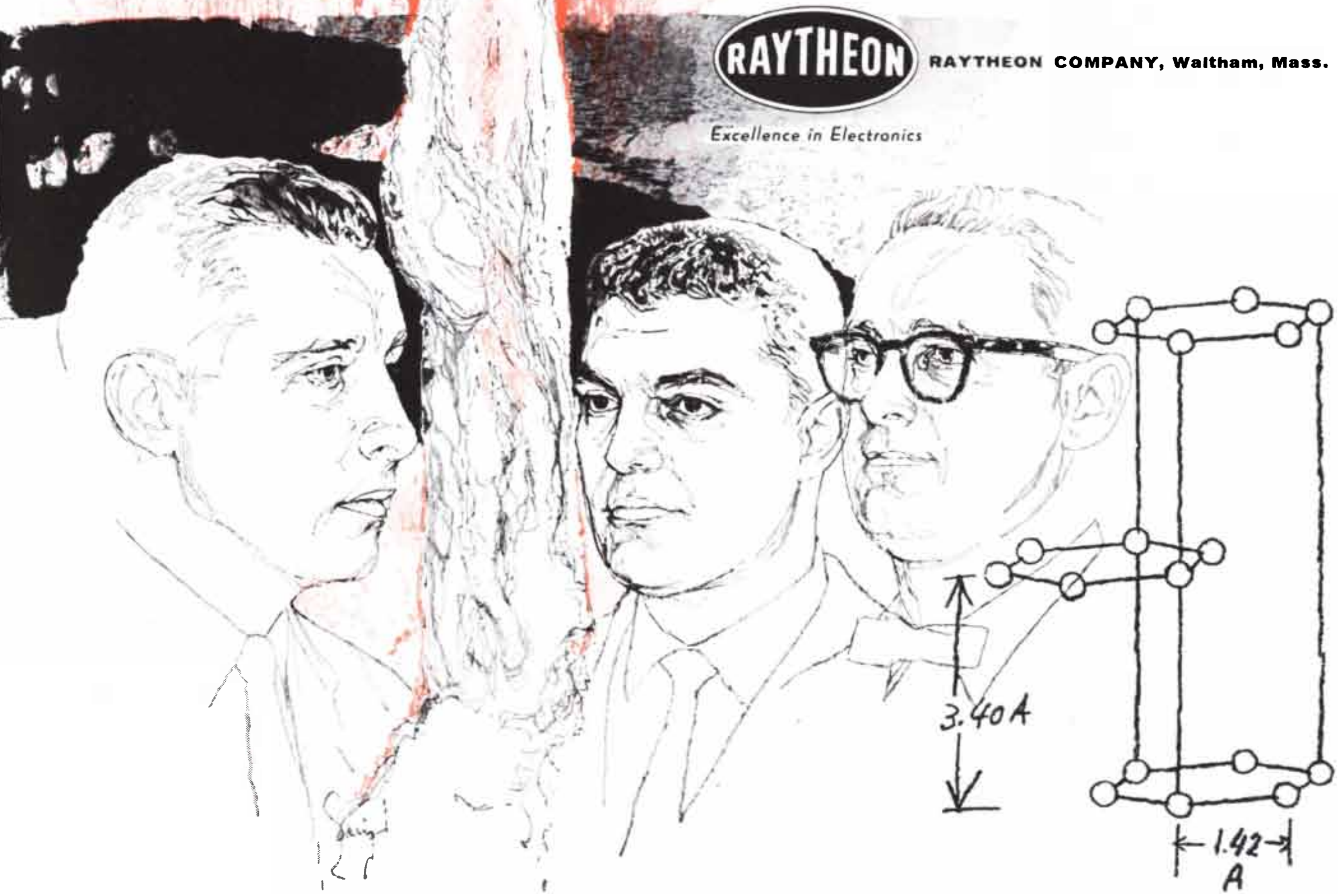


and reflects the high percentage of young persons in the U.S.S.R.

World War II cost the U.S.S.R. not only many millions of young men, but also a sizable part of the generation now coming of age. This is the result of a sharp decline in births and high child and civilian mortality during the war period. Analysis of figures in the census report indicates that the population within the present boundaries of the U.S.S.R. had a natural increase of not quite two million or 1.2 per cent a year in the decade before the war. If it had been possible to maintain the 1.2-per-cent rate—let alone reach the present annual increase rate of 1.75 per cent—throughout the war, the U.S.S.R. would now have a total population of 235 million or more.

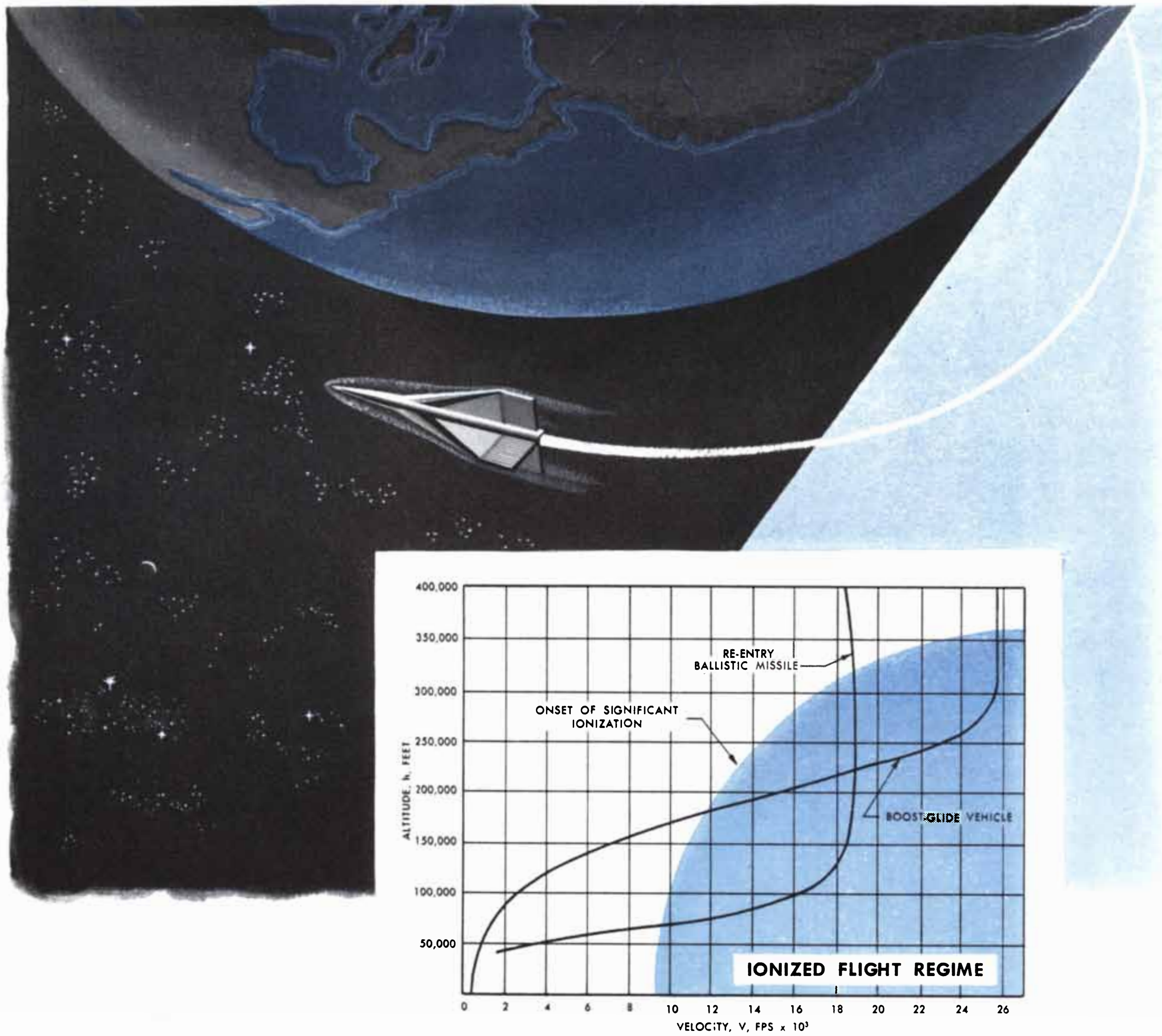
Tunnel Diode

A new entry in the burgeoning field of solid-state electronics promises to outperform the transistor in many important respects. Reports from several laboratories indicate that the tunnel diode, as the device is called, will make possible faster switches and less noisy, higher-frequency amplifiers and microwave oscillators.

As with transistors and most other semiconductor devices the functioning of the tunnel diode depends on the transfer of electric charge across a "p-n" junction. But the method of transfer is different and the action quicker.

A p-n junction is the region between a p-type semiconductor, containing mobile positive charges in the form of "holes" (vacant electron sites in the atoms of the crystal) and an n-type, containing mobile negative electrons. The opposite sides of the junction acquire a charge that resists the motion of electrons and holes across it. In the older devices the charges pass through only with the help of an outside voltage, which gives them enough energy to surmount the potential barrier.

According to the laws of quantum mechanics, however, another passageway exists. Regardless of its energy, an electron approaching one side of a potential barrier has a small but finite probability of disappearing from that side and simultaneously appearing on the other. It is as if the electron tunneled under the barrier. Last year a Japanese physicist, Leo Esaki, discovered that the tunnel effect can produce substantial currents across p-n junctions. The semiconductor must be heavily "doped" with impurities to give a high concentration of movable charges, and



COMMUNICATION

...through a plasma sheath

When man goes into the outer atmosphere, communication with ground installations will be a major problem. The shock wave preceding a hypervelocity vehicle flying at altitudes between 70,000 and 350,000 feet will cause the oncoming air to be heated to extremely high temperatures. Result: a sheath of ionized particles around the vehicle.

Communication through this plasma cannot be achieved with conventional equipment. That's why Bendix Systems Division is engineering a communications system in frequency bands specifically designed to penetrate the hypersonic shock layer. The solutions of these problems are common to hypersonic flight and ballistic missile re-entry.

The Bendix Systems Division, using the nearby University of Michigan's Ford Nuclear Reactor, is also developing radiation-resistant communication equipment to provide extreme reliability over long operating periods. These techniques are applicable to both nuclear-powered vehicles and space programs.

Bendix communications experience is also being applied to other programs for which the Systems Division has management and engineering responsibility—the Navy's EAGLE System and the Air Force's AN/AMQ-15 Weather Reconnaissance System, for example.

Better engineers and scientists are invited to write for further information on Bendix Systems Division.

Bendix Systems Division
ANN ARBOR, MICHIGAN

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the junction must be very thin. Such a junction constitutes a tunnel diode.

The action of the device depends on certain peculiarities in the tunneling current. With no outside voltage across the junction the electrons on either side reach a common energy-level, and tunnel with equal ease in both directions. There is no net current. If a small voltage is applied, raising the energy of the n-type conduction electrons, they find themselves opposite a band of unoccupied energy-states in the p-type material. The n-to-p tunneling increases and a net current appears. At a greater voltage, however, the n-type electrons reach the level of the so-called forbidden gap of energies in the p-type material. Now they cannot move across the junction, and the current decreases. Eventually, if the voltage is made high enough, the n-type electrons spill over the top of the potential barrier in the ordinary way, so that the current increases again.

Over the range where an increasing voltage causes the current to decrease, the diode has "negative" resistance. Any negative resistance element can be made to act as an amplifier or oscillator.

In vacuum-tube and transistor amplifiers, electrons (or holes) must pass from an emitter to a collector through a region where their motion is influenced by the input signal. This transit requires a minimum time, placing an upper limit on the frequency at which the devices can work. In the new diode, tunneling electrons set up virtually instantaneous surges of current through the whole semiconductor. Hence the possible frequency response is much higher. Also, at certain points small voltage changes cause the diode to flip almost instantaneously from one positive resistance to another. Thus it can act as a fast switch.

An announcement from the General Electric Research Laboratory says that tunnel-diode amplifiers already operate at 2,000 megacycles, the upper limit of the transistor. Frequencies of more than 10,000 megacycles should be possible, at noise levels very much lower than transistors can attain. The rapid switching action of tunnel diodes will find applications in computers and control circuits, particularly for nuclear reactors. Heat and atomic radiation do not disturb the tunnel effect so much as they do the transistor action of semiconducting crystals.

Virus-Destroying Bacterium

Viruses that destroy bacteria are familiar, especially the numerous strains that prey on the *Escherichia coli* organ-

AN ENTIRELY NEW CONCEPT IN PRESSURIZATION AND COOLING . . . A *Nose cone cooling,* **B** *Cabin pressurization and cooling,* **C** *Suit pressurization and cooling,* **D** *System control,* **E** *Heat exchangers,* **F** *Electronic bay (cooling and inerting),* **G** *Supply valve,* **H** *Nitrogen relief valve,* **I** *Liquid nitrogen storage tank,* **J** *Liquid nitrogen vent valve,* **K** *Liquid nitrogen filler valve,* **L** *Helium vent and buildup valve,* **M** *2-stage helium regulator, 4400-65 psi,* **N** *High pressure helium storage,* **O** *High pressure helium filler valve,* **P** *Helium relief valve.*

• *The AiResearch Pressurization And Air Conditioning System* in North American's X-15 is a radical departure from normal pressurization and cooling techniques, also pioneered by AiResearch, which up to now have utilized outside air surrounding the aircraft. When the X-15 manned spacecraft climbs into space beyond the earth's atmosphere, it will carry its own atmosphere in the form of liquid nitrogen dispensed through a self-sufficient AiResearch pressurization and air conditioning system for the pilot and vital equipment.

X-15 applications include: pressurizing and ventilating the cockpit and the pilot's flight suit inside of which he breathes pure oxygen; cooling and pressurizing electronic equipment and inerting its environmental atmosphere; cooling the plane's nose cone; and, operating pneumatic equipment.

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Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS ism and provide investigators with a handy tool for studying virus genetics. There also exists at least one species of bacterium able to destroy a virus.

The virus-destroying bacterium is a newly identified yellow organism named *Flavobacterium virurumpens* by its discoverer, Benjamin E. Volcani of the University of California Virus Laboratory. Volcani recovered the microbe from the mud of a creek crossing the Berkeley campus. The virus it destroys is the organism that causes the mosaic disease of tobacco.

The yellow bacterium dissects the tobacco-mosaic virus into an assortment of rodlets, granules, doughnut-shaped fragments and fragments of irregular shape by attacking the virus protein enzymatically. Four or five points in the virus's protein coat appear particularly susceptible to the bacterium's action.

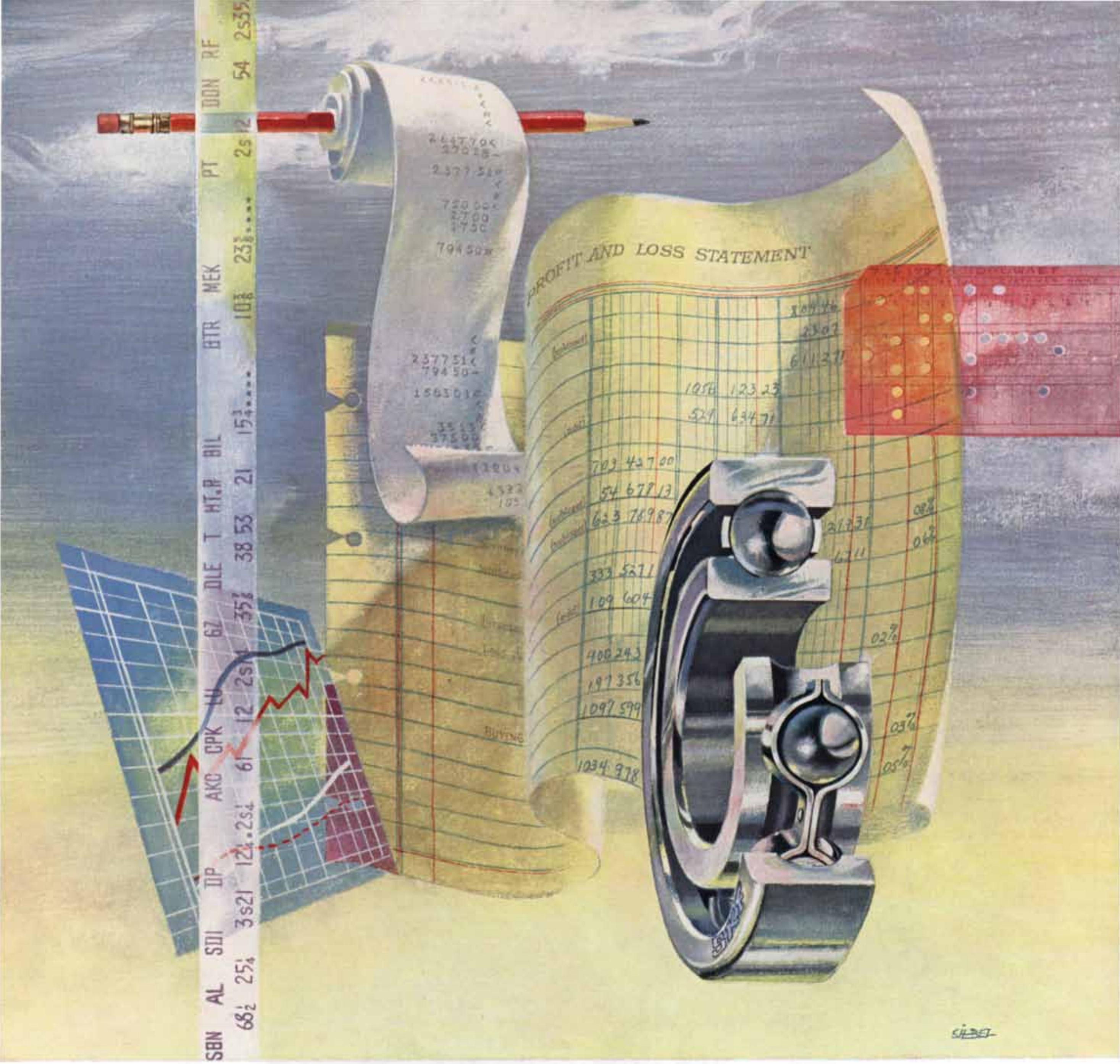
Volcani's discovery not only points to the possible existence of other virus-destroying bacteria; it also furnishes a new means of degrading viruses to determine their structure. Hitherto physical and chemical procedures have been the chief reliance of researchers seeking to break down tobacco-mosaic and other viruses for study.

Equatorial Electrojet

Variations in the earth's magnetic field, as measured at ground observing-stations, have long been attributed to electric currents circulating in the ionosphere. Rockoons (rockets fired from balloons) sent aloft during the International Geophysical Year confirmed the existence of these "dynamo currents." They have also led to the discovery of at least three currents, instead of the expected one, in the region of the magnetic equator: two flowing from west to east, and one, just to the north, flowing in the opposite direction.

Data on the triple equatorial electrojet were obtained on three rockoon flights near Fanning and Jarvis islands in the Pacific. The rockoons were launched from the Navy icebreaker *Glacier* under the direction of James A. Van Allen and Laurence J. Cahill, Jr., of the University of Iowa. They carried miniaturized proton precession magnetometers to record the absolute intensity of the magnetic field on the way up and down.

The first of the three data-yielding flights was made at latitude three degrees 23 minutes north and longitude 158 degrees 41 minutes west. At an altitude of 104 kilometers the rocket's magnetometer recorded a change in magnetic



HOW TO ILLUSTRATE A PROFITABLE IDEA

When SKF developed an advertisement entitled "Parts Determine Profits", artist Fritz Siebel was commissioned to create the illustration. The result of his effort appears above. Perhaps you saw the original ad in *Business Week*. In it SKF pointed out how a single bearing failure can halt production, boost operating costs and otherwise eat away profits. To avoid these penalizing possibilities it was also suggested that the manufacturers—or users—of equipment containing ball or roller bearings might profit by asking SKF for an impartial bearing analysis. Do the products you build—or buy—contain bearings?

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flux indicative of an east-west current.

The other two flights that penetrated the electrojet were made almost due south of the first one: just above the geographic equator, and at two degrees five minutes south. Both of these flights encountered a west-east current 97 kilometers above the earth. At 110 kilometers the current density dropped off, but not to zero. At roughly 117 kilometers the magnetic flux changed again, suggesting the existence of a second west-east current. One of the rockets reached an altitude of 129 kilometers, sufficient to carry it to the apparent center of the upper west-east current.

The equatorial currents are believed due to tidal movement of ions in the upper atmosphere under the influence of the sun and moon. Additional flights will be needed to permit estimates of actual current densities, which vary from hour to hour and day to day.

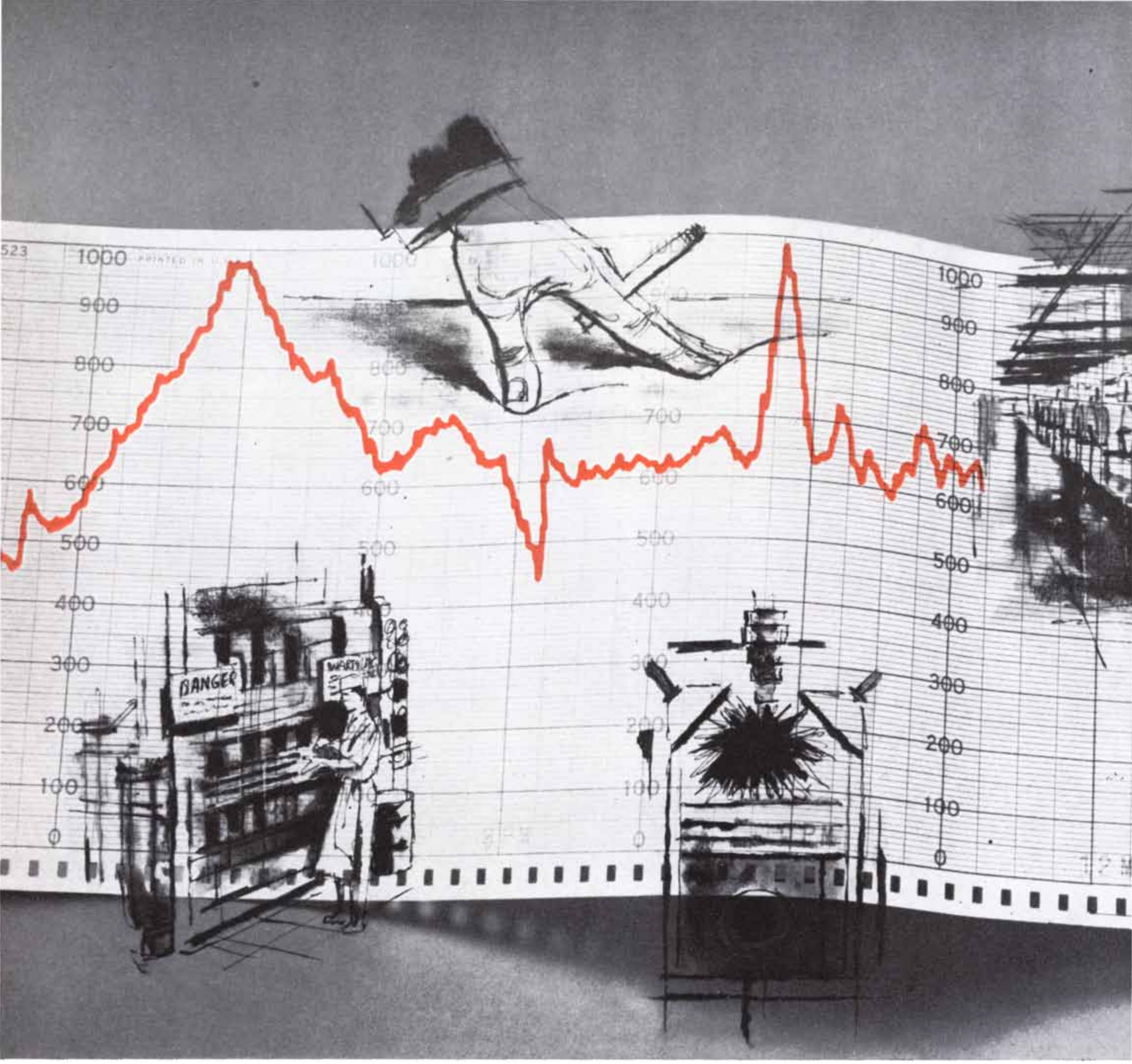
Diagnosis by Computer

In diagnosing illness the physician's usual starting point is to take the patient's medical history. Unfortunately not all physicians are equally skilled in questioning, nor do all have time to take a proper history. As a result Keeve Brodman of the Cornell University Medical College 10 years ago devised a medical-history questionnaire to be filled out by the patient himself.

Brodman and his colleagues have now carried the self-questionnaire a step farther. In studying the patient's history the physician makes deductions from particular combinations of patients' answers—a process that digital computers can be geared to perform. A computer was accordingly equipped with questionnaire answers pointing toward 60 common ailments, obtained by analysis of questionnaires filled out by 5,929 patients admitted to New York Hospital during an 18-month period a decade ago. Questionnaires filled out by 2,745 patients in 1956 and 1957 were then run through the machine.

The computer selected the proper diagnosis in 44 per cent of the questionnaires examined. (What the patients actually suffered from was, of course, known from hospital records.) Later, in a special test involving 350 questionnaires also analyzed by a physician, the computer batted 48 per cent as against 43 per cent for the physician.

Brodman sees rapid interpretation of medical interviews in mass surveys, not replacement of the individual physician, as the primary application of diagnosis by computer.



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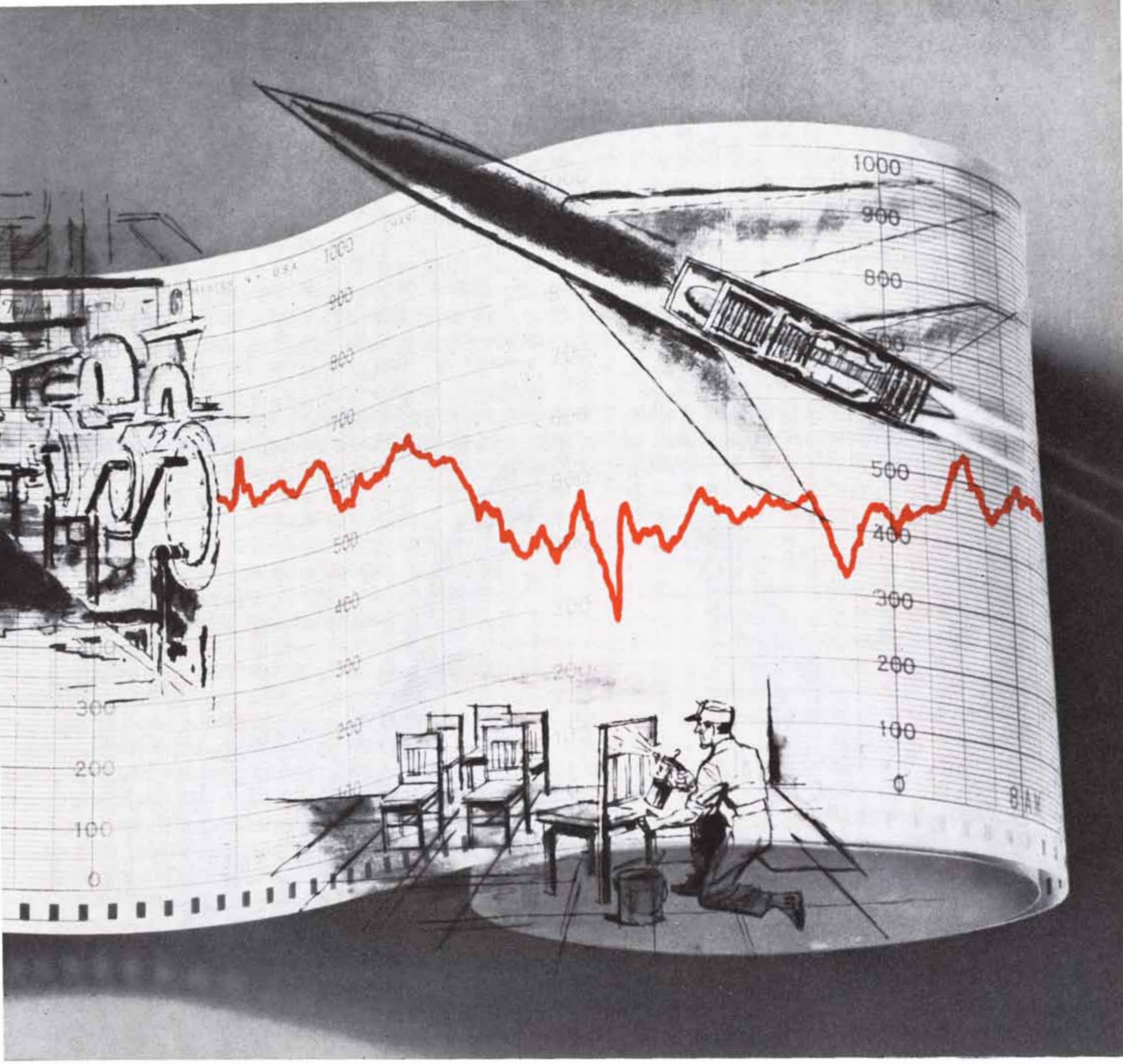

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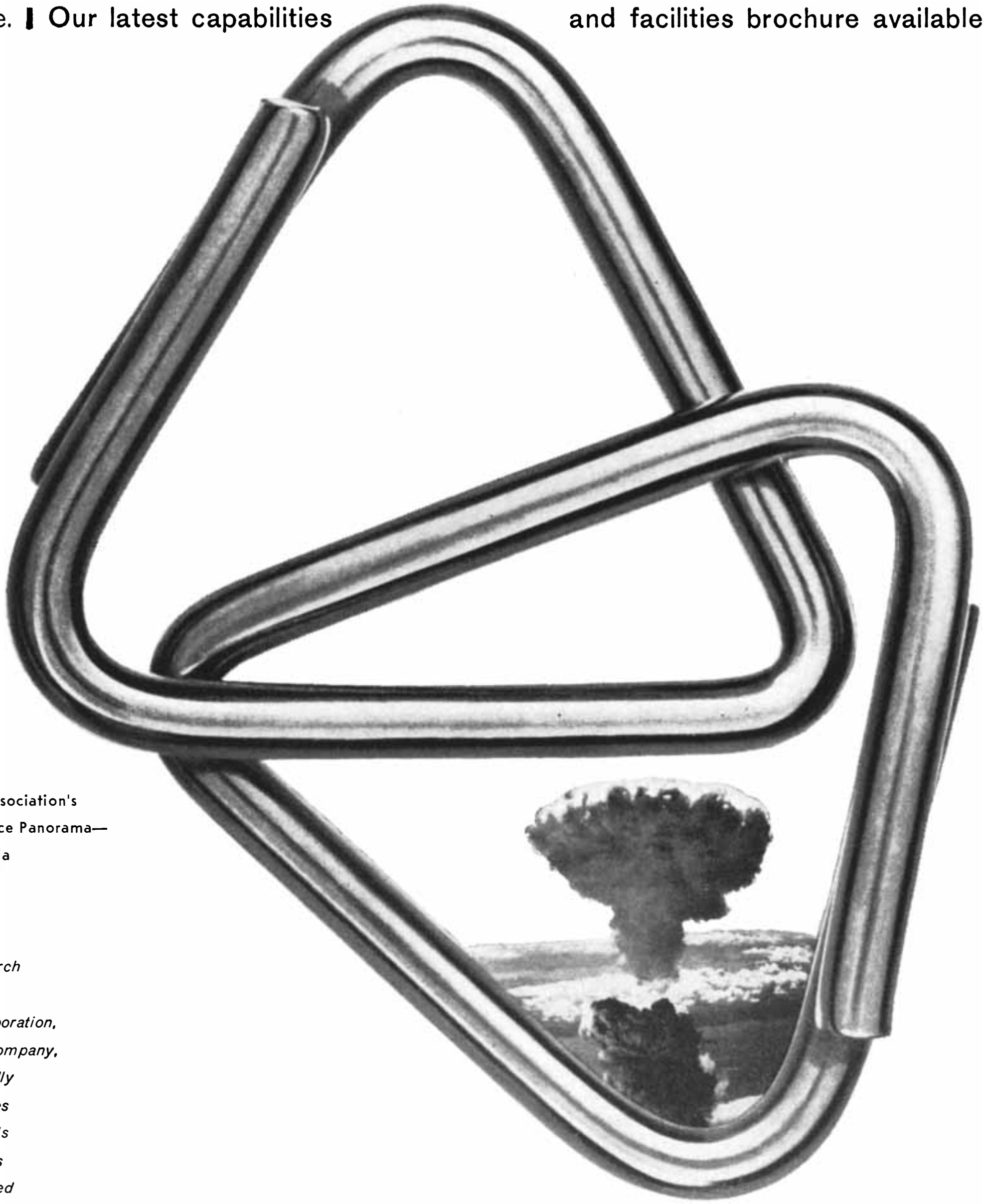

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Ionizing Radiation and the Whole Animal

The cells of the whole animal form an interconnected society, making the effects of radiation more difficult to trace. Some effects are apparent; others can only be inferred indirectly

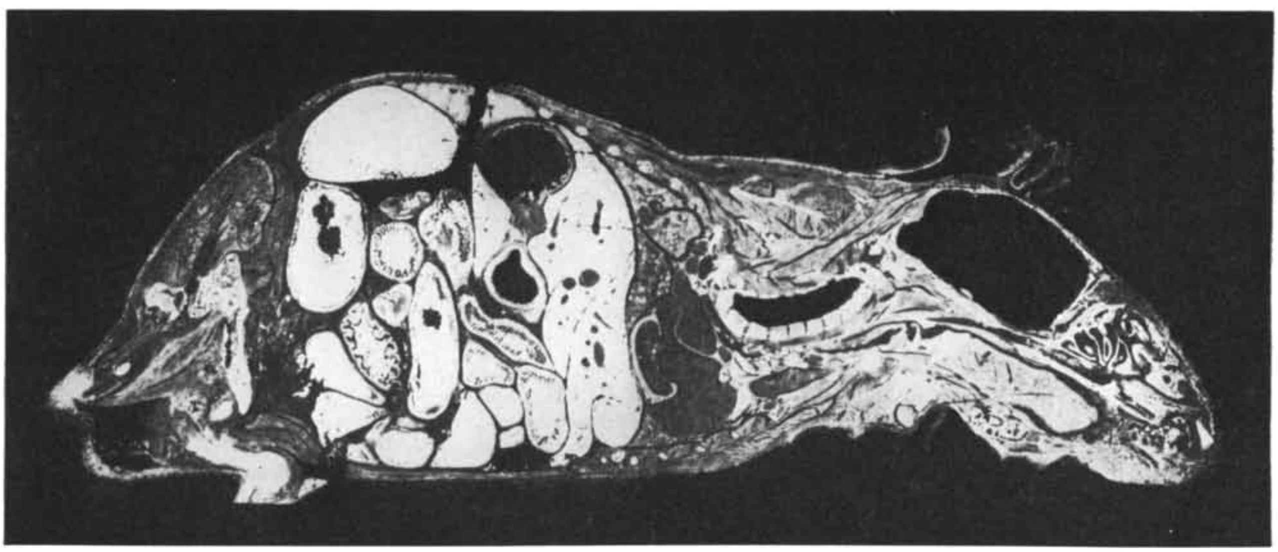
by John F. Loutit

The authors of the preceding article have outlined the effects of ionizing radiation on the living cell. An organism such as a mouse or a man consists of course of many cells. But such an organism is much more than that. It is a society of specialized and interdependent cells. What happens when a society of cells is exposed to ionizing radiation? Even if we knew exactly how each of the cells is affected, we could not answer the question for the organism as a whole. Radiation damage to one organ can disturb the functioning of another. The cooperative action of cells and tissues in a many-celled organism profoundly complicates the primary effects of radiation. Given time, this action can also mitigate or reverse some of the effects.

There is a great deal we do not know about these processes, and our ignorance has more to do with fundamental biochemistry and physiology than with radiation. Obviously more investigation is needed. Meantime ionizing radiation produced by human activities raises problems that may affect all the organisms that now inhabit the earth. These problems must be appraised with the help of the biological and medical tools currently at hand.

The range of the problems should be clearly understood at the outset. At one extreme we are concerned with doses of radiation large enough, and delivered quickly enough, to produce detectable effects in an individual organism. Here there are symptoms for the physician to perceive, tissue changes for the pathologist to examine or for the chemist to analyze.

At the other extreme we have to do with doses so small or so slowly delivered that their direct physiological effects, if any, are too faint for us to recognize. In such cases we can try a statistical approach; for example, we irradiate a large number of mice and try to find out whether more of them develop leukemia than do an equal number of nonirradiated animals. In the absence of statistical data for small doses, as is usually the case for human beings, a dubious form of extrapolation is sometimes attempted: If a dose of 500 rads [*see glossary of terms on page 78*] of mixed gamma rays and fast neutrons from an atomic bomb appears to cause 3,500 cases of leukemia per million people exposed, then one rad of X-rays should cause seven cases. Such a calculation has an appealing simplicity. It is easy for the layman to understand and may even be tempting to the nonmedical investigator. To those who have investigated the complex problems of cancer, however, the simple computation seems unwarranted. It is in this area, therefore, that much



RADIOAUTOGRAPH OF MOUSE given radioactive tetracycline shows that distribution depends on biochemical behavior of the molecules to which radioactive atoms (in this case tritium) are attached. Here the concentration was greatest in liver, kidneys, lymphoid tissue and skeleton. The autograph, by Torsten André, was made by placing section of mouse on photographic plate.

WHOLE-BODY IRRADIATION OF MICE is carried out at the Oak Ridge National Laboratory in this room. The cylindrical shielding-can on the floor contains a cobalt-60 source. The animals are placed in their cages on racks above and around the source.

misunderstanding arises. We shall have more to say about the matter later. Let us begin, however, by considering the more apparent effects.

Enough radiation will kill any organism. An overwhelming dose kills instantly; a smaller, but still lethal, dose causes death within hours, days or weeks. Organisms vary widely in their sensitivity to radiation—much more widely than the cells of which they are constituted. In general, the more complex the organism, the more vulnerable it is. It takes about 20,000 rem to kill a snail, a few thousand to kill a lizard, a few hundred to kill most mammals.

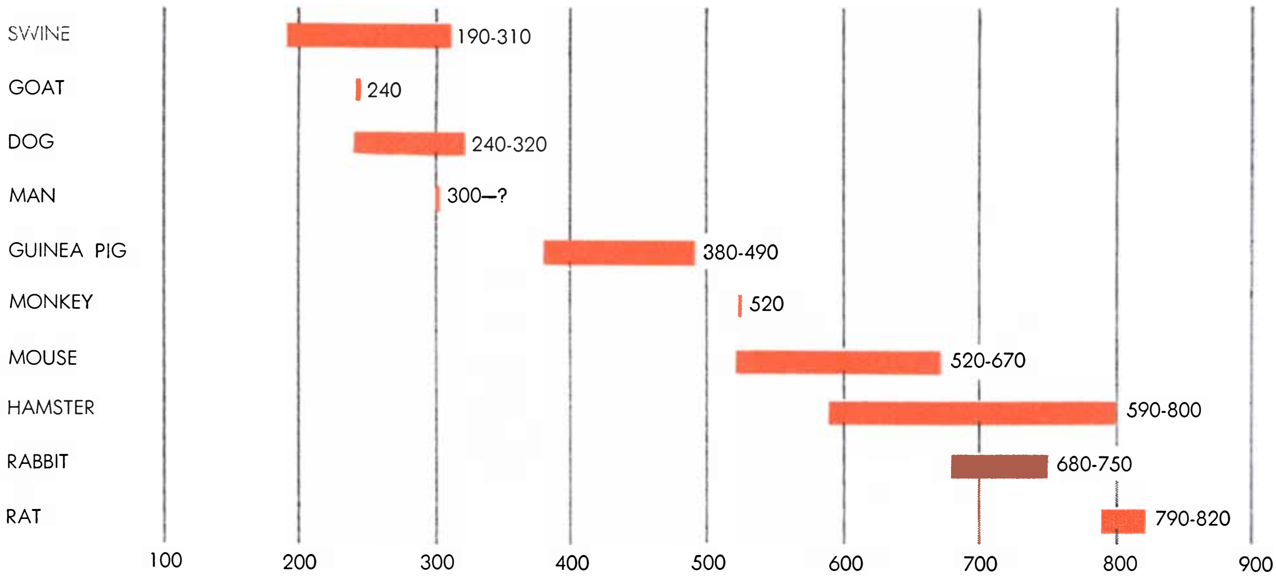
Furthermore, individuals of the same species react differently. Because of this variation we frequently use as a measure the dose that is lethal to 50 per cent of the individuals exposed, abbreviating it as LD_{50}. The "acute LD_{50}" (the single dose that will be fatal to 50 per cent of the exposed individuals within 30 days) for man is 300 or 400 r for 250-kilovolt X-rays; for monkeys, about 500 r; for mice, about 600 r [*see top chart on page 120*]. Immature and senile animals are more sensitive than young adults.

These figures refer to a single burst of radiation delivered to the whole body. As might be expected, much higher doses are tolerated when only a part of the body is exposed. Here the effect will depend on the amount and kind of tissue that is irradiated, its vulnerability to radiation and its role in the economy of the organism. A man could absorb a few hundred rads in his hand, say, with virtually no effect on his body as a whole. However, an equal dose to the abdomen would have serious consequences. Moreover, the rate at which radiation is received has a great deal to do with its effect. A much larger quantity of radiation can be tolerated if it is divided into small fractions and delivered at intervals than if it is administered all at once. By dividing and spreading the dose radiotherapists can treat cancerous tissue with thousands of rads without excessive damage to the patient.

What happens to the body of an animal when it receives a dose of radiation in or near the lethal range? The most critically sensitive tissues are the lining of the intestine and the bone marrow and lymphoid tissues that manufacture blood cells. Intestinal damage causes the body to lose water and salts. If the dose is big enough, say two or three times LD_{50}, the injury is irreversible and death follows in a few days. At smaller but still lethal doses the situation corrects itself and the most serious problem becomes the loss of blood-manufacturing tissue. Death is now delayed for several weeks. It may be due directly to anemia, or to infection following the destruction of white blood cells.

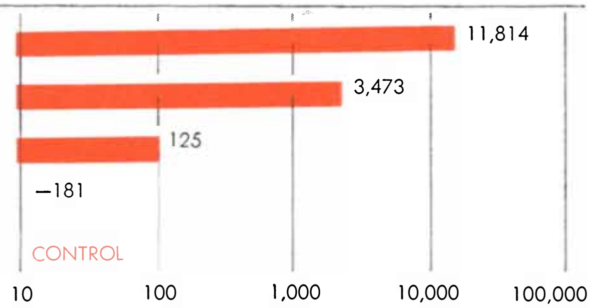
Accompanying these specific effects, whether or not they are severe enough to be fatal, is a generalized reaction called the radiation syndrome. Its first manifestation is radiation sickness, characterized by nausea and vomiting, usually together with a profound lassitude. Subsequently the patient may bleed from the gums or nose, and after 10 days or so may lose some hair. The initial radiation sickness does not seem to depend on damage to specific organs. It follows whenever too much tissue receives too big a dose, whether accidentally or deliberately, as in cancer therapy. The whole clinical picture suggests a general intoxication. Presumably substantial masses of tissue break down, releasing into the general circulation substances that are normally bound within the cells. But even in 1959 this explanation remains a hypothesis subject to further research. No one has thus far identified the toxic substances.

Is there any treatment for these acute reactions to exposure? So far as the radiation syndrome is concerned, we cannot hope to find a specific treatment until we

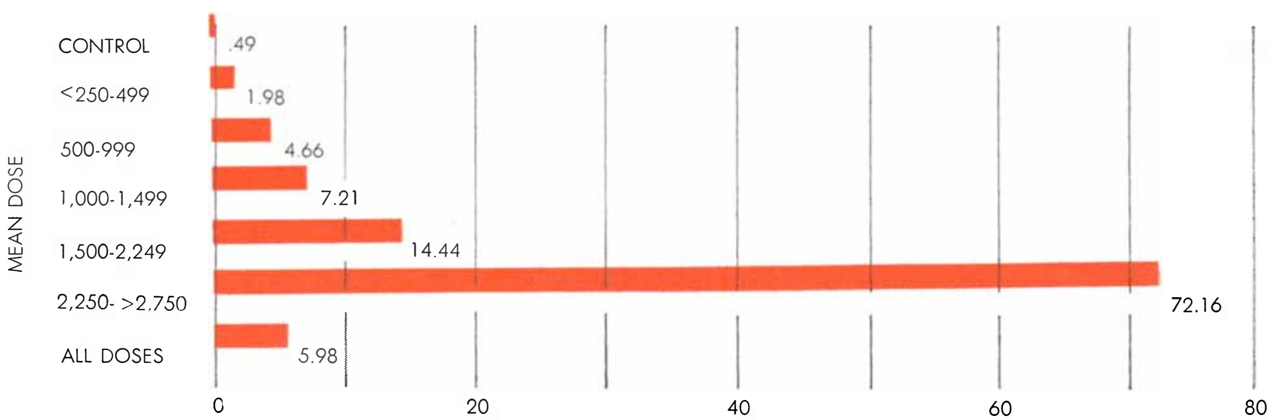


ACUTE LD_{50} (the single dose of radiation that will kill 50 per cent of the exposed individuals within 30 days) has been estimated for various mammals in a number of experiments. The sharp values for the goat, man and monkey reflect limitations in the amount of experimental data rather than precise knowledge. The figure for man is subject to considerable uncertainty. The dose unit in this chart is the rem [*see glossary of terms on page 78*]. As used here it is roughly equivalent both to the rad and the r.

DISTANCE FROM CENTER (METERS)	DOSE (REM)	PERSONS EXPOSED	CASES OF LEUKEMIA	RADIATION-INDUCED CASES PER MILLION
UNDER 1,000	1,300	1,241	15	11,814
1,000-1,499	500	8,810	33	3,473
1,500-1,999	50	20,113	8	125
2,000-2,999	2	32,692	3	−181
OVER 3,000	0	32,963	9	CONTROL



HIROSHIMA SURVIVORS within 2,000 meters of the point above which the atomic bomb was exploded developed more cases of leukemia than in the general population. Bars show incidence (per million people) attributable to radiation for the period 1950-57.



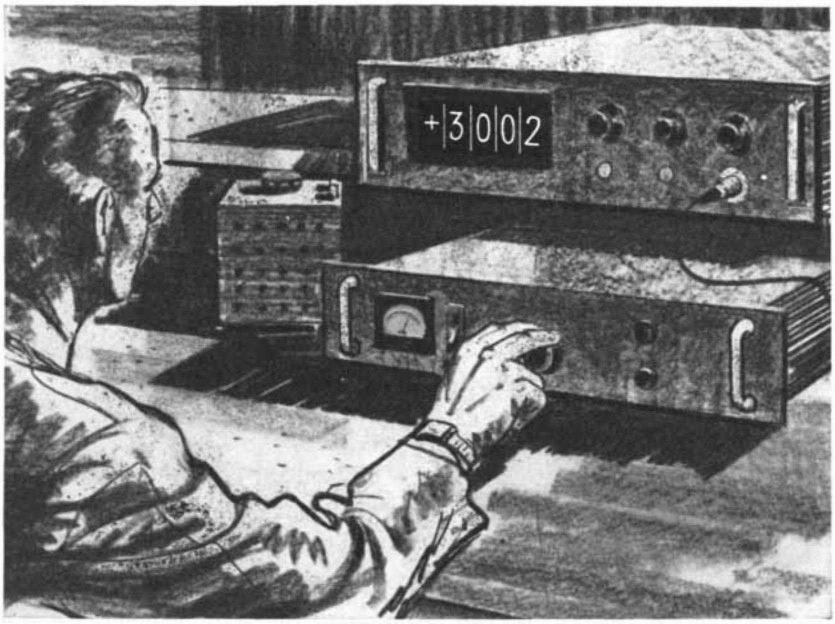
FRACTIONATED DOSES OF X-RAYS to the spines of British patients suffering from an arthritic disease called ankylosing spondylitis also produced an increased incidence of leukemia. Bars show number of cases of leukemia per year per 10,000 men.

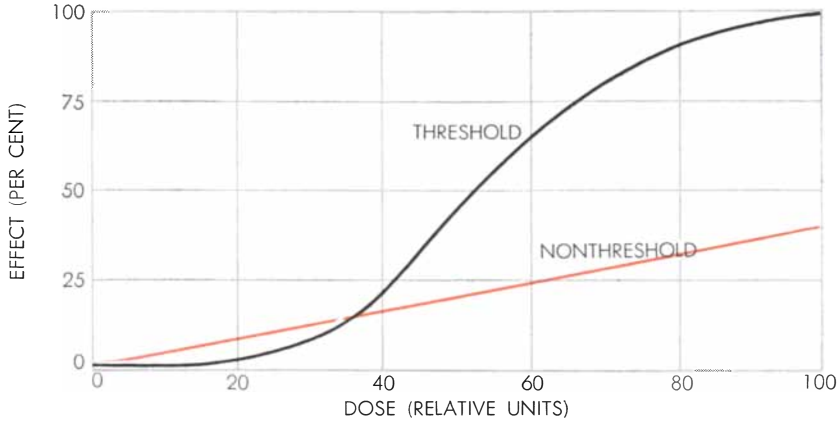
have a clearer picture of its cause. We do know that rest and proper diet promote recovery. Antibiotics help control infection. As to intestinal damage, no method has yet been found to assist the body's own repair mechanisms. The situation is more hopeful, however, in the case of the blood-forming tissues.

Ten years ago Leon O. Jacobson, then at the University of Chicago, showed that mice whose blood-manufacturing system had been destroyed by a lethal dose of radiation could be kept alive by implanting or injecting normal blood-forming tissue from healthy animals. Subsequent investigation has proved that this tissue acts as a functioning graft in the irradiated mouse. Under ordinary circumstances this could not happen; the host would become "immune" to foreign tissue and reject it. But the same radiation that affects the blood-forming system also destroys the capacity to produce an immune response. Thus it seems that the cells of the donor actually repopulate the bone marrow and the pulp of the spleen, where blood cells are manufactured, and in addition the lymphoid tissue responsible for immunity.

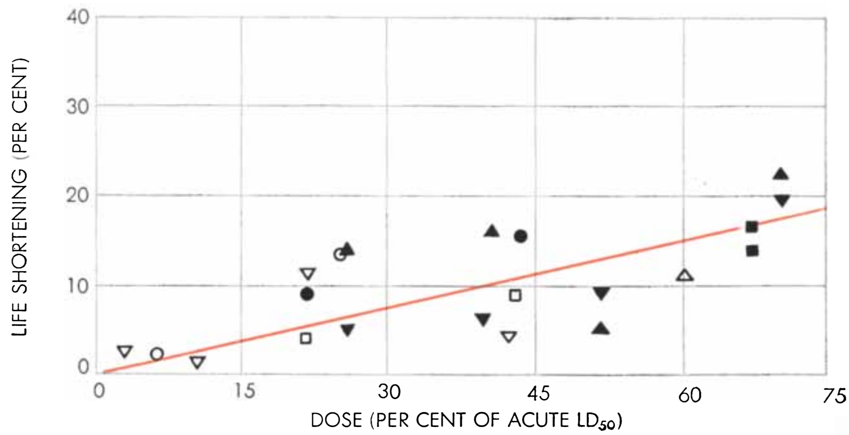
Whether the procedure would be equally effective in man is not certain. It happens that the dose of radiation necessary to inactivate the mouse's immunological system permanently is very nearly the same as the lethal dose. In the dog, however, it is considerably greater than the lethal dose, and in man it may also be greater. Even so, tissue transplants can be of some help. This was demonstrated recently after an accident at a nuclear reactor in Yugoslavia. Several persons exposed to intense radiation were treated in Paris. The French physicians judged from biological reactions that five of the Yugoslav workers had received lethal doses, and gave them transfusions of normal bone marrow. Four of the patients improved dramatically and eventually recovered. Subsequent studies showed that the marrow grafts were not permanent, and possibly did not include the lymphoid system. Apparently the irradiation had blocked the immune response of these individuals for a limited time only, and had not injured their blood-forming system beyond repair. Temporary acceptance of the foreign cells gave time for the repair to operate.

In addition to seeking cures for radiation damage, we should like to find ways to prevent or reduce it in the first place. At present this is only a hope. As the authors of the preceding article have pointed out, ionizing radiation produces many of its effects indirectly, by forming free radicals and peroxides. In in-

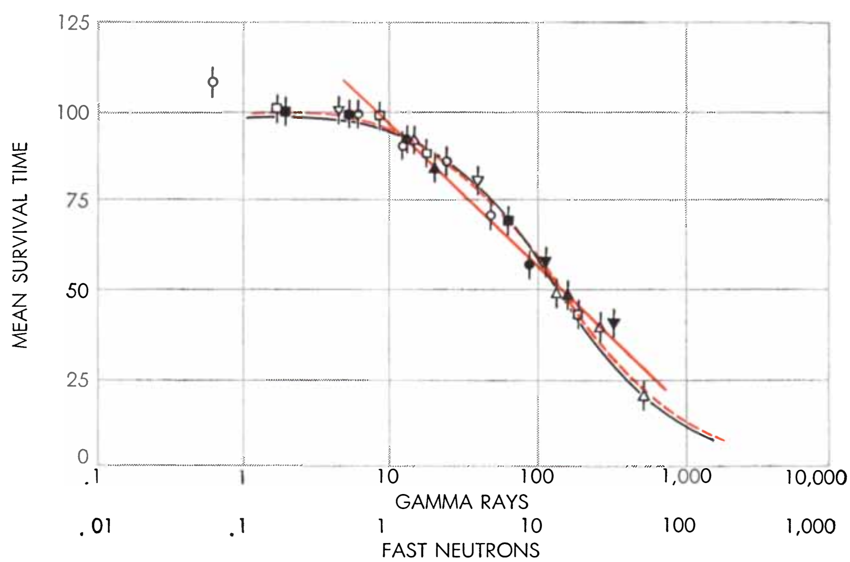




EFFECT OF RADIATION can be of two types, threshold or nonthreshold. In the former case small doses produce no detectable effect, shown by the fact that the S-shaped curve runs along the baseline for some distance before turning upward. In the latter case any dose, no matter how small, has some effect. In practice the shape of the curve is often uncertain.



SINGLE DOSES of radiation have shortened the lives of mice and rats in a variety of controlled experiments. The effect may have no threshold. Acute LD_{50} is the dose fatal to 50 per cent of the subjects in 30 days. Various symbols represent data from different experiments. This graph and the one below, as well as the charts on page 120, are based on the 1958 Report of the United Nations Scientific Committee on the Effects of Atomic Radiation.



WEEKLY DOSES of fast neutrons or gamma rays have also shortened the lives of mice and rats. Three curves appear to fit the data almost equally well. All indicate that there may be a threshold for the life-shortening effect when small, repeated exposures are involved.

dividual cells it is possible to reduce these effects several-fold by cutting off the oxygen supply or by adding certain substances. Only some of the substances can be used on intact animals. Most of them are toxic, and even in limited doses lower the body temperature profoundly. They do seem to give some protection against radiation, but how they operate is uncertain. Possibly they reduce the supply of oxygen in radiation-sensitive tissue, but other physicochemical mechanisms have also been proposed. In any case, none of them has practical value as yet.

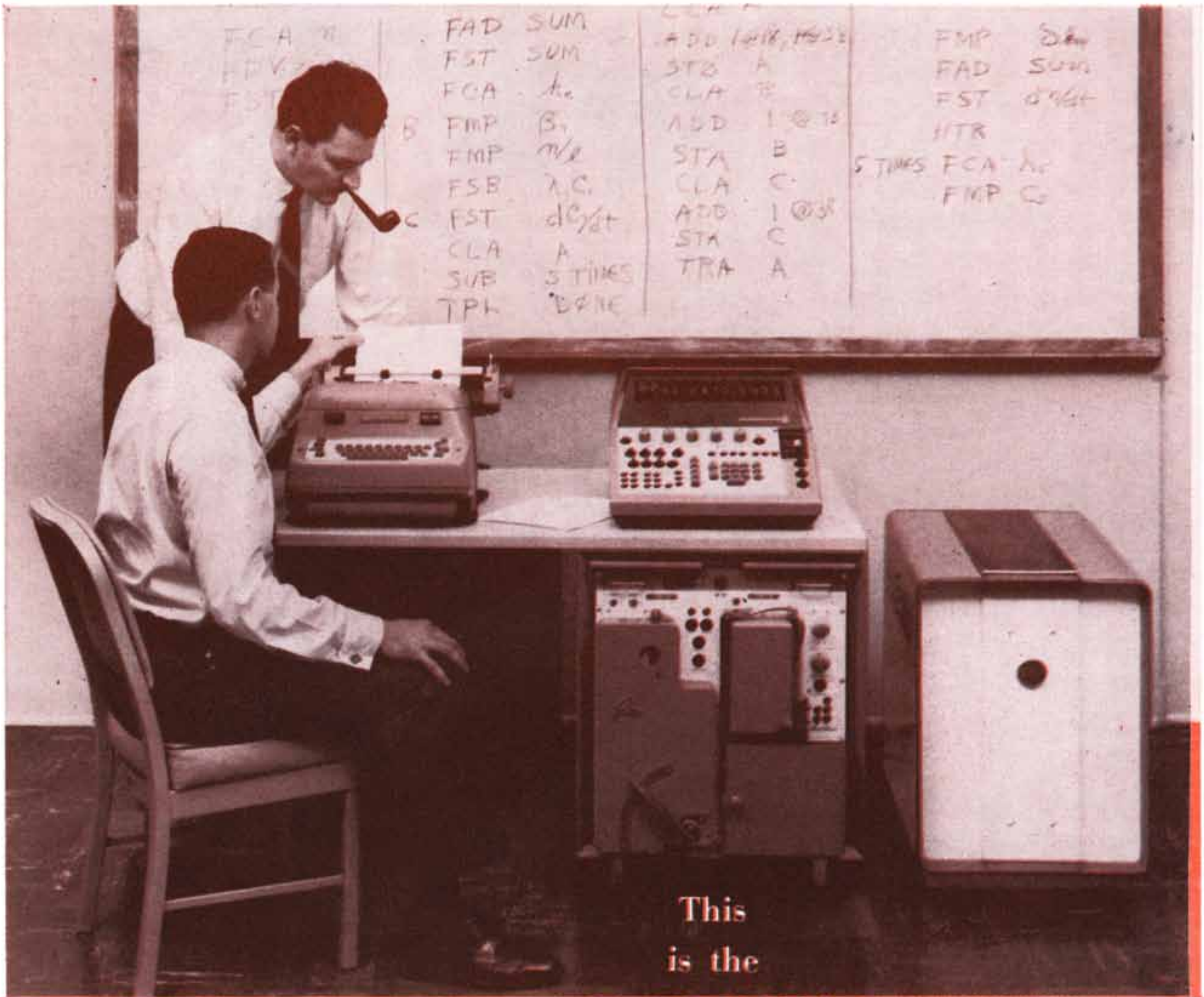
Thus far we have been speaking of the immediate response of the organism as a whole to a massive dose of radiation. This is only part of the story. Some effects manifest themselves more slowly, appearing months or years after exposure. Furthermore, repeated doses that are too small to produce any immediate reaction may eventually have an effect. Many of the early workers in radiation learned this by fatal experience.

Radiologists, then working with low-voltage X-ray machines, were exposed to radiation of low penetrating power. They absorbed most of their dosage in the skin. After a time they developed superficial lesions that resembled a sunburn but were much slower to appear and to heal. When the burns did heal, they left permanent scars. And the process of repair often carried with it further long-term changes. Years later many of the scars became cancerous.

Those researchers who dealt with more penetrating radiation also suffered delayed effects. As might be expected, most of the injuries were to the blood-forming tissues. Death from anemia and its complications was not uncommon. And as with the skin, so with the bone marrow. If the original injury repaired itself, malignant changes later led in a number of cases to leukemia.

This disease, in which the blood-forming tissue produces too many white cells, takes several forms in man. It can be acute, leading to death shortly after its appearance, or chronic but ultimately fatal. Two different types of white cell, known as granulocytes and lymphocytes, may be involved. Chronic lymphoid leukemia, the incidence of which increases with age, has not been shown to be induced by radiation. But there is good evidence both from the early radiologists and from more recent experience that chronic granulocytic leukemia and various types of the acute disease have followed overexposure to radiation.

The atomic bomb explosions at Hiro-



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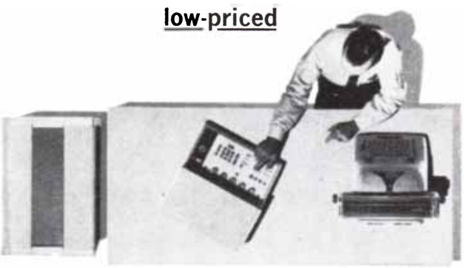

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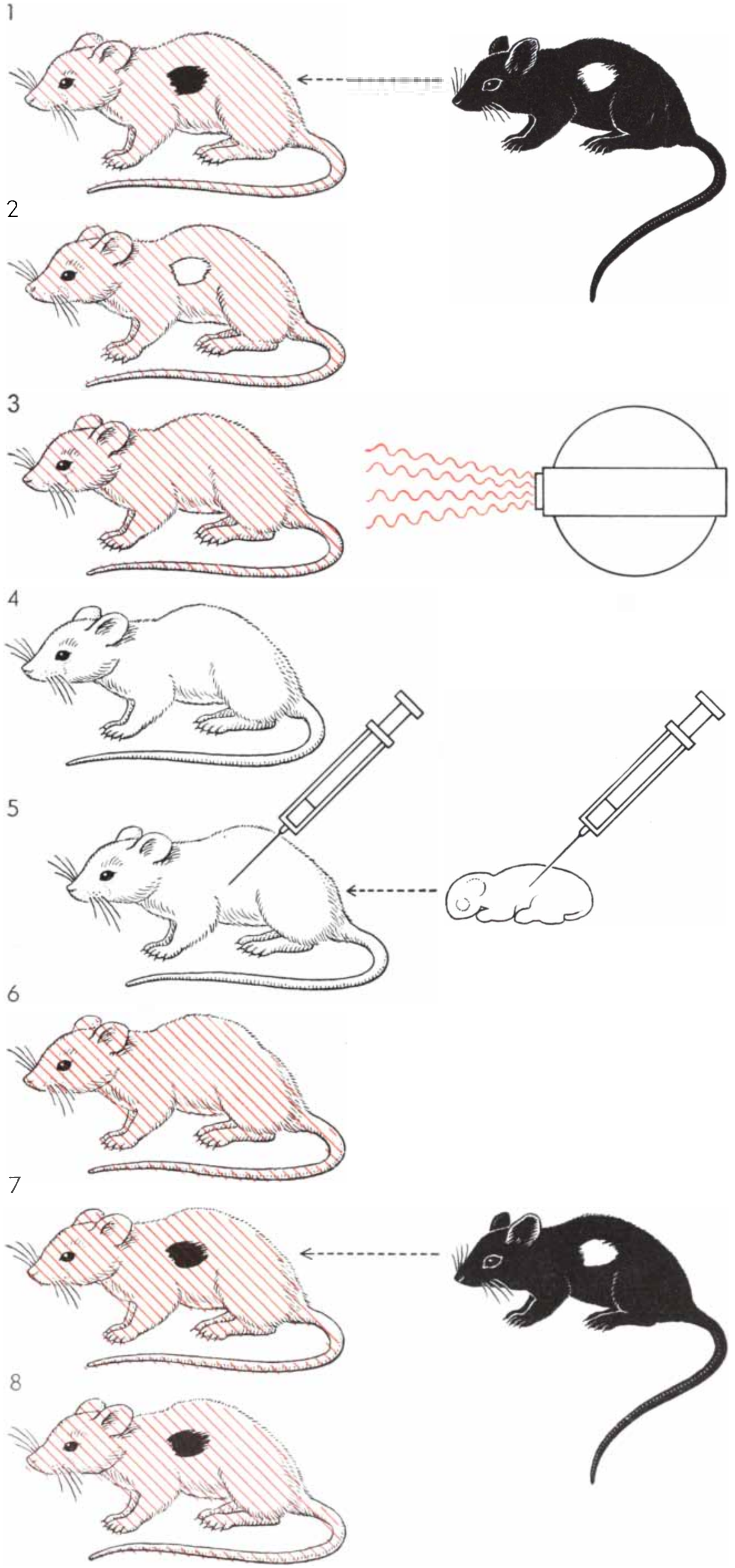
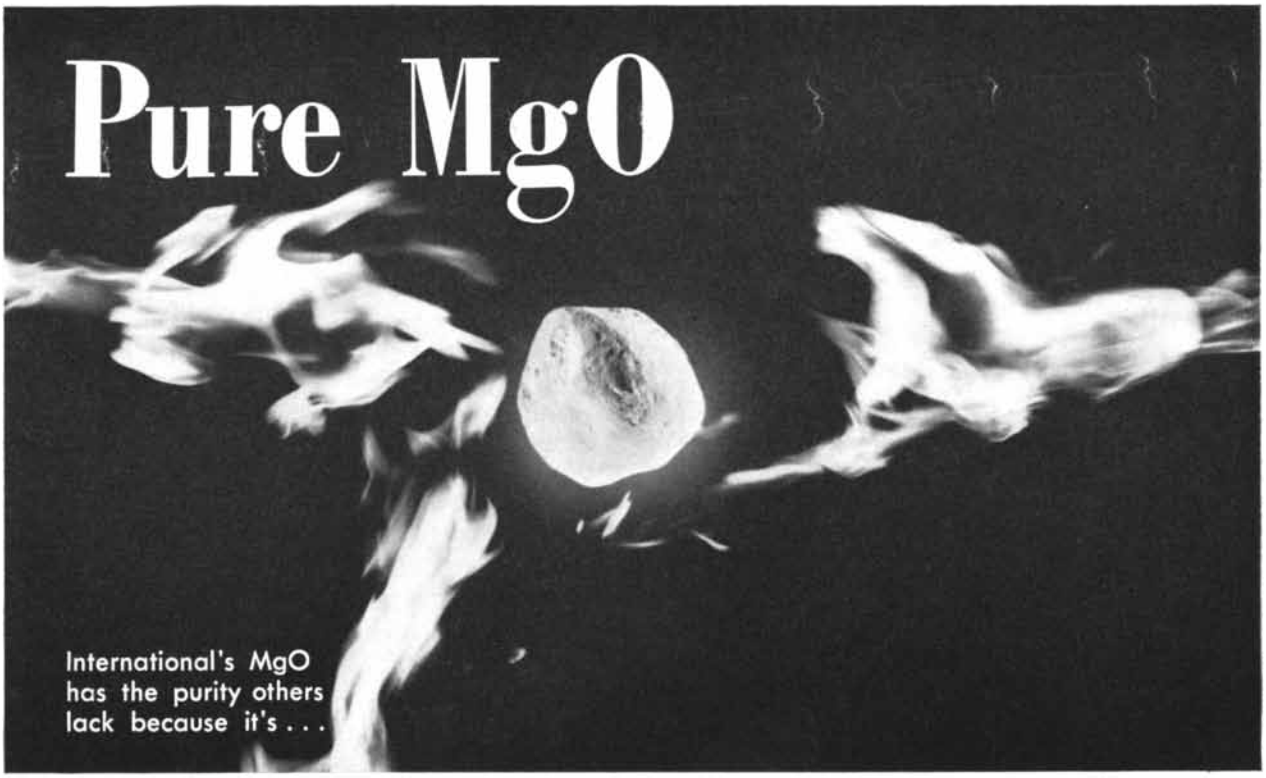
shima and Nagasaki undoubtedly increased the incidence of leukemia among survivors who were within a mile or so of the explosion center [*see middle chart on page 120*]. These people received doses of from 50 to 1,300 rads, presumably to the whole body. Intermittent exposures of parts of the body can also cause the disease. A British study has documented this in a group of men suffering from an arthritic spinal disease known as ankylosing spondylitis, or "poker back." The patients had been treated with X-rays concentrated on the spine, the total dose varying from 250 r to more than 2,500 r. Again the subsequent incidence of leukemia was substantially greater than that for the general population [*see bottom chart on page 120*]. On "a working hypothesis that, for low doses, the incidence of leukemia bears a simple proportional relationship to the dose of radiation," the authors of the study concluded that a dose of 30 to 50 r to the whole marrow would be likely to double the natural incidence of leukemia.

According to a recent report from the University of Oxford, the human fetus is very much more sensitive in this respect. The Oxford investigators studied the fetal history of children who had died of leukemia or other forms of cancer before the age of 10. A preponderance of these children proved to have been exposed to radiation during pelvic X-ray examinations of their mothers. Such an examination gives a dose of about two r to the fetus. Those receiving it proved about twice as likely as other children to die of malignant disease before their 10th birthday.

We should note that in all these instances, including the small doses to unborn children, the radiation was re-



TISSUE TRANSPLANTS that would be impossible in normal mice will "take" in irradiated animals. In the experiment represented schematically at left, skin from a mouse of one strain is grafted onto a normal animal of another strain (1). (Colored hatching indicates that animal has functioning blood-forming tissue.) The graft is rejected (2). Mouse is given a lethal dose of radiation (3), which destroys its blood-forming tissue (4) and the tissue responsible for its immune reaction to foreign grafts. Blood-forming tissue from the liver of a fetal mouse is injected (5), the blood-building system is restored (6) and the mouse recovers. The irradiated animal will also accept a foreign skin graft (7 *and* 8).



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ceived at a substantial rate. Whether very much lower dose-rates can also cause leukemia is a question to which we shall return later.

Delayed effects of radiation are also observed in bone. Large therapeutic doses (1,000 r or more) have destroyed bone tissue and led to fractures. Much of what we know about bone damage, however, we have learned from the famous U. S. case of the luminous-watch-dial painters, who were chronically exposed to radiation from within their own bodies. They had inhaled and swallowed radium and mesothorium which were used in luminous paint. From the lungs and gut these elements passed into the general circulation. Being chemically similar to calcium, they were eventually incorporated more or less permanently in the bones of the workers.

Those whose skeletons had taken up more than 10 microcuries of radioactive material suffered acute destruction of bone and marrow, and died within a few years as a result of this direct damage. (Each microcurie of radium delivers an average dose of about 30 rads per year.) For "burdens" of one to 10 microcuries the bone lesions were less acute; the affected workers lived longer, some long enough to develop bone cancers. There were very few cases of leukemia, however. At levels below one microcurie only rarely have serious changes been noted, and below a third of a microcurie no changes of significance have been observed. Some of the workers have now been under observation for as long as 30 years after their contamination.

Nuclear fission has added to the environment another bone-seeking radioactive isotope: strontium 90. Workers actively handling this material might conceivably take enough of it into their bodies to produce long-term damage. As practically everyone knows, strontium 90 has been released into the atmosphere by the testing of nuclear weapons, and small quantities of it have found their way through the food cycle into the bodies of human beings. The amounts involved, however, are very much smaller than those we have been discussing. Measurements on young children, whose rapidly growing bones incorporate strontium at a maximum rate, have shown burdens up to a few thousandths of a microcurie. The corresponding dose-rate is in the neighborhood of .01 rad per year.

Various human tissues in addition to those already mentioned exhibit special reactions and sensitivity to radiation. For example, cataracts have been produced

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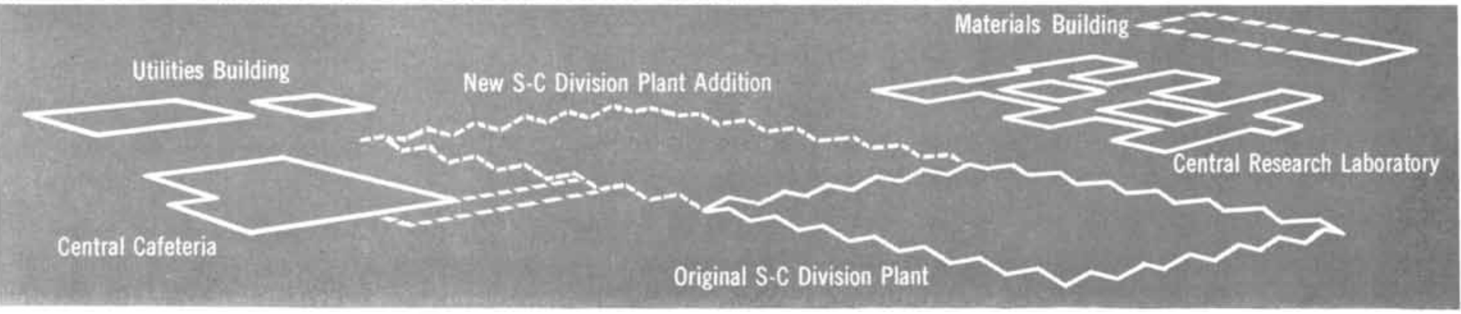

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in the lens of the eye by doses of a few hundred rads to parts of the body which include the eyes. Heavy irradiation of the lungs in radiotherapy causes a slowly developing, progressive inflammation known as radiation pneumonitis. The gonads are particularly vulnerable. Single exposures as low as 30 r can produce temporary sterility. Smaller, repeated doses have a similar effect, and larger exposures lead to permanent loss of fertility, especially in females.

In general, cells in the process of division are especially sensitive to radiation. In the adult organism division is responsible for the continuous renewal of blood cells, skin and intestinal lining and for the production of sperm. These systems, as we have seen, are among the most easily affected by radiation. As would be expected, the developing embryo (particularly at the stage where the various tissues are being organized) is liable to damage that is irremediable. Doses of 25 r or more at this stage may lead to serious malformations.

As a final comment on the detectable effects of radiation, it should be said that neither individual organisms nor their descendants seem able to develop tolerance, as is the case with some other poisons. Small doses, given steadily or repeatedly at intervals, do not increase the body's resistance to radiation, whatever else they may do.

We turn now to effects of very small quantities of radiation on the human organism. In studying the biological effects of chemical agents such as drugs, we generally use a particular type of graph to analyze the experimental data. Along the horizontal axis of the graph we measure dose on a logarithmic scale; along the vertical, the effect as a per cent of the maximum. In almost every case the resulting curve is S-shaped, running closely parallel to the horizontal axis for some distance before it turns upward. This means that below a certain dose we can detect no effect whatever [*see top chart on page 122*]. In other words, there is a threshold for the action of the agent. Not all dose-effect curves have the standard shape, however. Another possibility is a straight line running up from the zero point or from a point on the vertical axis. Such a line indicates that any dose, however small, has a measurable effect.

Now in the case of radiation effects, especially the effects of high dose rates on mammals, the lines on the graphs usually turn out to be curved, not straight. On the other hand, it has been

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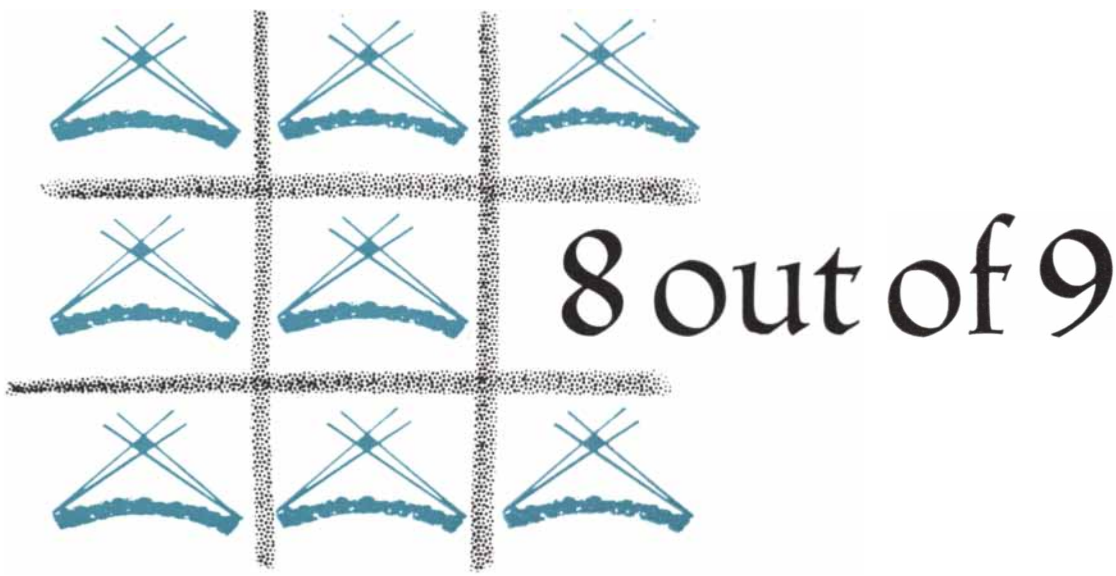

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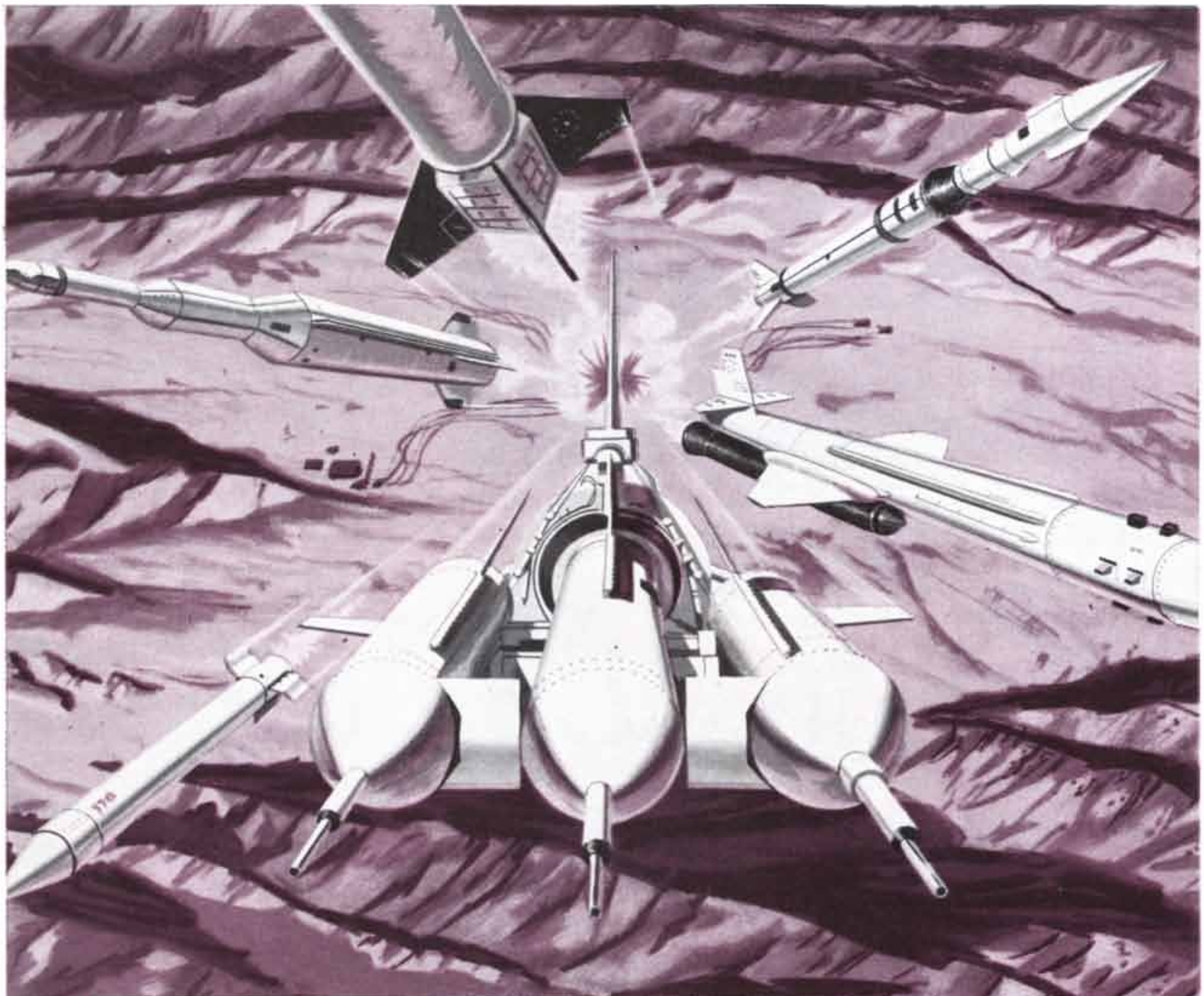
suggested that certain effects may be of the linear, nonthreshold type. This is perhaps more likely where dose rates are low (and where experimental data are difficult to obtain).

The capacity of X- and gamma-rays to cause point mutation in germ cells has been classically considered a universally linear effect. Any dose, no matter how small, was supposed to yield its proportionate share of mutations. Now, as the authors of the preceding article have mentioned, studies at the Oak Ridge National Laboratory indicate that the matter is not so simple. The mutability of the germ cell varies with its stage of development, and at some (but not all) stages the mutability may apparently change with dose rate.

Potentially valuable sources of information on the effects of low dose rates are to be found in human populations living in areas with a relatively high background of radiation. Such populations exist in parts of Kerala, in southern India, where the soil contains unusually large concentrations of thorium. It would be most desirable to compare the records of vital statistics for these people with records for similar groups living in regions of normal background-radiation. As yet, however, the necessary records are not in existence.

Lacking direct evidence as to very low dose-rates we can only fall back on the scanty records of human beings whose occupations have exposed them to intermediate but uncertain quantities of radiation, and on inferences, carefully drawn, from animal experiments. What can we say about leukemia, one of the radiation effects for which a linear relationship has been suggested? U. S. radiologists, but apparently not their British colleagues, have suffered a significantly higher death rate from the disease than have appropriate controls. Their total exposure is unknown, but it must have been intermittent, not uniform over the body, and received at substantial dose-rates.

Leukemia is a spontaneous disease of animals other than man. Mice are subject to both the lymphoid and the granular types; the former is more common. A suitable course of whole-body irradiation will greatly increase the incidence of lymphoid leukemia in mice: Given a series of intermittent exposures at high dose-rates, nearly 100 per cent of experimental animals will die of the disease. On the other hand, my colleague R. H. Mole has found a different situation at lower dose-rates. The induction of leukemia in mice receiving a total of 1,000 r in the same over-all period varies



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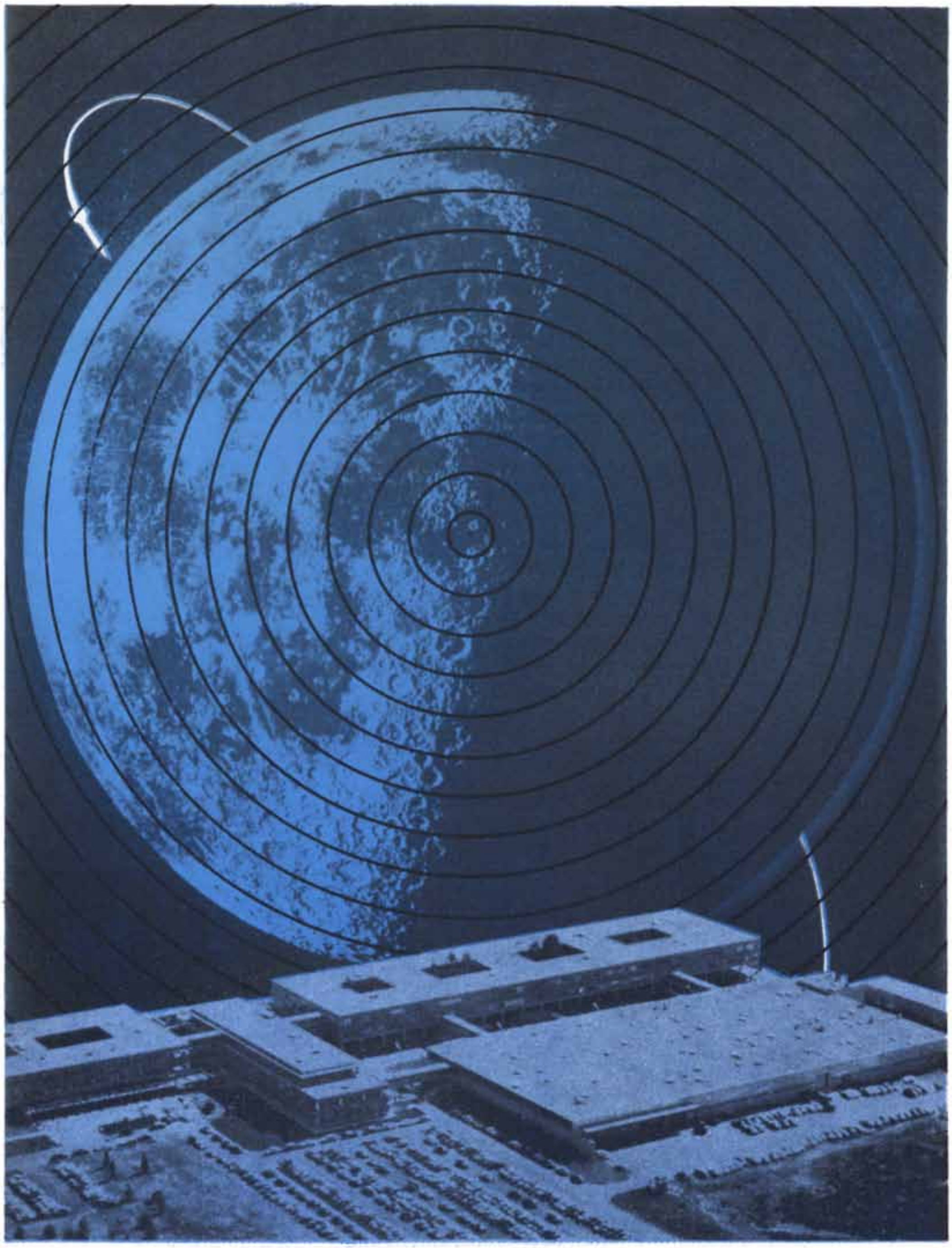
from the substantial, when the dose is given in fractions at a high rate, to the negligible when given continuously at a low rate. Such experiments lend support to the concept of a threshold; they are certainly at variance with a linear relationship unrelated to dose rate.

Another matter that has received a good deal of attention is the possibility that small doses of ionizing radiation may shorten life. Of course a person who dies of leukemia or bone cancer has been cut off before his time. But it is suggested that, in addition to such obviously lethal damage, radiation can cause a nonspecific reduction in longevity. It may accelerate the process of aging throughout life, or hasten the onset of senescence.

As always, we have very little evidence concerning human beings. A study of a few years ago indicated that U. S. radiologists die younger than other medical workers. However, upon further analysis the age distribution within the two groups proved to be different. The radiologists were generally younger, and the age of death of curates is notoriously less than that of bishops. British radiologists, an even smaller population than those in the U. S., live a normal term. Those of the earliest generation had a high rate of skin cancer, as one might expect. But there is no evidence of a nonspecific reduction in their life span.

Many investigators are working on the problem with animals. In some experiments the subjects are given single doses of various sizes and their subsequent term of life compared with that of nonirradiated controls. In others the animals are exposed at regular intervals starting at various ages and continuing for the rest of their lives. On the whole, a single irradiation appears to shorten the life span by an amount proportional to the dose; that is, the effect appears linear. However, in animals receiving daily irradiations of varying amounts, the results tend to exhibit a threshold. No significant change has been measured in mice that were subjected to five rads or less per week.

In any event all such results should be interpreted with the greatest caution. So far as nonspecific aging effects are concerned, we must be certain that the pattern of death is the same for the different experimental groups. For instance, if one scheme selectively produces a crop of radiation-induced leukemias where another does not, a comparison of the two sets of data will prove little about nonspecific aging. Until we



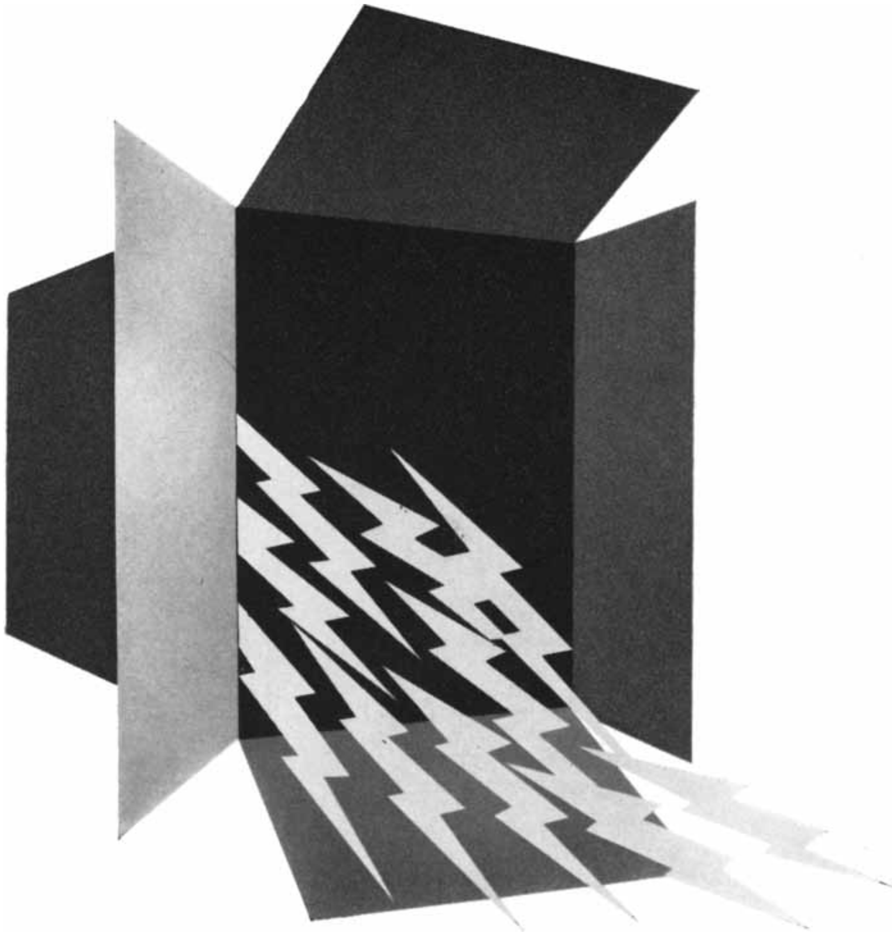
know more about the causes of death in the various populations, the pathologist like myself profoundly distrusts those who juggle numbers. Still more does he distrust those who attempt to translate the results of animal experiments directly to man. A man is not a mouse multiplied in size, life span and other biological characteristics. Each has its own racial character. At best the mouse is a model; it can easily become a siren. Experiments with mice can elucidate principles that may apply to man, but they cannot by themselves supply numbers to put into a human equation.

Since time is a factor for which there is as yet no substitute, many of our questions are likely to remain open for generations. Meanwhile we can say that dose-rates 1,000 times greater than background produce no demonstrable shortening of life in mice. Radiologists of a former generation probably took as great a dose with no decrease in life span.

Each advance in man's power over nature has brought with it an element of danger. Atomic energy is no exception. Consciously or unconsciously we adopt a policy of acceptable risk in every facet of our lives. Society must decide what risk it will accept in the development of atomic energy; the scientist must make clear the potential gains and losses.

Thus far, as we have seen, the limits of risk are not completely outlined, and research continues on the biological effects of ionizing radiation. Some problems, such as life-shortening, may not be solved completely for a long time. Others we are liquidating more quickly. Among these we might mention the accurate measurement of dose, particularly from internal sources, and the determination of the relative effectiveness of various kinds of radiation.

In the meantime we continue to explore the beneficent possibilities of nuclear fission and other aspects of radiation. Certainly we should proceed cautiously, within limits that seem reasonable in the light of expanding knowledge. If one microcurie of radium causes only minor effects in the body, and a third causes none that we can observe, is it not reasonable to set .1 microcurie as a limit for occupational exposure? If external radiation 1,000 times background produces no apparent damage, is not 50 times background an acceptable risk for radiation workers, as has been recommended? Perhaps the figures will need revising as time goes on. But they seem to be adequate guideposts for the present.



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The reason: Even though, as industrial materials, man-made fibers are new, all of them — from nylon to "Teflon" TFE fiber, — cover a wide range of properties. And, unlike those of natural fibers, their properties can be tailored to suit specific needs.

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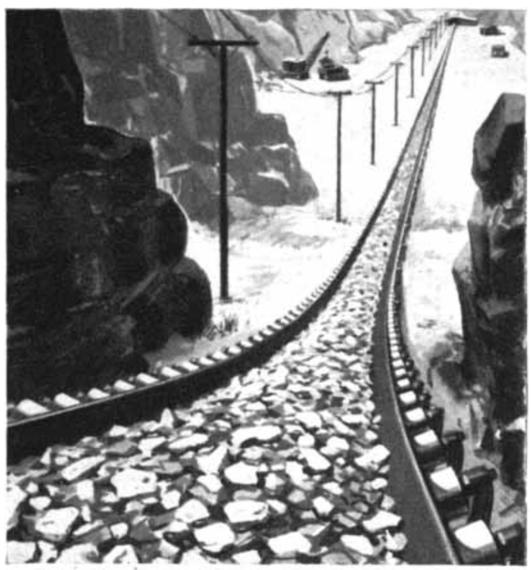
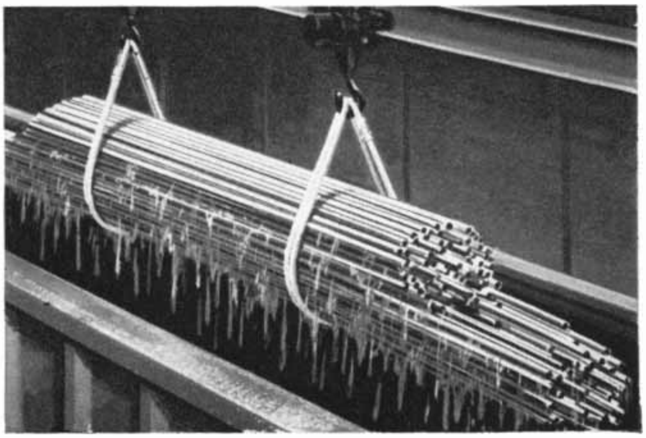
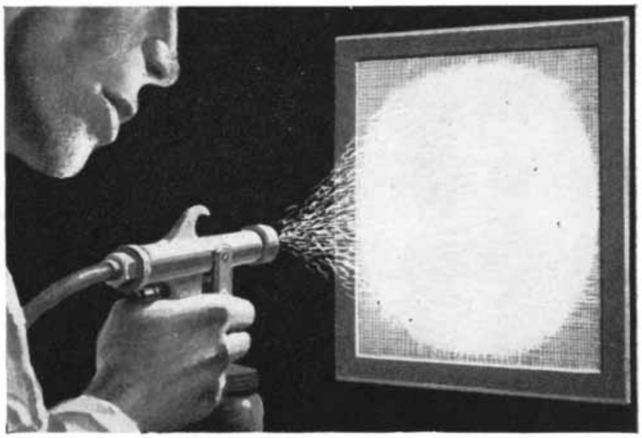


WORLD'S LONGEST SLOPE CONVEYOR will carry 700 tons of taconite per hour, traveling at a speed of 460 fpm. The ore will be carried upward approximately 800 ft. The belting — over 7,500 ft. long, with a center distance of 3,791 ft. — is reinforced with Du Pont high-tenacity rayon and nylon. The light weight and high strength of these fibers help make so long a conveyor-belt system economically feasible.

THE FIRST MAN IN SPACE may carry his own atmosphere with him in a special multi-fabric protective suit. Such experimental suits have an outer layer of nylon fabric and rubber. Owing to the strength and stretchability of nylon, the suit allows freedom of movement, yet protects the astronaut from possible explosive decompression which would boil his blood in seconds. Also in the suit may be a temperature-resistant layer of aluminized "Dacron". This is designed to maintain the space man's body at normal temperature, even though he may be subject to the intense cold of space and the extreme heat generated by the re-entry into the earth's atmosphere.



ACID-RESISTANT ROPE SLINGS made with ¾″ filament rope of "Dacron" polyester fiber support up to 5,000 pounds of stainless-steel tubing in pickling operations. The tough, low-stretch properties of "Dacron" permit repeated immersion of these slings in acid pickling baths for continuous periods of service up to six months long. When slings of "Dacron" are used instead of stainless-steel chains, dents and handling marks on the tubes are drastically reduced, with a resultant saving in cost.



HIGH-EFFICIENCY SUPERFINE FILTERS are easily produced in a new process utilizing "Dacron". This method involves spraying a 10% solution of polystyrene in methylene chloride at 50 psi onto a backing mesh of "Dacron". The solvent evaporates almost instantaneously, leaving thin fibers less than 1 micron thick and 1 in. long. The mesh of "Dacron" is then peeled off, and the mat is rolled to produce a completely organic filter that retains 99.5% of the particles it picks up, down to 0.01 micron.

Ionizing Radiation and Evolution

Living things evolve as a result of random mutations in hereditary characteristics that survive when they make the organism more fit. What role does ionizing radiation play in the evolutionary process?

by James F. Crow

The mutant gene—a fundamental unit in the mechanism of heredity that has been altered by some cause, thereby changing some characteristic of its bearers—is the raw material of evolution. Ionizing radiation produces mutation. Ergo, ionizing radiation is an important cause of evolution.

At first this seems like a compelling argument. But is it really? To what extent is the natural rate at which mutations occur dependent upon radiation? Would evolution have been much the same without radiation? Is it possible that increased exposure to radiation, rising from human activities, has a significant effect upon the future course of human evolution?

Radiation has been of tremendous value for genetic research, and therefore for research in evolution. To clarify the issue at the outset, however, it is likely that ionizing radiation has played only a minor role in the recent evolutionary history of most organisms. As for the earliest stages of evolution, starting with the origin of life, it is problematical whether ionizing radiation played a significant role even then. Laboratory experiments show that organic compounds, including the amino acid units of the protein molecule, may be formed from simple nitrogen and carbon compounds upon exposure to ionizing radiation or an electric discharge. But ultraviolet radiation serves as well in these demonstrations, and was probably present in large amounts at the earliest ages of life. In the subsequent history of life the development of photosynthesis in plants and of vision in animals indicates the much greater importance of nonionizing radiation in the terrestrial environment.

Nonetheless, as will be seen, man presents an important special case in any discussion of the mutation-inducing effects of ionizing radiation. The mutation rate affects not only the evolution of the human species but also the life of the individual. Almost every mutation is harmful, and it is the individual who pays the price. Any human activity that tends to increase the mutation rate must therefore raise serious health and moral problems for man.

H. J. Muller's great discovery that radiation induces mutations in the fruit fly *Drosophila*, and its independent confirmation in plants by L. J. Stadler, was made more than 30 years ago. One of the first things to be noticed by the Drosophila workers was that most of the radiation-induced changes in the characteristics of their flies were familiar, the same changes having occurred repeatedly as a result of natural mutation. Not only were the external appearances of the mutant flies recognizable (white eyes, yellow body, forked bristles, missing wing-veins); it could also be shown that the mutant genes were located at the same sites on the chromosomes as their naturally occurring predecessors. Thus it seems that radiation-induced mutants are not unique; they are the same types that occur anyhow at a lower rate and that we call spontaneous because we do not know their causes.

The prevailing hypothesis is that the hereditary information is encoded in various permutations in the arrangement of subunits of the molecule of deoxyribonucleic acid (DNA) in the chromosomes. A mutation occurs when this molecule fails, for some reason, to replicate itself exactly. The mutated gene is thereafter reproduced until its bearer dies without reproducing, or until, by chance, the altered gene mutates again.

A variety of treatments other than radiation will induce mutation. Most agents, including radiation, seem to affect the genes indiscriminately, increasing the mutation rate for all genes in the same proportion. But some chemical mutagens are fairly selective in the genes they affect. It is even conceivable that investigators may find a chemical that will regularly mutate a particular gene and no other. This will probably be very difficult to achieve: A mutagen capable of affecting a specific gene would probably have to have the same order of informational complexity as the gene itself in order to recognize the gene and influence it.

Moreover, different mutant genes known to be at different locations on the chromosome frequently produce effects that mimic each other. Geneticists who work with fruit flies are familiar with several different genes that result in indistinguishable eye colors. This is not surprising when we consider the complexity of the relationship between the genes and the characteristics that they produce. There are many different paths by which any particular end-point may be reached; it is to be expected that many different gene changes can lead to the same result, though the chemical pathways by which this is accomplished may be greatly different.

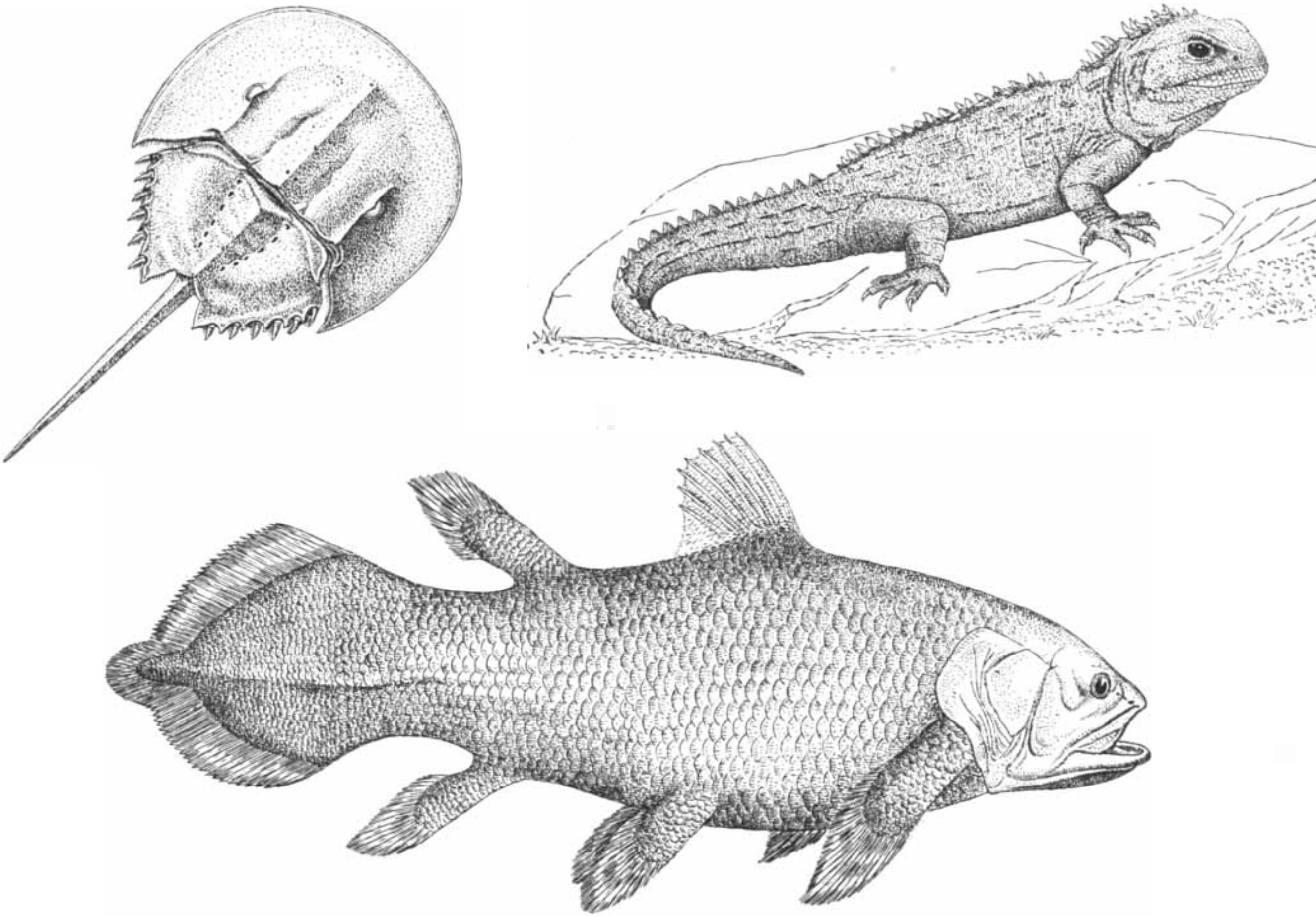
To consider another kind of example, many insects have come to survive insecticides. They do so by such diverse means as behavior patterns that enable them to avoid the insecticide, mechanisms that interfere with the entrance of the insecticide into the body, enzymes that detoxify the insecticide, and by somehow becoming able to tolerate more of the insecticide. All these modes of survival develop by selection of mutant genes that are already present in low frequency in the population. This is one of the characteristic features of evolution: its opportunism. It makes use of the raw materials—that is, the mutant genes—that happen to be available.

As a first conclusion it appears that radiation-induced mutations do not play any unique role in evolution. The same gene mutations would probably occur anyhow. Even if they did not, the same end result could be achieved with other mutants.

One might still suspect that spontaneous mutations are caused by natural radiations. This was quickly ruled out as a possibility in Drosophila. For one thing, the spontaneous-mutation rate is strongly dependent upon temperature, which would be surprising if mutation were a simple and direct consequence of radiation. But much more decisive evidence comes from the fact that the amount of natural radiation is entirely inadequate to account for the rate of spontaneous mutation. The natural-mutation rate in Drosophila, if it were caused solely by radiation, would require 50 or more r [*see glossary of terms on page 78*]. Yet the amount of radiation received by a fly in the 12-day interval between egg and mature adult is about .004 r. Natural radiation would have to be increased more than 10,000 times to account for the natural Drosophila mutation rate! Thus, in Drosophila at least, radiation accounts for only a trivial part of the spontaneous rate. The same is true for mice. Although the fraction of spontaneous mutations that owe their origin to radiation is higher than that in Drosophila, it is still less than .1 per cent.

It is clear that natural-mutation rates, if they are measured in absolute time-units, cannot be the same in all organisms. One example will demonstrate this decisively. The spontaneous-mutation rate in Drosophila is such that about one embryo in 50 carries a lethal mutation (a mutation harmful enough to cause death) that occurred during the preceding generation. Most such mutations are recessive, that is, they have a lethal effect only when they are in a double dose, but this does not prevent the death; it only postpones it. The reproductive life-cycle in man is approximately 1,000 times as long as that of a fly: some 30 years as compared with 12 days. If the

MUTATION of a single gene in a mouse results in offspring that have an unusually short tail (*skeleton at left*). A mouse that receives such a mutant gene from both of its parents has more serious defects, including the absence of the lower part of its spine (*skeleton at right*); it dies soon after birth. These specimens were prepared in the laboratory of L. C. Dunn of Columbia University. The soft tissues were treated with strong alkali and glycerin to make them transparent; the bones were stained with a red dye.



RATE OF EVOLUTION in certain organisms is extremely slow. Depicted in these drawings are four animals that have not changed appreciably over a period of millions or even hundreds of millions of years. At top left is the horseshoe crab; at top center, the tuatara;

absolute mutation-rate in man were the same as that in Drosophila, each human embryo would bear an average of 20 new lethal mutations; man would quickly become extinct.

Actually, if the rate is measured in mutations per generation, the spontaneous-mutation rate of those few human genes whose mutation rates can be effectively measured is roughly the same as that of Drosophila genes. The rule seems to be that the absolute mutation-rate divided by the generation period is much more nearly constant from one species to another than the rate itself. The implication of this is exciting. It can only mean that the mutation rate itself is capable of modification; that it, too, is changed by natural selection. By being brought into adjustment with the life cycle, the underlying mechanism of evolution itself is undergoing evolution!

It appears, however, that the rates of radiation-induced mutations are not as readily modified. If these rates were being adjusted along with the rates of mutations from other causes, we would expect that mice would show a lesser response to radiation than do fruit flies because their life cycle is longer. The facts are otherwise; mouse genes average some 15 times as many mutations per unit of radiation as Drosophila genes.

This strongly suggests that the process whereby mutations are produced by radiation is less capable of evolutionary adjustment than other mutation-producing processes. The implication is that organisms with a long life-cycle—Sequoia trees, elephants, men—have a larger fraction of mutations due to natural radiations. It may be that the majority of mutations in a very long-lived organism are due to radiations. Possibly this sets an upper limit on the length of the life cycle.

Unfortunately the rate of radiation-induced mutations is not known for any organism with a long life-cycle. If we assume that the susceptibility of human genes to mutation by radiation is the same as that of mouse genes, we would conclude that less than 10 per cent of human mutations are due to natural radiations. But the exact fraction is quite uncertain, because of inaccurate knowledge of the rate of spontaneous human mutations. So it cannot be ruled out that even a majority of human mutations owe their origin to radiation.

Thus the over-all mutation rate is not determined by radiation to any significant extent, except possibly in some very long-lived organisms. In general, radiation does not seem to play an important role in evolution, either by supplying qualitatively unique types of mutations or by supplying quantitatively significant numbers of mutations.

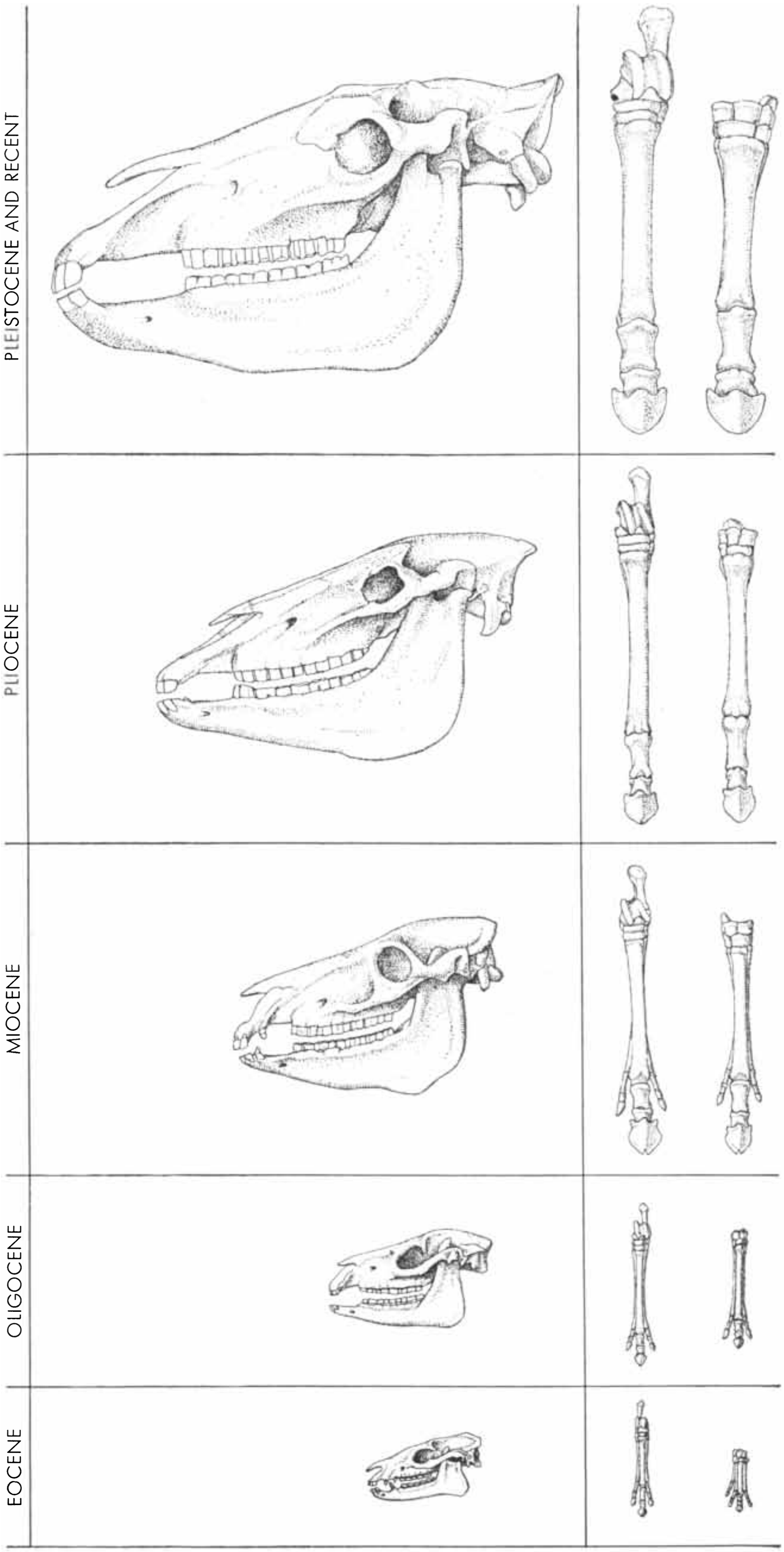
There is another question: To what extent is the rate of evolution dependent on the mutation rate? Will an organism with a high mutation-rate have a correspondingly higher rate of evolution? In general, the answer is probably no.

The measurement of evolutionary rates is fraught with difficulty and doubt. There is always some uncertainty about the time-scale, despite steady improvements in paleontology and new techniques of dating by means of the decay

at bottom center, the recently discovered coelacanth; at the far right, the opossum.

of radioactive isotopes. In addition there is the difficulty of determining what a comparable rate of advance in different species is. Is the difference between a leopard and a tiger more or less than that between a field mouse and a house mouse? Or has man changed more in developing his brain than the elephant has by growing a trunk? How is it possible for one to devise a suitable scale by which such different things can be compared?

Despite these difficulties, the differences in rates of evolution in various lines of descent are so enormous as to be clear by any standard. One criterion is size. Some animals have changed greatly. The horse has grown from a fox-sized ancestor to its present size while many other animals have not changed appreciably. (The British biologist J. B. S. Haldane has suggested that the word "darwin" be used as a unit for rate of size change. One darwin is taken to be an increase by a factor e per million years. By this criterion the rate of evolution of tooth size in the an-



RAPID RATE OF EVOLUTION is illustrated by the horse. Comparisons of the skulls, hindfeet and forefeet of animals of successive periods indicate the changes which led from a fox-sized ancestor in the Eocene period, 60 million years ago, to the modern horse (*top*).

cestors of the horse was about 40 millidarwins.)

More difficult to quantify, but more significant, are changes in structure. Some animals have changed very little in enormous lengths of time. There are several examples of "living fossils," some of which are depicted on the preceding two pages. During the time the coelacanth remained practically unchanged whole new classes appeared: the birds and mammals, with such innovations as feathers, hair, hoofs, beaks, mammary glands, internal temperature-regulation and the ability to think conceptually. What accounts for such differences in rate?

The general picture of how evolution works is now clear. The basic raw material is the mutant gene. Among these mutants most will be deleterious, but a minority will be beneficial. These few will be retained by what Muller has called the sieve of natural selection. As the British statistician R. A. Fisher has said, natural selection is a "mechanism for generating an exceedingly high level of improbability." It is Maxwell's famous demon superimposed on the random process of mutation.

Despite the clarity and simplicity of the general idea, the details are difficult and obscure. Selection operates at many levels—between cells, between individual organisms, between families, between species. What is advantageous in the short run may be ruinous in the long run. What may be good in one environment may be bad in another. What is good this year may be bad next year. What is good for an individual may be bad for the species.

A certain amount of variability is necessary for evolution to occur. But the comparison of fossils reveals no consistent correlation between the measured variability at any one time and the rate of evolutionary change. George Gaylord Simpson, now at Harvard University, has measured contemporary representatives of low-rate groups (crocodiles, tapirs, armadillos, opossums) and high-rate ones (lizards, horses, kangaroos) and has found no tendency for the latter to be more variable. Additional evidence comes from domesticated animals and plants. G. Ledyard Stebbins, Jr., of the University of California has noted that domesticated representatives of slowly evolving plant groups produce new horticultural varieties just as readily as those from more rapidly evolving groups. Finally, the rates of "evolutionary" change in domestic animals and plants under artificial selection by man

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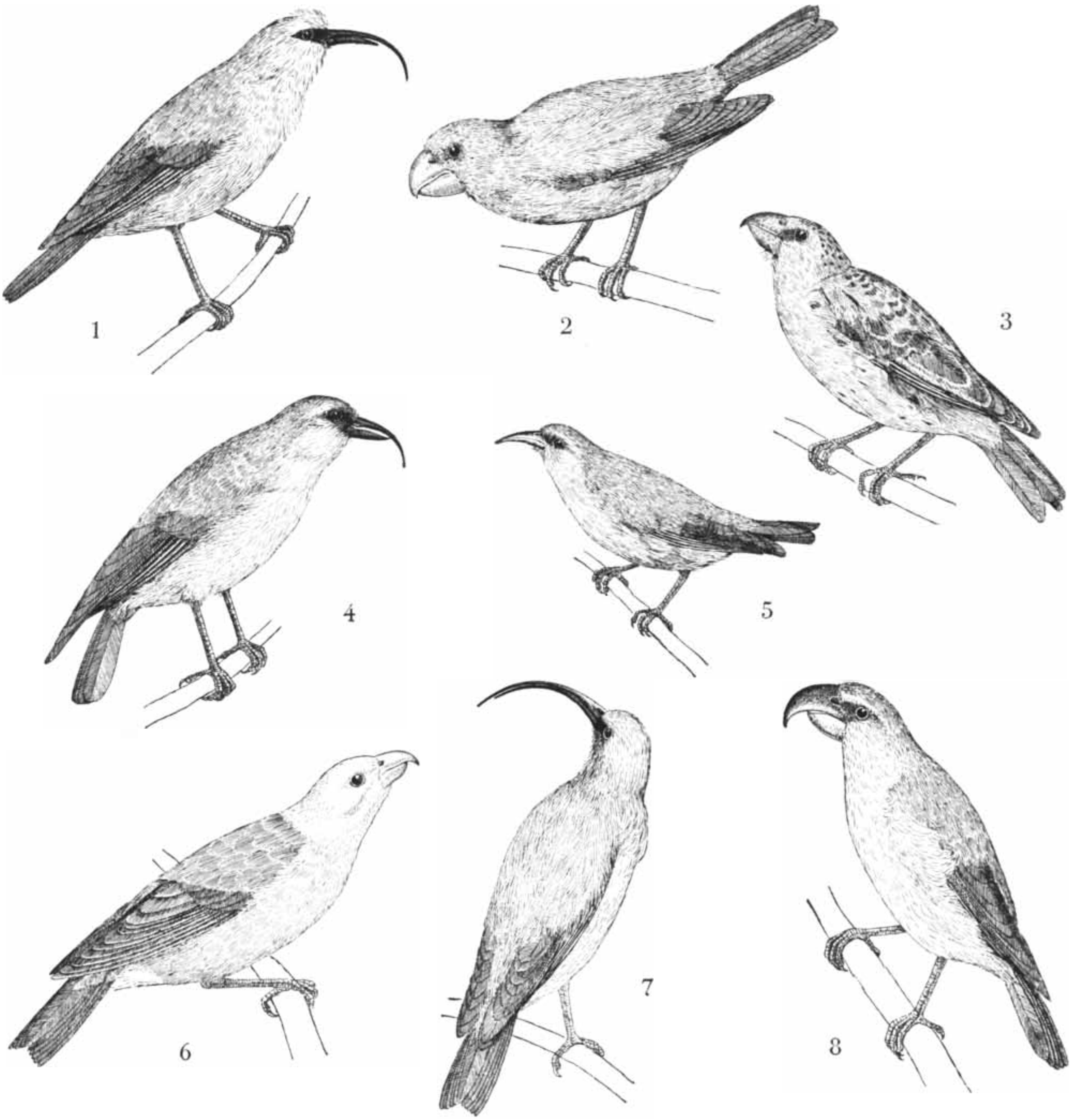
Royal Precision is jointly owned by the Royal McBee and General Precision Equipment Corporations. LGP-30 sales and service are available coast-to-coast, in Canada and abroad through Royal McBee Data Processing offices. For complete information and specifications, write **ROYAL McBEE CORPORATION,** data processing division, Port Chester, New York are tremendous compared with even the more rapidly evolving natural forms—perhaps thousands of times as fast. This can only mean that the genetic variability available for selection to work on is available in much greater abundance than the variability actually utilized in nature. The reasons why evolution is so slow in some groups must lie elsewhere than in insufficient genetic variability.

Instances of rapid evolution are probably the result of the opening-up of a new, unfilled ecological niche or environmental opportunity. This may be because of a change in the organism itself, as when the birds developed the power of flight with all the new possibilities this offered. It may also be due to opening-up of a new area, as when a few fortunate colonists land on a new continent.

One of the best-known examples of rapid change is to be found in the finches of the Galápagos Islands that Charles Darwin noted during his voyage on the *Beagle*. Darwin's finches are all descendants of what must have been a small number of chance migrants. They are a particularly striking group, especially in their adaptations to different feeding habits. Some have sparrow-like beaks for seed feeding; others have slender beaks and eat insects; some resemble the



HONEY CREEPERS of Hawaii are a striking example of rapid evolution. Dozens of varieties, adapted to different diets, arose from a common ancestor. The long bills of *Hemignathus lucidus affinis* (1), *Hemignathus wilsoni* (4) and *Hemignathus o. obscurus* (7) are used to seek insects as woodpeckers do or to suck nectar. The beaks of *Psittirostra kona* (2), *Psittirostra cantans* (3), and *Psittirostra psittacea* (6) are adapted to a diet of berries and seeds. *Loxops v. virens* (5) sucks nectar and probes for insects with its sharp bill. *Pseudonestor xanthrophrys* (8) wrenches at hard wood to get at burrowing insects. Some of these species are presently extinct.

EXTENSIVE DOW PRODUCTION FACILITIES FASHION VARIED NEW MAGNESIUM WARES

Coiled sheet, thin wall castings, many other production items are now available from Dow's big rolling mill, foundry and fabrication facilities.

Manufacturers on the alert for improved materials and production methods would enjoy a quick tour of the four Dow plants that turn out magnesium products. New ways of forming and fabricating magnesium now being practiced in these plants open up new areas of use for the lightweight metal.

TOOLING PLATE, extra flat, is annealed to eliminate residual stresses.

At the huge Madison, Illinois, rolling mill, for example, they're making magnesium sheet that doesn't require stress relief after welding. This is a major step forward in light metal technology and a boon to manufacturers using magnesium assemblies. Madison has also increased the maximum width of sheet to six feet. Five different sheet alloys, including elevated temperature alloys, are now available either flat or in coils.

To keep abreast of the rapidly increasing demand for precision jigs and fixtures, Madison keeps a close watch on the tolerances of Dow magnesium tooling plate. Typical flatness tolerances, for example, are 0.010 inches in any six feet. This means greater accuracy and less machining for users of Dow tooling plate. A mammoth 13,200 ton extrusion press, also located at Madison, is now turning out magnesium extrusions up to 30-inch circumscribed circle in size.

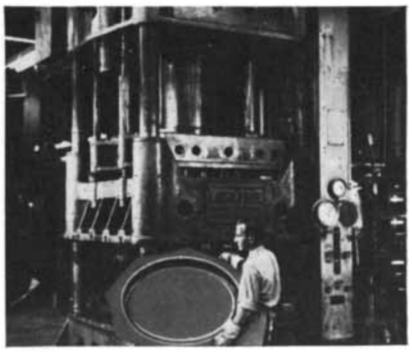
Over in Bay City, Michigan, interesting things are happening, too. At the well-equipped Dow magnesium foundry, largest in the U. S., sand and permanent mold castings of all sizes and shapes are being produced on a volume basis. Complete facilities are maintained for heat treatment, styrene DMI impregnation and chemical treatment. A well-staffed quality control team makes sure that all specifications are met or exceeded, and that the most modern equipment and techniques are fully utilized.

The Bay City foundry casts many complex and difficult designs. Large castings with walls as thin as 0.100 are now being produced. Other useful developments include cast-in tubeless passageways for use as hydraulic lines, special coring techniques for casting enclosed shapes and new magnesium casting alloys.

A new die casting plant is now on stream at Bay City. This facility houses the most advanced magnesium die casting equipment, including cold chamber metering units which automatically feed metal to the machines and contribute to unusually high production rates. To assure close alloy composition control in both die casting plant and foundry, a direct reading spectrometer provides frequent and precise analyses of the molten metal. Similarly, X-ray equipment is also available where radiography is needed in quality control.

The Dow fabrication plant, also in Bay City, offers capacity for volume work on magnesium assemblies. Here, too, developmental work on magnesium is constantly in progress. The plant is set up to handle large or small jobs, and plenty of both. Its activities include deep drawing, bending, spinning, stamping, piercing, machining, arc and spot welding, assembly, chemical treatment and painting. This plant has pioneered many "firsts" in magnesium production, such as hot drawing, spot welding and automatic welding.

DOW FOUNDRY offers production capacity for sand and permanent mold castings of all sizes.



LARGE DRAW PRESS at Dow's fabrication plant forms magnesium sheet in one operation.

WRITE TODAY for more information about Dow's magnesium production facilities. Request "Fabrication Brochure", "Foundry Brochure", "Die Casting Brochure" or all three. THE DOW METAL PRODUCTS COMPANY, Midland, Michigan, Sales Department 1351EQ9.

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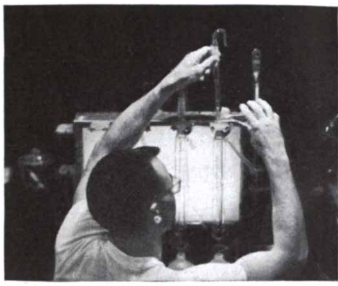
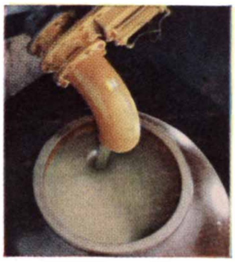


At Eastman QUALITY CONTROL is a company's conscience "at work"



Tenite is more than a trade name for Eastman's plastics ...it's a pledge of promised performance

You can measure a company's conscience by the care taken to uphold the quality of its products.

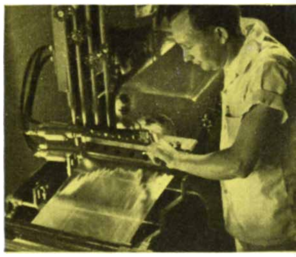
If those products are plastics, uncompromised control is a "must"...for plastics are unique materials. Perhaps no other class of raw materials used by the manufacturing industries has so many variable—yet controllable—physical properties. Flow or moldability, stiffness, heat resistance, weather durability, color, light transmission, hardness... are just a few of the properties that can be custom tailored to meet the needs of a specific application or a specific fabricating procedure. Such flexibility in setting the physical properties of a raw material is an advantage which must be protected by accurate control. For once an acceptable formulation has been created and sold to satisfy both performance and production demands, it is necessary to maintain those properties within extremely narrow limits to assure trouble-free molding operations as well as satisfactory service.

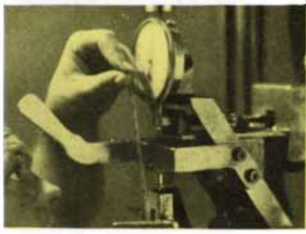
At Eastman, Tenite Quality Control is the vigilant watchdog over the production of all Tenite plastics. This group has the continuing responsibility to conduct all necessary testing to forestall deviation from the specifications set for each of the many formulations.

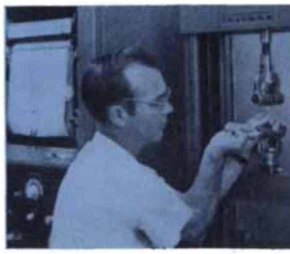
So varied and so complete is the testing done by Tenite Quality Control, that this one control section of Eastman requires a staff of over 100 trained personnel.

Acting as a nerve center, sensitive to any factor that could swing a formulation away from its prescribed limits, Quality Control approves or rejects the results in all phases of the production of every pound of Tenite plastic made.

Control of quality begins with approval of the basic raw materials. Even though most of the basic materials that go into Tenite plastics are supplied by other members of the Eastman industrial family, Tenite Quality Control has the final voice in the acceptance or rejection of these materials. At Kingsport, Tennessee, where Butyrate, Acetate and Propionate are made, raw materials such as cellulose esters, plasticizers, colorants and other additives are rigorously tested and graded on their suitability for compounding into clear transparent plastic or into transparent, translucent or opaque colored plastics. Indicative of the care taken to assure shipments of Tenite plastics that are right for each use, is the fact that no order for Tenite Butyrate, Tenite Acetate or Tenite Propionate is filled "out of stock." *Every* order for these three plastics







s made to order as a separate batch, custom-roduced to meet the exact specifications as equested.

At Longview, Texas, where Tenite Poly-thylene in both low- and medium-density rades is produced via continuous processing, Quality Control maintains a constant check n the purity of the ethylene gas as it enters he reactors.

During production of both cellulosic and olyethylene plastics, various tests are con-lucted at intermediate stages to insure proper ontrol of the chemical reaction. Similarly, fter production, samples of the plastics re carefully molded by Quality Control to be sure their forming charac-teristics are suited to the customer's fabricating equip-ment. In addition, flow, color, along with physical and chemical stability are also checked. If any special qualities, such as fire retardance or resistance to ultra-violet have been specified, Quality Control runs extra tests on the plastic before shipment to con-firm that these requirements have been met.

Color gets particular attention. Over the years, Tenite plastics have won an enviable reputation for accurate color matches. To date, plastics in more than 40,000 different colors and color effects have been produced by Eastman.

Finally, after Quality Control has been satisfied that the Tenite plastic will fully meet all specifications of the customer's order, it is approved for shipment. Even after shipment, Quality Control remains in the picture. Physi-cal samples of all plastics shipped are kept for six months. In addition, all records on the processing of these shipments are retained for five years. Result: Quality Control has a continuing record as a guide in filling subse-quent orders with exact duplications of the original plastic.

Ever since Eastman began producing plas-tics in 1932, an alert awareness has existed that users of plastics have a critical need for material that is consistent in its performance and handling properties shipment after ship-ment. If one word were to be singled out to describe the outstanding virtue of Tenite plastics, it would have to be chosen from such adjectives as *uniform, consistent, unvarying, dependable.* But whatever the word, the end-result has been satisfaction for our customers *...and for us.*

And, after all, that's the purpose of having a conscience.

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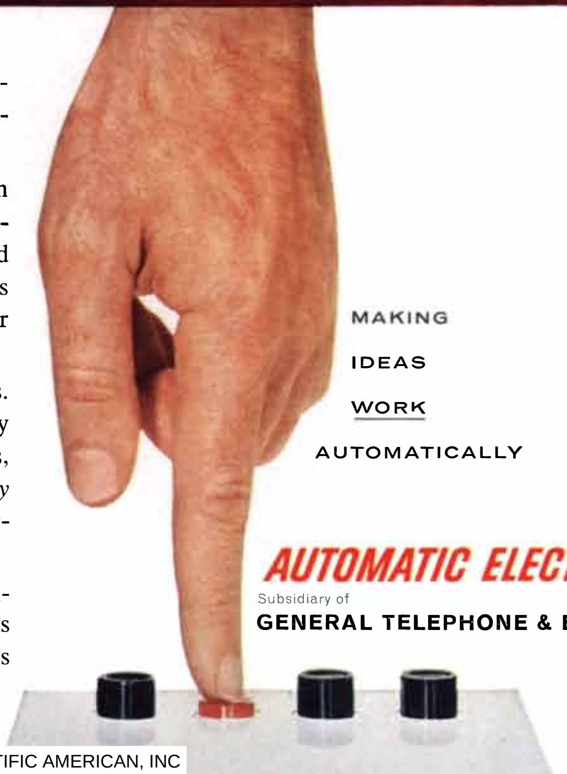

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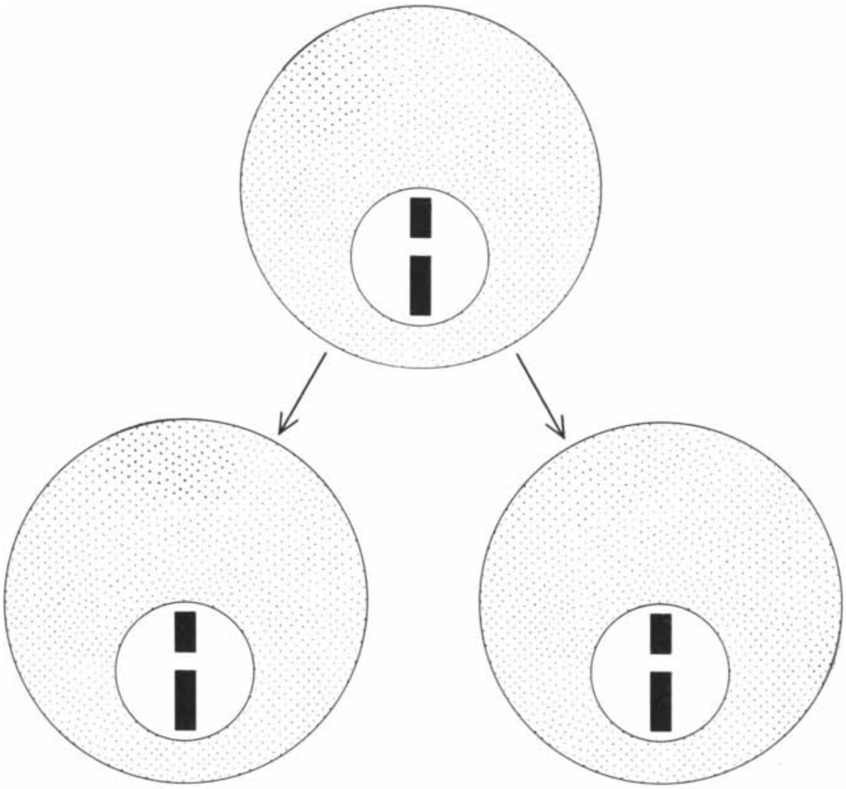


ASEXUAL REPRODUCTION permits little variability in a population; the evolution of asexual organisms depends entirely on mutation. At top is a schematic diagram of an asexual cell. Within its nucleus (*open circle*) are chromosomes (*rectangles*). When the cell divides (*bottom*), its two daughter cells have replicas of the original chromosomes and are exactly like the parent. To simplify the diagram only two of the chromosomes of a cell are shown.

woodpeckers and feed on insect larvae in wood; still others feed with parrot-like beaks on fruits. The woodpecker type is of special interest. Lacking the woodpecker's long tongue it has evolved the habit of using a cactus spine or a twig as a substitute—it is the only example of a tool-using bird. In the rest of the world the finches are a relatively homogeneous group. Their tremendous diversity on these islands must be due to their isolation and the availability of new, unexploited ecological opportunities. A similar example of multiple adaptations is found in the honey creepers of the Hawaiian Islands [*see illustration on page 144*].

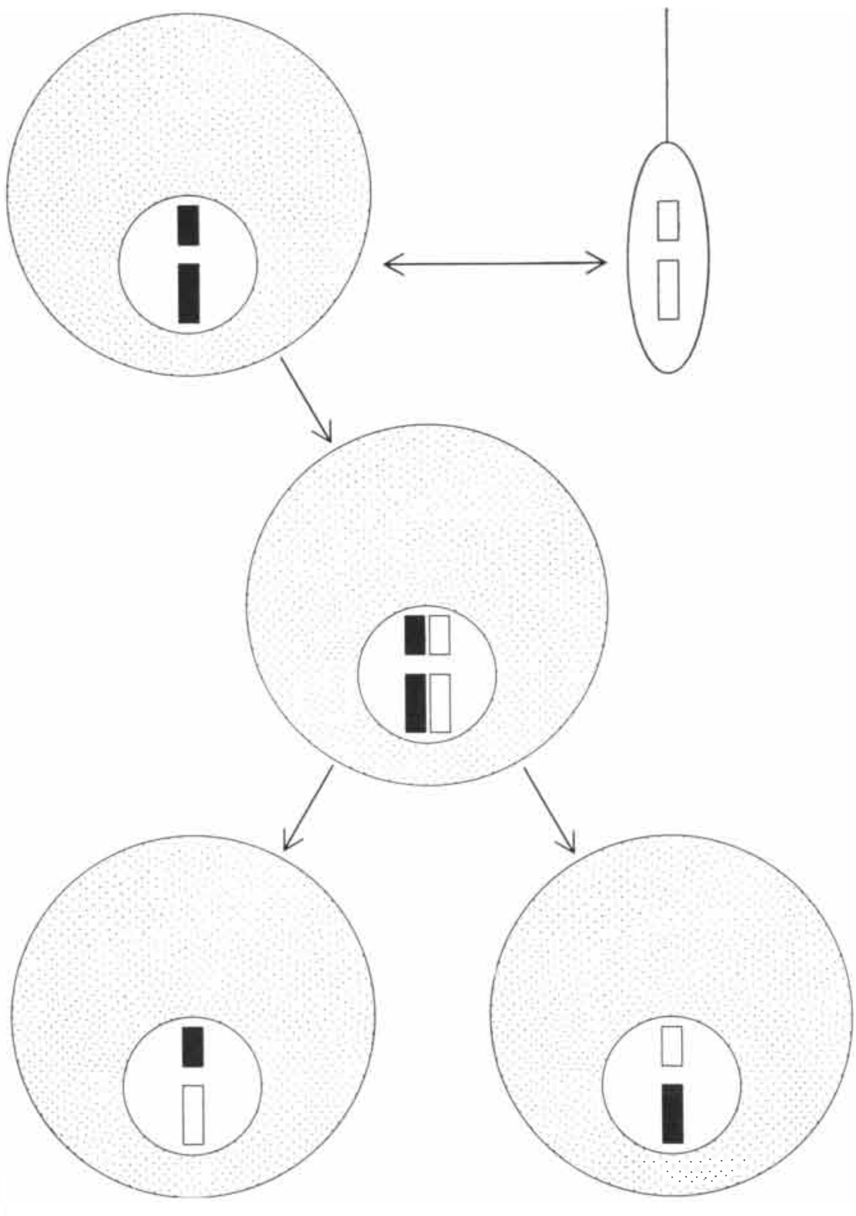
When paleontologists look into the ancestry of present-day animals, they find that only a minute fraction of the species present 100 million years ago is represented by descendants now. It is estimated that 98 per cent of the living vertebrate families trace their ancestry to eight of the species present in the Mesozoic Era, and that only two dozen of the tens of thousands of vertebrate species that were then present have left any descendants at all. The overwhelmingly probable future of any species is extinction. The history of evolution is a succession of extinctions along with a tremendous expansion of a few fortunate types.

The causes of extinctions must be many. A change of environment—due to a flood, a volcanic eruption or a succession of less dramatic instances—may alter the ecological niche into which the species formerly fitted. Other animals and plants are probably the most important environmental variables: one species is part of the environment of another. There may be a more efficient predator, or a species that competes for shelter or food supply, or a new disease vector or parasite. As Theodosius Dobzhansky of Columbia University has said, "Extinction occurs either because the ecological niche disappears, or because it is wrested away by competitors."

Extinction may also arise from natural selection itself. Natural selection is a short-sighted, opportunistic process. All that matters is Darwinian fitness, that is, survival ability and reproductive capacity. A population is always in danger of becoming extinct through "criminal" genes—genes that perpetuate themselves at the expense of the rest of the population. An interesting example is the so-

called SD gene, found in a wild Drosophila population near the University of Wisconsin by Yuichiro Hiraizumi. Ordinarily the segregation ratio—the ratio of two alternative genes in the progeny of any individual that carries these genes—is 1:1. In this strain the segregation is grossly distorted to something like 10:1 in favor of the SD gene; hence its name, SD, for segregation distorter. The SD gene somehow causes the chromosome opposite its own chromosome to break just prior to the formation of sperm cells. As a result the cells containing the broken chromosome usually fail to develop into functional sperm. The SD-bearing chromosome thus tends to increase itself rapidly in the population by effectively killing off its normal counterpart. Such a gene is obviously harmful to the population. But it cannot be eliminated except by the extinction of the population, or by the occurrence of a gene that is immune to the SD effect.

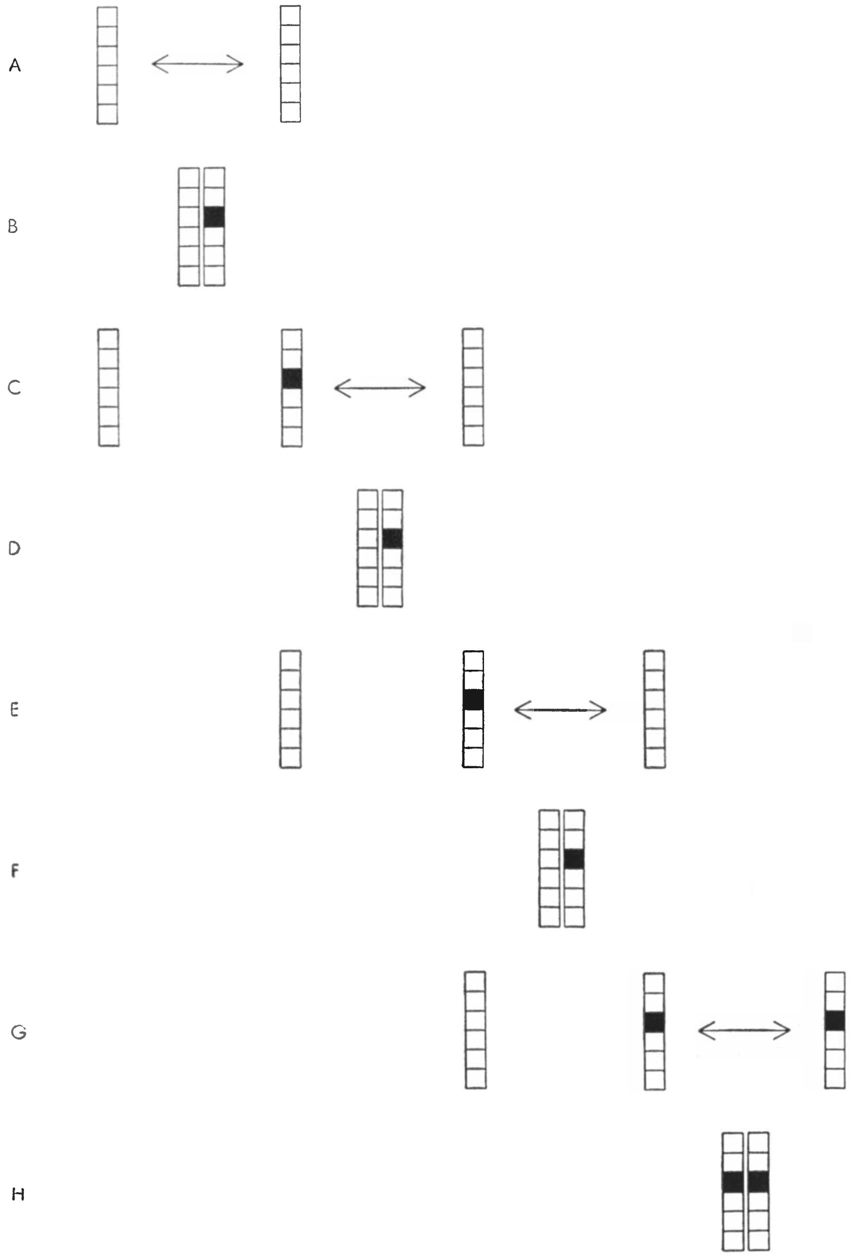
A similar gene exists in many mouse populations. Causing tail abnormali-



SEXUAL REPRODUCTION, also depicted in highly schematic form, depends on the union of two cells that may be from different lines of descent. At top left is an egg cell; at top right, a sperm cell. Each contains one set of chromosomes (*rectangles*). They join to form a new individual with two sets of chromosomes in its body cells (*center*). When this organism produces its own sperm or egg cells (*bottom*), each receives a full set of chromosomes. Some, however, may be from the father and some from the mother. Evolution in sexual organisms thus does not depend entirely on new mutations, because the genes already present in the population may be combined in different ways leading to improvements in the species.

ties, it is transmitted to much more than the usual fraction of the offspring, though in this case the detailed mechanism is not known. L. C. Dunn of Columbia University has found this gene in many wild-mouse populations. Most of these genes are highly deleterious to the mouse (a mouse needs a tail!), and some are lethal when they are borne in a double dose, so that the gene never completely takes over despite its segregational advantage. The result is an equilibrium frequency determined by the magnitude of the two opposing selective forces: the harmfulness of the gene and its segregational advantage. The population as a whole suffers, a striking illustration of the fact that natural selection does not necessarily improve the fitness of the species.

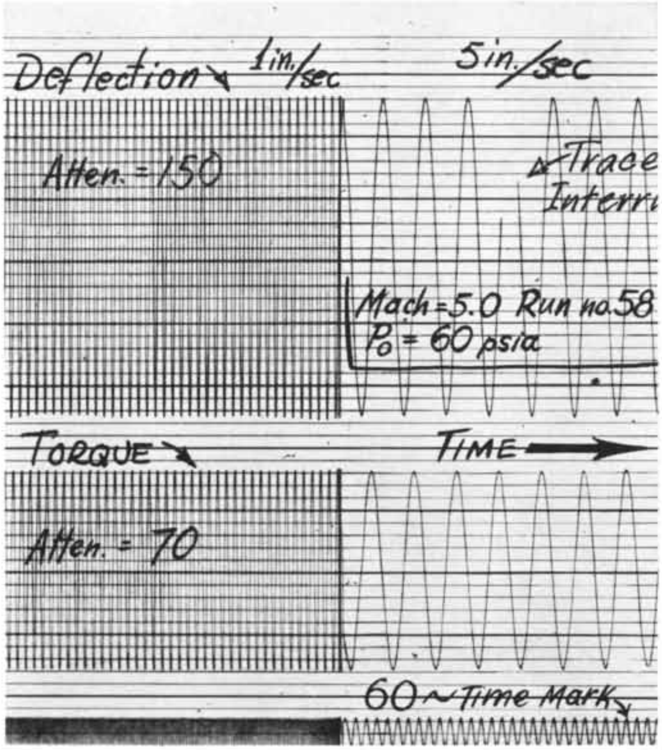
A gene causing extremely selfish, anti-



RECESSIVE MUTATION cannot be expressed in a sexual organism unless the corresponding gene of the paired chromosome has the same defect. Thus a harmful mutation can remain latent for generations. In this diagram the bars representing chromosomes are divided into squares, each symbolizing the gene for a different character. In row A the chromosomes of normal parents are paired (*arrows*). In row B a gene of their offspring mutates (*black*). In row C the mutant gene has been transmitted to the next generation but is still latent because the other parent has supplied a normal gene. This continues (*rows E and F*) until two individuals harboring the mutant gene mate (*row G*). The full effect of the mutation, harmful or otherwise, is expressed in offspring receiving a pair of mutant genes (*row H*).

In science...

This "diary" of an airframe in wind-tunnel flight is an instantly-readable record taken on a Model 906A Visicorder by ARO, Inc., at the USAF Arnold Engineering Development Center, Tullahoma, Tennessee, the ARDC wind tunnel facility. This record measures damping-in-pitch derivatives for a clipped-delta-wing-body configuration over a Mach number range of 2.0 to 5.0 so that these measurements could be compared with Mach number trend predicted by theory. The values discovered through this experiment showed discrepancies from theoretical values because the theory pertained to simpler bodies than that used in the tests. The new set of Visicorder data will result in more accurate predictions for future design.



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In industry...

This "cardiogram" of a diesel engine was taken on a Model 906 Visicorder by research engineers at the Worthington Corporation. It is a directly-recorded chart of pressure variations in the exhaust manifold, cylinder, and intake manifold of a Worthington Tripower diesel operating at 450 RPM and developing 265 HP per cylinder. These pressure-variation studies enable Worthington engineers to determine optimum valve timing and engine configuration, and led to changes in the Tripower engine for best performance. In these and in hundreds of other scientific and industrial applications, Visicorders are bringing about new advances in product design, computing, control, rocketry, nucleonics, and production.

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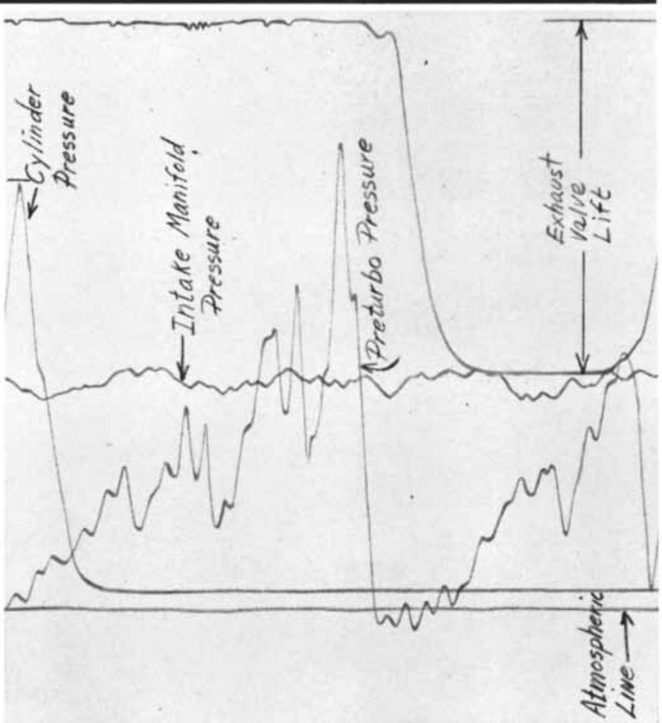
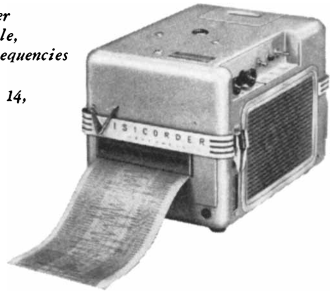


Visicorder records 2/3 actual size.



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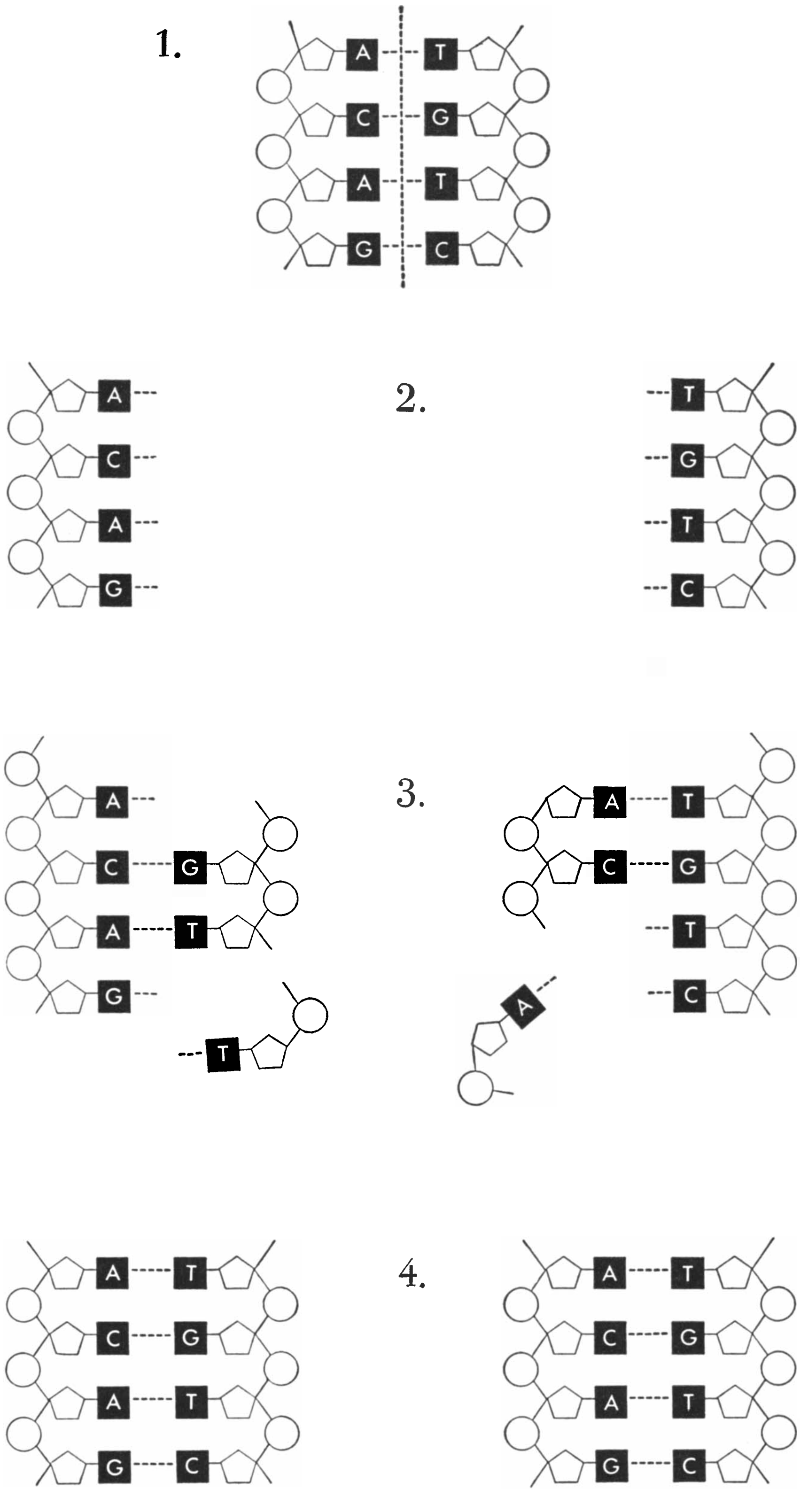

THE GENETIC MATERIAL, deoxyribonucleic acid (DNA), consists of a chain of sugar units (*pentagons*) and phosphate groups (*circles*) with side chains of bases: adenine (A), cytosine (C), thymine (T) and guanine (G). One possible mechanism for replication postulates that DNA normally contains two complementary strands, linked A—T and C—G (1). The chains then separate (2), and separate precursor units assemble along each chain (3). When they are completed, the double strands are identical to the original (4).

social behavior—for example genes for cannibalism or social parasitism—could have similar effects in the human population. Any species must be in constant danger from the short-sightedness of the process of natural selection. Those that are still here are presumably the descendants of those that were able to avoid such pitfalls.

Aside from mutation itself, the most important evolutionary invention is sexual reproduction, which makes possible Mendelian heredity. The fact that such an elaborate mechanism exists throughout the whole living world—in viruses and bacteria, and in every major group of plants and animals—attests to its significance.

In a nonsexual population, if two potentially beneficial mutations arise in separate individuals, these individuals and their descendants can only compete with each other until one or the other type is eliminated, or until a second mutation occurs in one or the other group. A Mendelian species, with its biparental reproduction and consequent gene-scrambling, permits both mutants to be combined in the same individual. An asexual species must depend upon newly occurring mutations to provide it with variability. Sexual reproduction permits the combination and recombination of a whole series of mutants from the common pool of the species. Before they enter the pool the mutants have been to some extent pretested and the most harmful ones have already been eliminated.

Suppose that a population has 50 pairs of genes: Aa, Bb, Cc, etc. Suppose that each large-letter gene adds one unit of size. The difference between the smallest possible individual in this population (aa bb cc . . .) and the largest possible (AA BB CC . . .) is 100 units. Yet if all the genes are equally frequent, the size of 99.7 per cent of the population will be between 35 and 65 units. Only one individual in 2^{100} (roughly 1 followed by 30 zeros) would have 100 size units. Yet if the population is sexual, this type can be produced by selection utilizing only the genes already in the population.

This example illustrates the evolutionary power of a system that permits Mendelian gene-assortment. In an asexual system the organism would have to wait for new mutations. Most of the size-increasing mutations would probably have deleterious side effects. If the asexual organism had a mutation rate sufficient to give it the potential variability of a sexual population, it would probably become extinct from harmful mutations.

The very existence of sexual reproduction throughout the animal and plant kingdoms argues strongly for the necessity of an optimum genetic variability. This is plain, even though there is no consistent correlation between evolution rates as observed in the fossil record and the variability of the animals observed. It must be that a certain level of genetic variability is a necessary, but by no means sufficient, condition for progressive evolution.

Evolution is an exceedingly complex process, and it is obviously impossible, even in particular cases, to assign relative magnitudes to the various causal factors. Perhaps species have become extinct through mutation rates that are too high or too low, though there is no direct observational evidence for this. Probably many asexual forms have become extinct because they were unable to adapt to changes. Other forms have become overspecialized, developing structures that fit them for only a particular habitat; when the habitat disappears, they are lost. The population size and structure are also important. To be successful in evolution, by the criterion of having left descendants many generations later, a species has the best chance if it has an optimum genetic system. But among a number of potentially successful candidates, only a few will succeed, and probably the main reason is simply the good luck of having been at the right place at the right time.

Of all the natural selection that occurs, only a small fraction leads to any progressive or directional change. Most selection is devoted to maintaining the status quo, to eliminating recurrent harmful mutations, or to adjusting to transitory changes in the environment. Thus much of the theory of natural selection must be a theory of statics rather than dynamics.

The processes that are necessary for evolution demand a certain price from the population in the form of reduced fitness. This might be said to be the price that a species pays for the privilege of evolving. The process of sexual reproduction, with its Mendelian gene-shuffling in each generation, produces a number of ill-adapted gene combinations, and therefore a reduction in average fitness. This can be avoided by a nonsexual system, but at the expense of genetic variability for evolutionary change in a changing environment.

The plant breeder knows that it is

easy to maintain high-yielding varieties of the potato or sugar cane because they can be propagated asexually. But then his potential improvement is limited to the varieties that he has on hand. Only by combining various germ plasms sexually can he obtain varieties better than the existing best. But the potato and cane breeder can have his cake and eat it. He gets his new variants by sexual crosses; when he gets a superior combination of genes, he carries this strain on by an asexual process so that the combination is not broken up by Mendelian assortment.

Many species appear to have sacrificed long-term survival for immediate fitness. Some are highly successful. A familiar example is the dandelion; any lawn-keeper can testify to its survival value. In dandelion reproduction, although seeds are produced by what looks superficially like the usual method, the chromosome-assorting features of the sexual process are bypassed and the seed contains exactly the same combination of genes as the plant that produced it. In the long run the dandelion will probably become extinct, but in the present environment it is highly successful.

The process of mutation also produces ill-adapted types. The result is a lowering of the average fitness of the population, the price that asexual, as well as sexual, species pay for the privilege of evolution. Intuition tells us that the effect of mutation on fitness should be proportional to the mutation rate; Haldane has shown that the reduction in fitness is, in fact, exactly equal to the mutation rate.

The environment is never constant, so any species must find itself continually having to adjust to transitory or permanent changes in the environment. The most rapid environmental changes are usually brought about by the continuing evolution of other species. A simple example was given by Darwin himself. He noted that a certain number of rabbits in every generation are killed by wolves, and that in general these will be the rabbits that run the slowest. Thus by gradual selection the running speed of rabbits would increase. At the same time the slower wolves would starve, so that this species too has a selective premium on speed. As a result both improve, but the position of one with respect to the other does not change. It is like the treadmill situation in Lewis Carroll's famous story: "It takes all the running *you* can do, to keep in the same place."

A change in the environment will

cause some genes that were previously favored to become harmful, and some that were harmful to become beneficial. At first it might seem that this does not make any net difference to the species. However, when the change occurs, the previously favored genes will be common as a result of natural selection in the past. The ones that were previously deleterious will be rare. The population will not return to its original fitness until the gene numbers are adjusted by natural selection, and this has its costs.

Just how much does it cost to exchange genes in this way? Let us ask the question for a single gene-pair. If we start with a rare dominant gene present in .01 per cent of the population, it requires the equivalent of about 10 selective "genetic deaths" (*i.e.*, failure to survive or reproduce) per surviving individual in the population to substitute this gene for its predecessor. This means that if the population is to share an average of one gene substitution per generation, it must have a sufficient reproductive capacity to survive even though nine out of 10 individuals can die without offspring in each generation. The cost is considerably greater if the gene is recessive. The surprising part of this result is that the number does not depend on the selective value of the gene. As long as the difference between two alternative genes is small, the cost of replacing one by the other depends only on the initial frequency and dominance of the gene and not at all on its fitness.

If the gene is less rare, the cost is lowered. Thus the species can lower the price of keeping up with the environment by having a higher frequency of deleterious genes that are potentially favorable. One way to accomplish this is to have a higher mutation rate, but this, too, has its price. Once again there is the conflict between the short-term objective of high fitness and the longer-term objective of ability to change with the environment.

There are known to be genes that affect the mutation rate. Some of them are quite specific and affect only the mutation rate of a particular gene; others seem to enhance or depress the over-all rate. A gene whose effect is to lower the mutation rate certainly has selective advantage: it will cause an increase in fitness. This means that in most populations there should be a steady decrease in the mutation rate, possibly so far as to reduce the evolutionary adaptability of the organism. This is offset by selection for ability to cope with fluctuating environments.

How does man fare in this respect?

From the standpoint of his biological evolution, is his mutation rate too high, is it too low or is it just right? It is not possible to say.

In general one would expect the evolutionary processes to work so that the mutation rate would usually be below the optimum from the standpoint of long-term evolutionary progress, because selection to reduce the mutation load has an immediate beneficial effect. Yet selection for a mutation-rate-adjusting gene is secondary to selection for whatever direct effects this gene has on the organism, such as an effect on size or metabolic rate. So we do not have much idea about how rapidly such selection would work.

Our early simian ancestors matured much more rapidly than we do now. This means that the mutation rate would have to be lowered in order to be brought into adjustment with the lengthening of our life cycle. To whatever extent the adjustment is behind the times, the mutation rate is too high. Furthermore, if it is true (as it appears to be) that radiation-induced mutation rates are less susceptible to evolutionary adjustment than those due to other causes, then an animal with a life cycle so long that it receives considerable radiation per generation may have too many from this cause.

I think it is impossible, however, to say whether man has a mutation rate that is too high or too low from the viewpoint of evolutionary advantage. It is worth noting that man, like any sexually reproducing organism, already has a tremendous store of genetic variability available for recombination. If all mutation were to stop, the possibilities for evolution would not be appreciably altered for a tremendous length of time—perhaps thousands of generations. Consider the immense range of human variability now found, for example the difference between Mozart, Newton, da Vinci and some of our best athletes, in contrast to a moron or the genetically impaired. Haldane once said: "A selector of sufficient knowledge and power might perhaps obtain from the genes at present available in the human species a race combining an average intellect equal to that of Shakespeare with the stature of Carnera." He goes on to say: "He could not produce a race of angels. For the moral character or for the wings he would have to await or produce suitable mutations." Surely the most hopefully naive eugenist would settle for considerably less!

I would argue that from any practical

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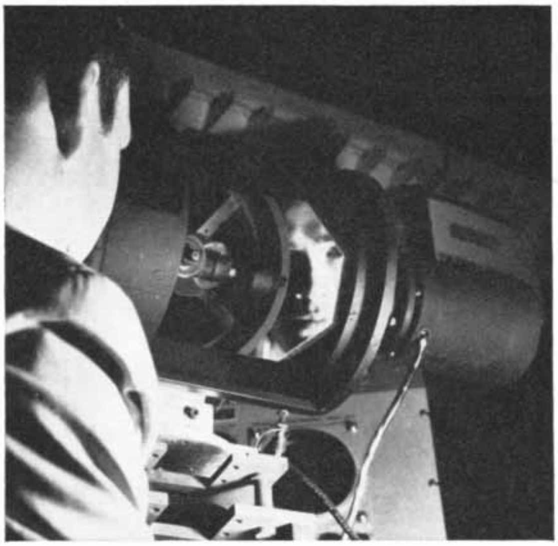
standpoint the question of whether man's mutation-rate is too high or too low for long-term evolution is irrelevant. From any other standpoint the present mutation rate is certainly too high. I suspect that man's expectations for future progress depend much more on what he does to his environment than on how he changes his genes. His practice has been to change the environment to suit his genes rather than vice versa. If he should someday decide on a program of conscious selection for genetic improvement, the store of genes already in the population will probably be adequate. If by some remote chance it is not, there will be plenty of ways to increase the number of mutations at that time.

There can be little doubt that man would be better off if he had a lower mutation-rate. I would argue, in our present ignorance, that the ideal rate for the foreseeable future would be zero. As George W. Beadle makes clear in the last article of this series, the effects produced by mutations are of all sorts, and are mostly harmful. Some cause embryonic death, some severe disease, some physical abnormalities, and probably many more cause minor impairments of body function that bring an increased susceptibility to the various vicissitudes of life. Some have an immediate effect; others lie hidden to cause their harm many generations later. All in all, mutations must be responsible for a substantial fraction of human premature death, illness and misery in general.

At the present time there is not much that can be done to lower the spontaneous-mutation rate. But at least we can do everything possible to keep the rate from getting any higher as the result of human activities. This is especially true for radiation-induced mutations; if anything they are probably more deleterious and less likely to be potentially useful than those from other causes. It is also important to remember that there are very possibly things in the environment other than radiation that increase the mutation rate. Among all the new compounds to which man is exposed as a result of our complex chemical technology there may well be a number of mutagenic substances. It is important that these be discovered and treated with caution.

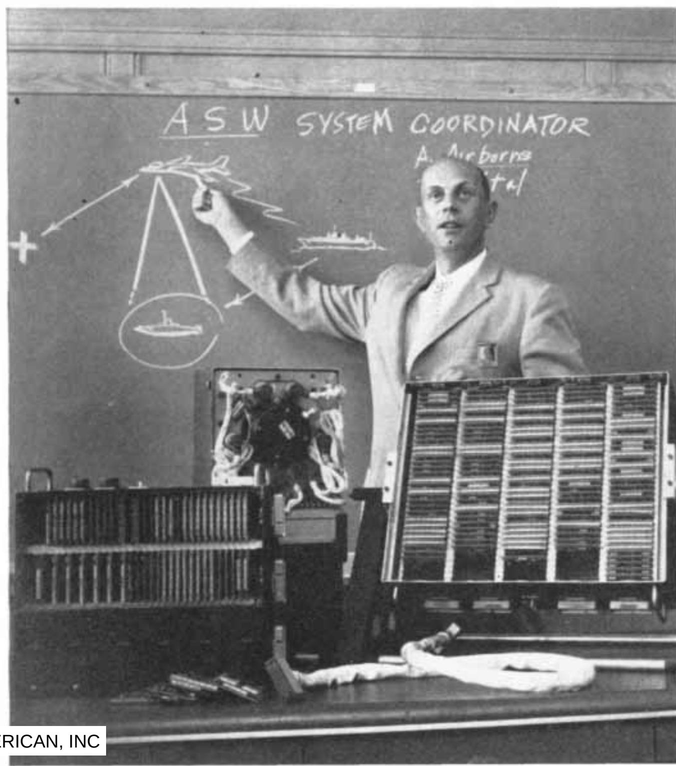
The general conclusion, then, is that ionizing radiation is probably not an important factor in animal and plant evolution. If it is important anywhere it is probably in those species, such as man, that have a long life span, and at least for man it is a harmful rather than a potentially beneficial factor.



A BROAD WESTINGHOUSE

IMAGINATION: Westinghouse developments in scanning systems, cells and special circuitry make possible detection of submarines in a tactical environment.

Developments in computer techniques and components provide the means for fully integrated ASW weapon systems, assuring early detection and sure kill. Typical is this new digital computer from the Westinghouse AIR ARM DIVISION.



The environment of the sea favors the submarine. This makes antisubmarine warfare—from detection to kill—one of the most formidable tasks faced by the U. S. Navy. Missile-firing nuclear subs further complicate this acute defense problem. ASW calls for all the imagination, skill and resourcefulness that industry, in its assisting role, can bring to bear.

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ASW PROGRAM IS HELPING TO MEET THIS MENACE

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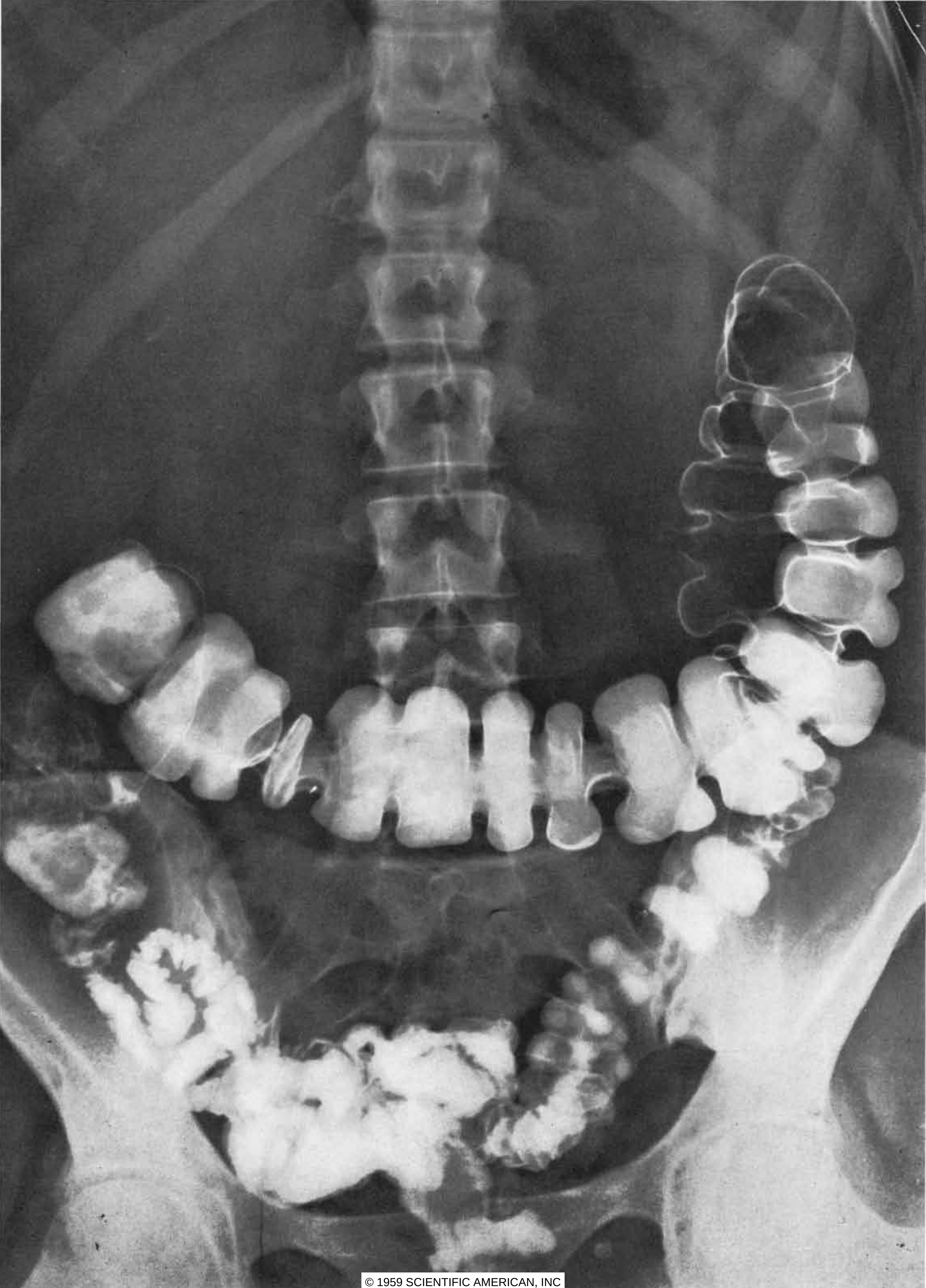


Ionizing Radiation and Medicine

X-rays have done much to conserve human life, but they have also doubled the exposure of people in advanced nations to radiation. The physician now has many ways to reduce the dosage to patients

by Shields Warren

If we could ask a physician of 1890 what he needed most to assist him in the diagnosis and treatment of disease, he might well reply: "A way of seeing inside the human body." This fantastic dream was soon to be realized. In 1895 Wilhelm Conrad Roentgen discovered X-rays, the first form of ionizing radiation known to man.

The modern physician employs the X-ray photograph and the fluoroscope to see bones, blood vessels, the lungs, the heart and practically every other internal organ. He utilizes the ionizing radiation of radioactive isotopes to "see" inside organs such as the thyroid gland and to measure their performance. And the uses of ionizing radiation go beyond diagnosis to therapy. The physician employs large doses of radiation to kill malignant cells, controlling the radiation so that it will do maximum damage to these cells and minimum harm elsewhere.

As other articles in this issue point out, however, the powerful diagnostic and therapeutic tool of ionizing radiation is also capable of injuring the patient and of causing genetic mutations. The conscientious physician is aware of these dangers and takes measures to minimize them. (Some patients, made fearful by the recent arousal of public interest in ionizing radiation, have the notion that exposure to X-rays will make them radioactive. This, of course, is nonsense. Radiation is present only while the X-ray machine is operating.)

Roentgen himself saw the first interior "view" of living human tissue when he unintentionally fluoroscoped his own hand while holding a bit of lead between a fluorescent screen and the cathode-ray tube that produced his X-rays. Describing the scene, Otto Glasser has written: "One can only imagine how this first ghostly shadow picture of the human skeleton within living tissue affected the observer: doubt must have been followed by wonder and perhaps a reluctance to continue experiments that promised to bring him disrepute in the eyes of his colleagues. At that point (in November, 1895) he determined to continue his experiments in secrecy until such time as he himself was certain of the validity of his observations." A few days later Roentgen made the first X-ray photograph, or radiograph, of human tissue when he used the newly discovered rays to picture his wife's hand. Frau Roentgen, according to Glasser, shuddered when she realized she was looking at her own skeleton. Roentgen, a physicist, was so well aware of the implications of his discovery for medicine that he gave the first report of it to the Physical Medical Society of Würzburg rather than to an organization of physicists.

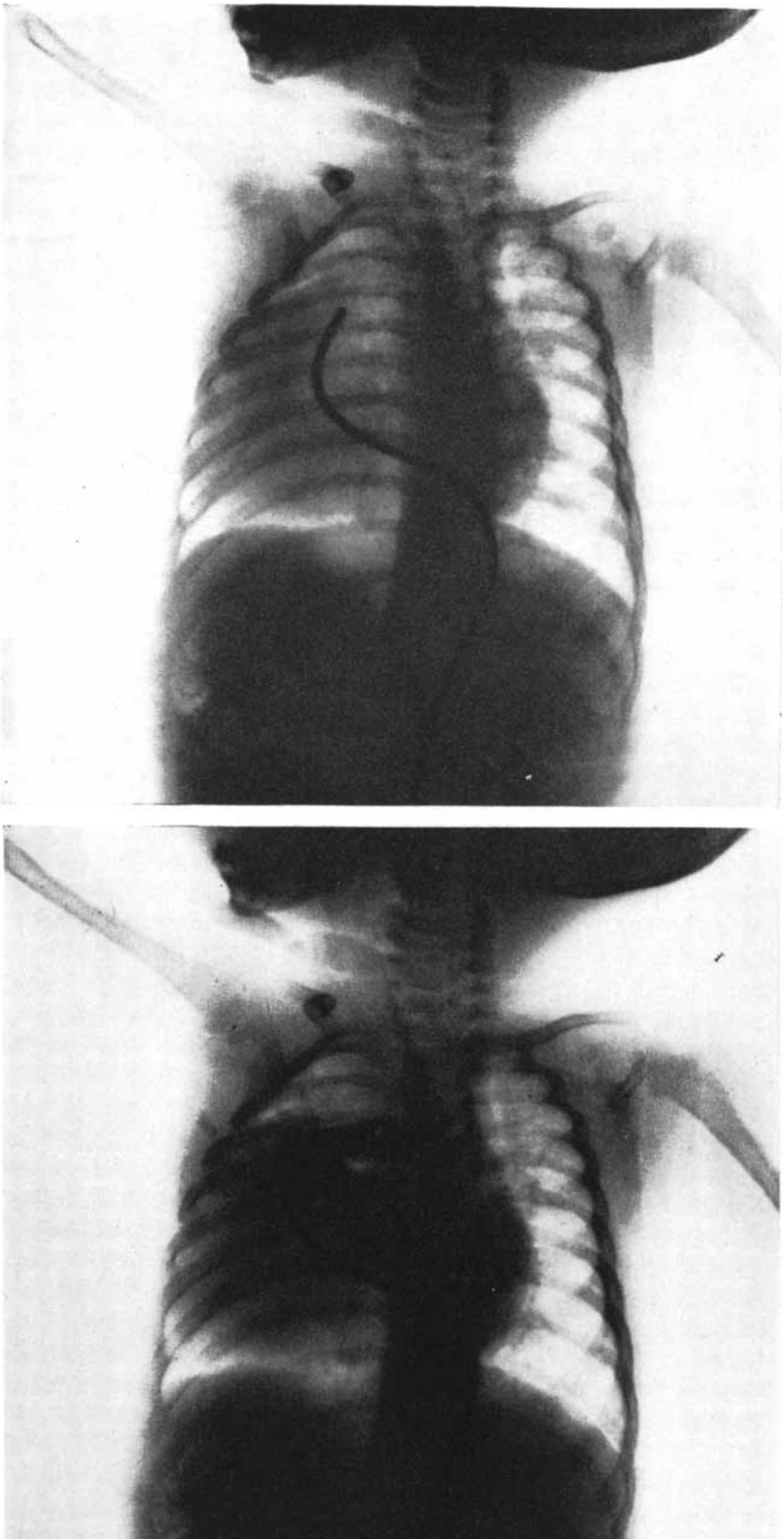
In making the radiograph of his wife's hand, Roentgen applied the principle that the shadow cast by X-rays varies in density with the density of the substance through which the rays pass. Because bones are denser than soft tissues, they more effectively absorb X-rays. Variations in the density of bone show up plainly, and permit us to examine this tissue in detail. Soft tissues, however, consist largely of water, and X-rays alone cannot clearly distinguish one organ from another. Because fat is less dense than other soft tissues, it absorbs less X-radiation. Air is still less dense, so the air-filled lungs are most transparent to X-rays and appear darkest on the X-ray negative.

When an X-ray machine is set at 40,000 volts (40 kvp in radiation terminology), almost any tissue will stop some of its radiation and cast a shadow on film. At 80 to 100 kvp, a common setting for the diagnostic X-ray machine, the radiograph displays shadows differentiating air space, fat, other soft tissue and bone. Certain physical characteristics of X-rays enable the radiologist to use higher voltages and special techniques to obtain on film a faint but usable image of the lungs, for example, without the interfering image of the ribs. Other techniques are capable of producing stereoscopic pictures of the interior of the body.

Injured or diseased tissue often appears on radiographs lighter or darker than surrounding tissue, due to departures from normal density. By itself, of course, the radiograph or fluoroscope image presents only a shadow or silhouette of the subject. A physician who has not had training or extensive experience can overlook significant but subtle variations in the density of the image.

When the objective is to look at a particular internal organ, the physician undertakes to fill the organ, by one means or another, with a material that is relatively opaque to X-rays. A stomach or intestine filled with barium sulfate, which the patient has simply swallowed, stands out in silhouette on a fluoroscope screen or photographic film, clearly differentiated from surrounding tissues. A stomach ulcer will be an outward bulge in the silhouette; an intestinal block, a constriction of the opaque area. To per-

X-RAY PHOTOGRAPH on opposite page reveals a normal colon (*loop extending across picture*). The colon has been made visible with a meal of radio-opaque barium sulfate. Some small intestine is visible near the bottom. The radiograph clearly shows variations in the thickness of the bones.



CATHETER IN THE HEART OF AN INFANT ***(top radiograph)*** **was inserted through a leg vein. In bottom radiograph a radio-opaque solution has been injected to make heart visible. A series of pictures made within a few seconds shows how heart is working and its defects.**

ceive such abnormalities the physician must often view the organ silhouette from various angles; when he uses the fluoroscope, he may move the patient about or manipulate the organ from outside the body. The physician also studies the rate of motion of the intestinal contents by timing the passage of the radio-opaque material.

The heavy and correspondingly dense atoms of iodine frequently contribute the desired X-ray opacity to compounds used for making internal organs visible in radiography. Recently solutions of iodine compounds have made it possible to look inside the living human heart. A metal-tipped rubber tube, or catheter, is slipped into the heart via a vein or artery of the leg, arm or neck. Since the catheter is radio-opaque, the physicians observe its progress in a fluoroscope. When the tip of the catheter is in place, they inject the radio-opaque solution, then make as many as 12 radiographs a second from the front and side simultaneously. Such radiographs provide insight into the performance as well as the anatomy of the heart, and give the surgeon a secure background for proceeding with the radical operations that are now performed on this vital organ.

Certain organs preferentially take up iodine compounds. The liver, for example, absorbs iodophthalein and similar compounds and concentrates them in the gall bladder. This makes the gall bladder visible under X-rays, and gallstones or other abnormalities stand out. The kidneys, ureters and other organs can be visualized by similar methods.

The exposure to ionizing radiation during a given diagnostic X-ray procedure can vary by a factor of 10 or more, depending on the patient and his condition, on the machine and its accessories and on the physician and his knowledge and ability. When radiography is conducted by a competent physician, however, it requires a surprisingly small dose of radiation, even to the skin. A complete gastrointestinal survey with barium, using both the fluoroscope and radiographs, produces a skin dose of from five to 50 r [*see glossary of terms on page 78*]. The testes or ovaries receive a smaller but still measurable dose. Radiographic examination of the pelvic area of a woman can result in large doses of radiation to the ovaries, and, if the woman is pregnant, to the entire body of the fetus; the skin dose varies widely, depending upon the position of the patient and the technique used. The dose to the fetus is .4 r to seven r per examination, with

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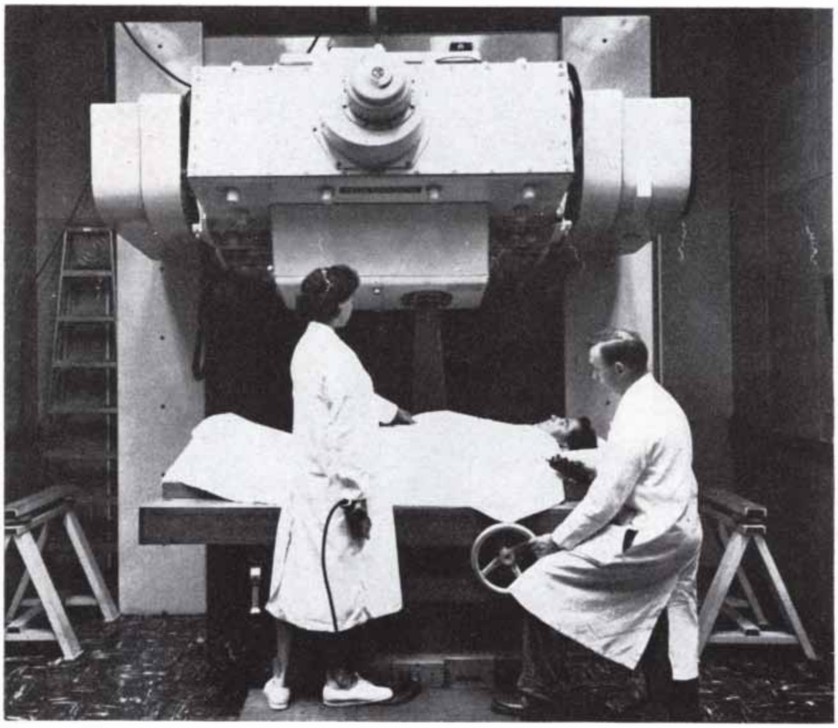
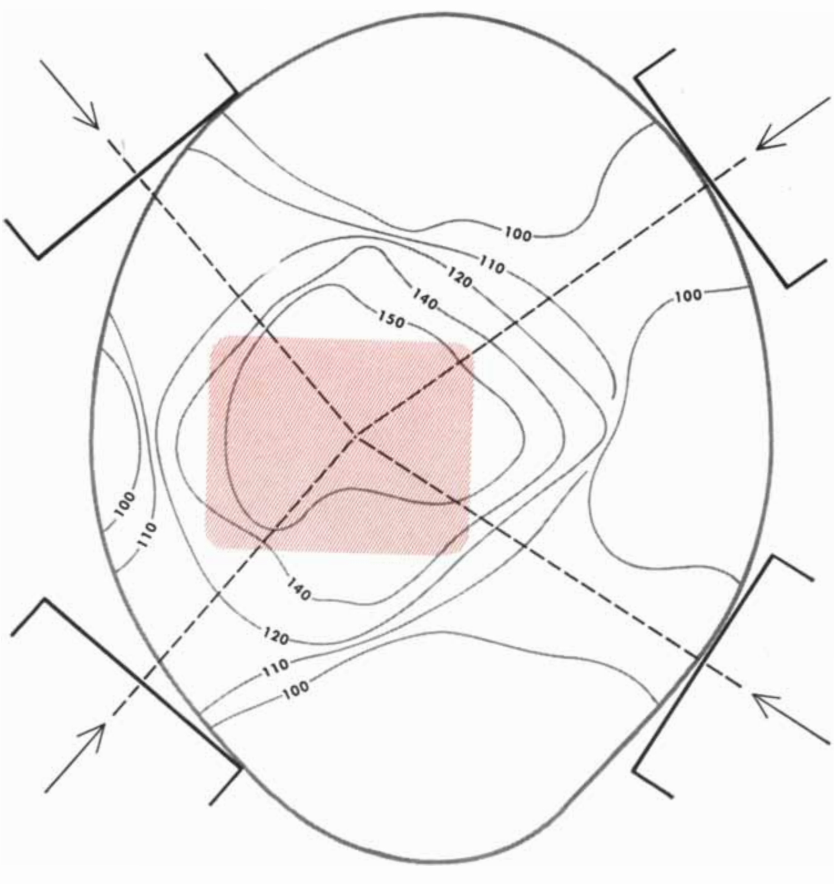


A 22-MILLION-VOLT BETATRON ACCELERATOR at Columbia-Presbyterian Medical Center in New York produces extremely penetrating X-rays for treatment of deep cancers. A lucite guide extends from X-ray port on machine to delineate abdominal area to be treated.



PLAN OF TREATMENT OF BRAIN TUMOR shows skull from top. Betatron will be aimed from four different angles in successive treatments and tumor (*shaded*) will receive most irradiation. Contour lines indicate relative amount of radiation in various regions.

similar doses to the ovaries. Because of the large dose involved the procedure is avoided if at all possible, especially during the first three months of pregnancy, when the fetus is most susceptible to radiation effects.

In general, much larger doses of radiation result from fluoroscopy than from radiography. The exposure is of least significance, both from the standpoint of body damage and of the genetic hazard, when X-rays are used to examine the limbs. As John F. Loutit has explained elsewhere in this issue, there is a considerable difference between exposing a limited region of the body to 25 r and exposing the entire body to the same dose. The skin over the region being examined will also sustain a much larger dose than the internal organs.

The fact that radiation can damage living tissue became apparent soon after the discovery of X-rays and radioactivity. The early investigators found themselves suffering intractable burns and even more serious injuries. Many of these later became cancerous. The destructive effect of the new radiations suggested that they be used to attack diseased tissue. It was observed that X-rays were especially damaging to rapidly dividing cells, such as appear in cancerous tissue. Soon physicians were employing X-rays for the therapy of cancerous and noncancerous tumors, in some cases with apparently good results.

Physicians nowadays have come to limit radiation therapy largely to malignant tumors and to benign tumors that present surgical difficulties. Among the noncancerous, superficial conditions still sometimes treated with X-rays, however, are hemangiomas (the "strawberry marks" on the skin of young children), warts, ringworm and acne. The use of X-rays to treat such skin conditions is not desirable, except as a last resort. In the treatment of benign skin tumors the dose is much smaller than the 5,000 r (or more) administered in skin cancer. In the treatment both of deep-seated and of superficial cancers radiation is given a few hundred r at a time, so that between treatments the normal tissue in the region can recover to some extent from radiation damage.

Radiation is also used (and sometimes misused) to treat nonmalignant conditions within the body. The painful and crippling rheumatic disease ankylosing spondylitis ("poker back") was until recently quite frequently treated with radiation. Now radiation is becoming a "last resort" treatment. The dosage to bone marrow is fairly high, and studies in Great Britain, cited by Loutit, indicate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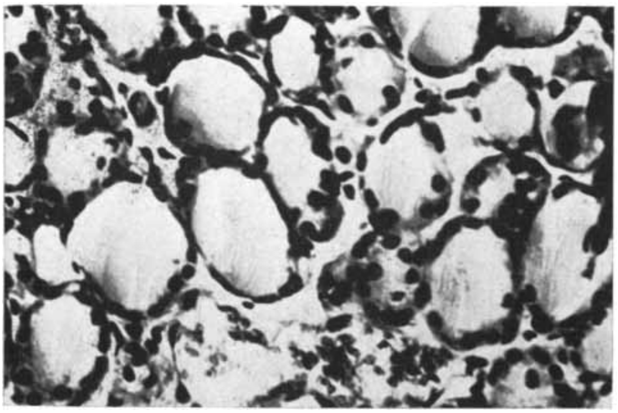 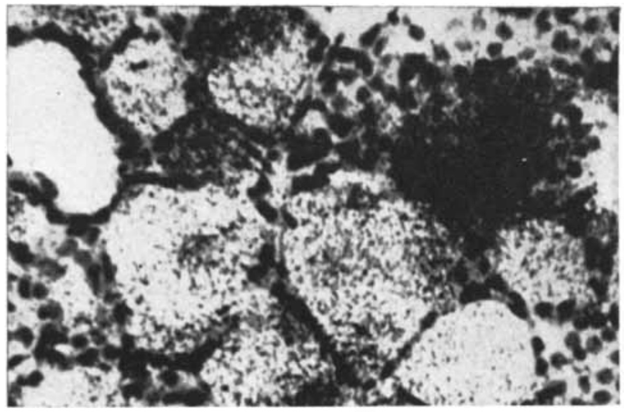

THYROID-GLAND FOLLICLES in photomicrograph at left contain colloid (*white blobs*) surrounded by barely visible cells. At right similar follicles have absorbed radioiodine and blackened a photosensitive emulsion in contact with them. Thyroid tissue and emulsion on it were photographed through microscope, enlarged 400 times. The dark follicle at upper right was the most active one.

that the treatment increases the incidence of leukemia. The pituitary gland may be irradiated in cases of infertility or certain hyperthyroid conditions. Hyperacidity of the stomach in older people, when it does not respond to other treatment, is sometimes alleviated by radiation.

For therapeutic radiation purposes we now recognize three types of malignant tumor: radiosensitive, radioresponsive and radioresistant. The first type will regress and sometimes disappear after exposure to 2,500 r or less. A radioresponsive growth will regress with 2,500 to 5,000 r, and a radioresistant one will not regress below 5,000 r. Radioresistant tumors are generally not treated with radiation because the damage to surrounding tissue is too great. Cancers of the intestine especially tend to be resistant, and since normal intestinal cells divide rapidly, they are almost as sensitive to radiation as the cancer cells. One of the principal problems in the radiotherapy of cancer is that the cancer cells tend to become resistant to radiation. If the first series of treatments does not succeed, it is often found that the renascent tumor has become radioresistant and that further radiation is valueless.

High-powered machines have greatly improved the treatment of deep cancer. Thirty years ago it was a rare X-ray machine that operated in the range of 100,000 volts. Today many medical centers have two-million-volt equipment, and the largest centers have machines that develop 20 million to 100 million volts. Comparable to the two-million-volt machines are the "bombs" that contain radioactive cobalt, an especially powerful source of high-energy gamma rays.

Cancers of the larynx, the cervix, the uterus and the bladder often respond successfully to supervoltage radiation. Treatment by radiation, as opposed to surgery, makes it possible to save the affected organ and to reach inoperable cancers. Supervoltage machines can deliver a larger dose to a deep tumor with less systemic and skin response from the patient. To minimize skin effects and concentrate the radiation on the target within the body, the radiation may be directed into the patient from a different angle during each successive treatment; the patient may also be placed in a special chair or litter and rotated during a treatment, with the tumor at the center of rotation.

X-rays are often used for merely palliative treatment. In leukemia small doses of radiation administered to the whole body can kill many of the leukemic cells and relieve the distress of the disease, occasionally prolonging life for years.

Within the past several years investigators and clinicians have developed the possibility that whole-body irradiation might be employed to suppress the immune or antibody response so that the patient can accept a tissue graft from another individual. Normally the body will reject foreign tissue, and such grafts have until now been successful only between identical twins. Whole-body irradiation, destroying the blood-forming tissues where antibodies originate, makes it possible to transplant blood-forming and other tissues to experimental animals from animals of different species. In humans the results are not yet clear-cut. In the case of six Yugoslav physicists who sustained lethal doses of radiation in a reactor accident early this year, further irradiation of the bone marrow made them at least temporarily receptive to bone marrow from donors. The treatment is credited with helping five of the victims to survive. A similar procedure attempted in a Boston hospital last spring helped to effect an apparently successful graft of a whole kidney to a young woman, though the patient died later of other causes. In such operations it may prove desirable and necessary to employ fetal bone-marrow, which does not bear antibodies of its own to evoke reaction in the patient. In England radiotherapists have performed successful "autografts" of bone marrow. Finding it necessary to subject the thorax or entire trunk to heavy irradiation, they have withdrawn the patient's own marrow from the sternum, the bone in the midline of the chest, and from pelvic and spinal bones. After the treatment they have restored the marrow to the bone, where it resumed its normal functions undamaged by irradiation.

While X-ray machines are still the major source of ionizing radiation for medical diagnosis and treatment, radioactive isotopes are becoming more and more important. Before the advent of the nuclear reactor, radioactive isotopes were obtained for medical purposes almost entirely by laborious bombardment in cyclotrons. Today a wider variety and a much larger quantity of such isotopes are manufactured in reactors. The most useful to medicine are cobalt 60, phosphorus 32, iron 59, iodine 131, sodium 24 and gold 198.

Iodine 131 is widely used in diagnosis and therapy because it has a short half-life and emits high-energy beta particles and gamma rays. Its physical half-life of 8.05 days and its biological half-life (the time it takes the body to excrete half the material) combine to give it an "effective half-life" of six to eight days. Sodium 24 has a physical half-life of 15 hours and a shorter effective half-life in the body. In contrast, radium, which is

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Tests with compounds of iodine 131 are replacing the basal metabolism (oxygen consumption) test as a means of determining whether a thyroid gland is overactive, underactive or normal. Since iodine is a key element in the thyroid hormone, a certain fraction of the diagnostic dose concentrates in the thyroid gland. Measurement of the radioactivity in the gland shows how much iodine is being retained and thus indicates the rate of thyroid activity. A hyperactive thyroid may absorb up to 80 per cent of the diagnostic radioiodine, while a hypoactive gland will absorb less than 15 per cent. With a scintillation counter to scan the gland, the radioactivity will even produce a "map," locating sites that have absorbed abnormal amounts of iodine. The dose of radiation to the thyroid gland from a diagnostic test is about four r; the whole-body dose is negligible.

In thyroid cancer physicians may administer sufficient radioiodine to give the thyroid gland 5,000 r or more of radiation exposure. The concentration of the element in the gland is such that the whole-body exposure does not exceed 75 r. During the treatment the patient is sufficiently radioactive to make it necessary to isolate him. A nurse who stays with him for more than two hours a day may receive a radiation dose greater than that permitted for radiation workers.

The usefulness of radioactive iodine is not limited to the thyroid. It may be used, for example, to locate brain tumors; the isotope tends to concentrate in the tumor because the tumor has a richer blood supply than normal brain tissue. Counters in several positions around the head indicate the direction of the most intense radiation and locate the tumor.

The injection of a known quantity of fluid containing a known concentration of a radioactive isotope provides an elegant method for computing the volume of blood in the body. Simple arithmetic yields the blood volume when the concentration of the isotope in the blood has been measured. The rate of blood flow can also be calculated by using a radioactive isotope of short biological half-life. Measurement of the time between the injection of the material in one part of the body and its appearance in another part, after passage through the heart and lungs, gives an index of circulatory-system output. A similar procedure can be used to locate abnormalities such as an occlusion in the circulatory system. In diagnosis of kidney abnormalities the concentration of radioactive iodo-Pyracet, measured by scintillation counters placed over each kidney, shows how much work each is doing. In certain kinds of anemia, radioactive iron helps to determine the age of red blood cells.

Useful as the radioisotopes are proving to be in diagnosis, they have been disappointing in the field of treatment. The ideal would be a whole arsenal of radioisotopes, each of which would concentrate selectively in one organ. The only isotope other than iodine 131 that has such selectivity and has found significant clinical application is phosphorus 32. It is the treatment of choice in polycythemia vera, a rare disease involving the overproduction of red blood cells, and it is helpful in some types of leukemia. The phosphorus has a tendency to concentrate in the bone marrow; by killing some of this tissue it cuts down the overproduction of red or white blood cells. A few patients treated in this way 20 years ago are still doing well.

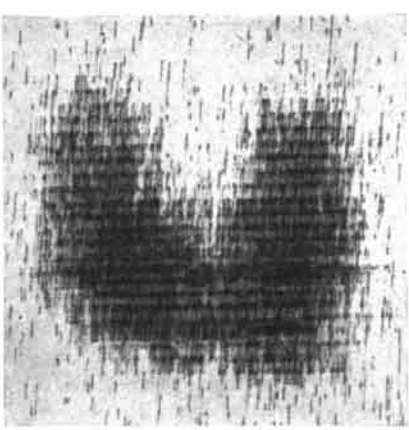
Otherwise the radioisotopes in general

SCINTILLATION COUNTER DRAWS "MAP" of thyroid gland after patient has taken diagnostic dose of radioactive iodine solution. The counter is on a clockwork mechanism, moves back and forth above the throat and makes a mark on paper for each pulse

use are biochemically inert or are encapsuled in inert materials to insulate them from the patient's body chemistry. Radioactive gold, for example, is employed as a palliative in terminal treatment of cancers of the chest or abdomen. Radioactive cobalt is cheaper than radium and is now replacing it; the cobalt needles can be placed at specific locations in or on the body to attack localized growths. Similarly, tiny beads containing yttrium 90, which has a physical half-life of 64 hours, are being embedded in deep-seated tumors. The beta rays they emit have been found less damaging to normal tissues than radiation from outside the body.

The neutron flux of the nuclear reactor that produces these isotopes may itself find direct application in therapy. At the Brookhaven National Laboratory neutrons are being used in the experimental treatment of brain tumors. The stable element boron, injected into the patient's bloodstream, is preferentially absorbed by the tumor. Eight minutes after the injection, with the boron approaching peak concentration in the tumor, a port into the pile beside the patient's head is opened. The boron absorbs neutrons from the reactor, becomes unstable and in breaking down to lithium emits an alpha particle, which at short ranges is biologically the most potent form of ionizing radiation. The port into the pile is closed after 20 minutes because then the boron has begun to move into the normal brain tissue.

In the 64 years since Roentgen's discovery the medical applications of radiation have approximately doubled the radiation dose received by the population of Western nations. Committees of the U. S. National Academy of Sciences, the United Nations and other bodies have estimated that natural background-



of radioactivity. The "map" it draws is shown at right. This gland is a normal one.

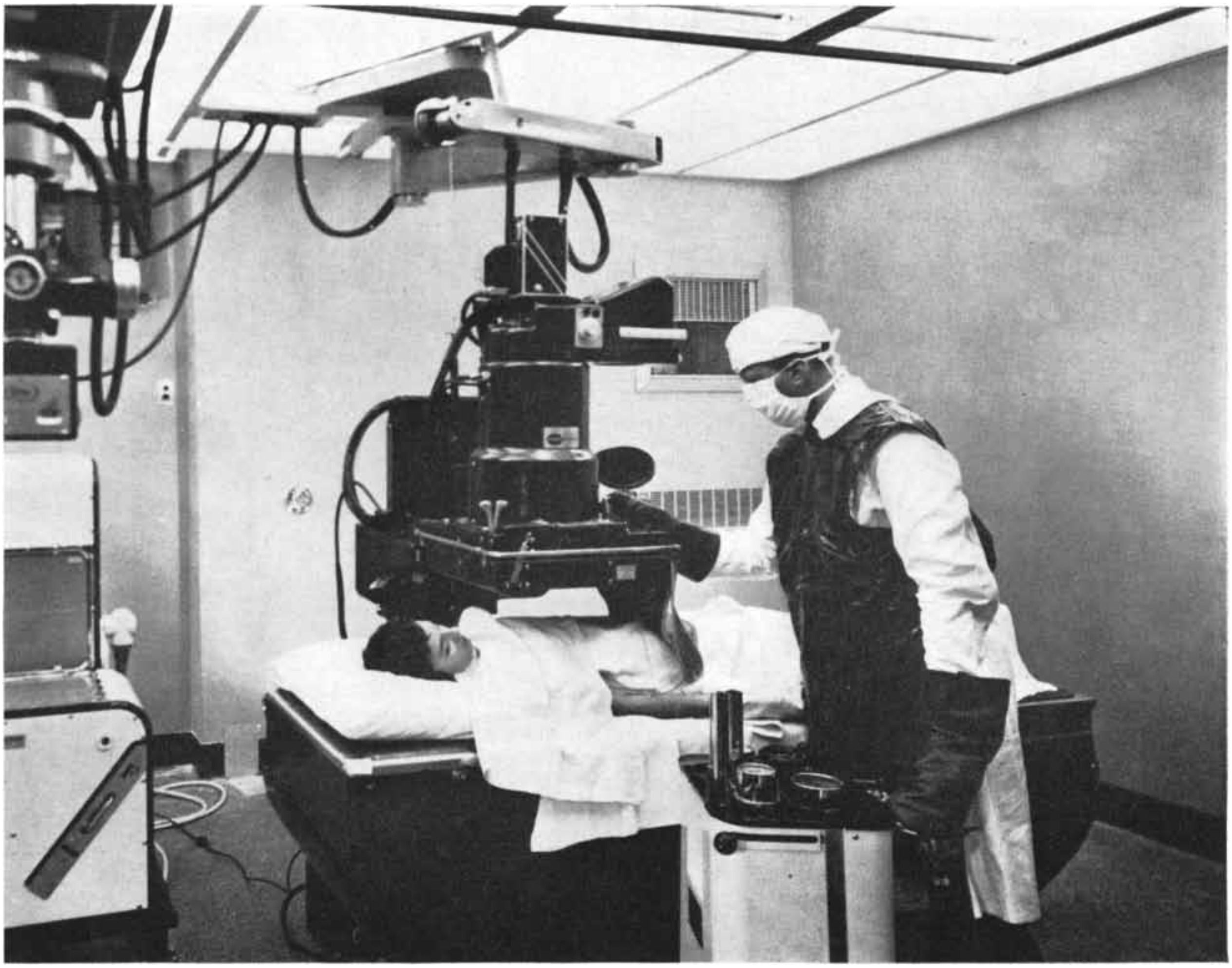


IMAGE AMPLIFIER FOR FLUOROSCOPY *(vertical black object)* lets the physician use his daylight vision, see more than with the unaided fluoroscope and reduce patient exposure by a factor of four. The radiologist here is wearing leaded gloves and apron to protect himself from radiation. This photograph and the one on page 172 were made at Columbia-Presbyterian Medical Center.

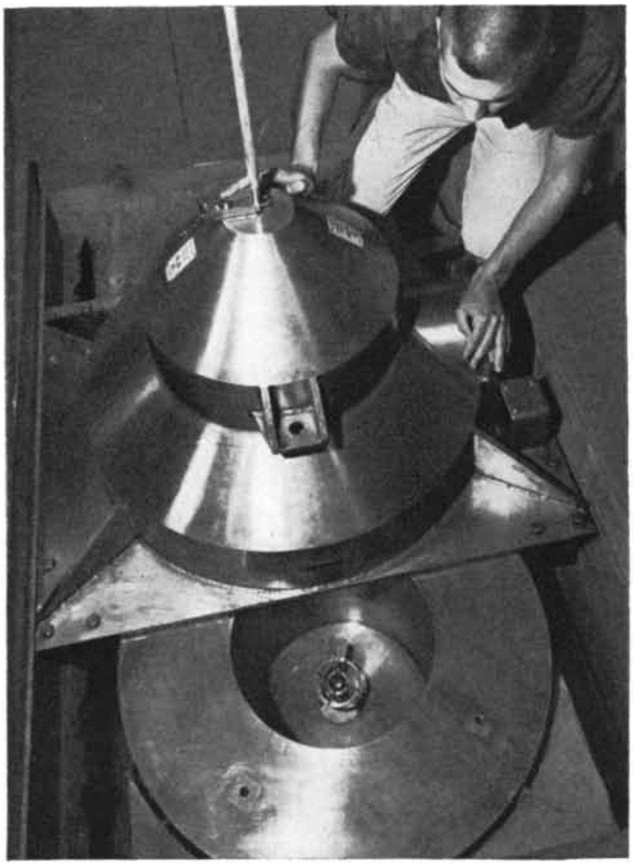
radiation gives man an average dosage of three to five r from birth to age 30, roughly the reproductive span. These same groups estimate that the dosage from medical and dental radiation in the same period equals the background dosage. Radioactive fallout from tests of nuclear weapons, which has caused such public concern, contributes 10 per cent of the medical dosage, provided the present test suspension continues.

Conscientious physicians are fully aware of the biological price that must be paid for the advantages of radiation. They take steps to minimize the radiation exposure of their patients, particularly the exposure of the gonads in patients who have not yet passed the reproductive years. They are also careful to protect themselves and their aides; leaded gloves and aprons and radiation badges to keep track of exposure are standard equipment in a well-managed radiological department, and the machines are shielded to contain stray radiation.

Over the years the profession has been taking active measures to reduce the exposure that must attend the use of radiation. The physician has his machines calibrated so that he knows the radiation output required for all the major procedures. He takes care to place the X-ray tube at the proper distance from the patient; the intensity of radiation falls off as the square of the distance, and there is an optimum distance for each procedure. In radiography the X-ray tube should be three to six feet from the patient; in fluoroscopy, at least 18 inches away. Modern dental X-ray machines are commonly and safely used closer to the patient.

A simple filter, the equivalent of 2.5 millimeters of aluminum, now eliminates the diagnostically useless "soft" or longer-wave radiation that is entirely absorbed by the skin. Other accessories to cut radiation include lead diaphragms and lead tubes or cones to confine the X-ray beam to the precise region under study or treatment. Adjustable lead shields or aprons to protect the patient's gonads are desirable. The film cassettes, or holders, should be equipped with intensifying screens, which fluoresce strongly under very little radiation and thereby amplify the action of the radiation. New fast films and methods of forced film-development have contributed in a major way to reducing the exposure necessary to accomplish a given purpose.

Unfortunately a few old-fashioned radiologists, and too many physicians who are not radiologists, are still not doing all that they might to decrease their own and their patients' exposure in fluoroscopy. The simplest way to decrease the time of exposure in this procedure is for the physician to allow sufficient time for his eyes to become adapted to the dark of the examination room. Under the pressure of daily practice many physicians



γ-Irradiation of Organic Compounds Begins at Western Reserve

Fifteen-inch Diameter Irradiation Chamber Will Provide Up To 5 x 10^5 Roentgens/Hour

A Model "L" Hotrodder irradiation unit has been put into operation at Western Reserve University, Cleveland, Ohio, to test irradiation effects on organic compounds.

At Western Reserve, a group of young scientists led by Dr. R. F. Firestone, has obtained AEC approval for experimentation with halogenated methanes and simpler aliphatic hydrocarbons. Halogenated methanes are of special interest to the group because of the unusual and apparently inconsistent behavior of several members of this class under the influence of ionizing radiation. Dibromodichloromethane, bromoform, chloroform, and carbon tetrachloride are being used in the first year's experiments.

In the compact cylindrical irradiation chamber used by Western Reserve, 100 curies of cobalt 60 wafers are stacked to form a single rod-shaped source. This source shape permits a high radiation rate at uniform flux density. Samples can be inserted and withdrawn from the chamber in complete safety with a special sample changer. The chamber can contain many test tube or larger samples.

A further safety feature is an electro-mechanical interlock which prevents any movement of the source shield while the source itself is in an exposed position. When in its stored position—for sample changing—the source is safely contained in an easily movable shield which doubles as an approved shipping container.

Nuclear Systems Division of The Budd Company designed and built this Hotrodder for Western Reserve University so that it could be used safely and conveniently under normal laboratory working conditions. Nuclear Systems also encapsulated its cobalt 60 source. The unit was designed to hold surface radiation to a safe limit with five times the amount of cobalt presently used.

The device is one of a series of portable Hotrodder irradiation facilities available from Nuclear Systems.

Information about irradiation units for research is available from Nuclear Systems Division, The Budd Company, 2450 Hunting Park Avenue, Philadelphia 32, Pennsylvania.

BODIES, CHASSIS, WHEELS, HUBS & BRAKE DRUMS | RAILWAY PASSENGER CARS & DISC BRAKES | CDF INSULATING MATERIALS, MOLDED & LAMINATED PLASTICS | PRODUCTS FOR DEFENSE | RADIOACTIVE SOURCES & SYSTEMS | MEASURING SYSTEMS | INTERNATIONAL SALES & LICENSING | Budd do not allow sufficient time for dark-adaptation, and so must turn up the X-ray beam to produce a brighter image on the screen. A 10-minute adaptation period makes the physician's eyes 10 times more sensitive to light than a three-minute period; an 18-minute adaptation period makes his eyes 100 times more sensitive. Dark-adaptation can also be achieved by wearing red goggles, but busy practitioners find this just as inconvenient as staying in a dark room.

A new development that reduces the need for dark-adaptation is the image-amplifier. Its complex electronic and optical system so greatly intensifies the fluoroscope image that the screen may be observed with daylight vision. Such an intensifier cuts radiation exposure by a factor of four or more, and lets the radiologist see more than ever before. Because the cost of these machines is high, they are found only in large hospitals and the offices of a few radiologists.

In view of the need to protect the genetic resources of the population, as well as the welfare of the patient, it is becoming a general rule not to use X-rays unless there is a specific indication for this use. Public-health officials now discourage mass chest X-rays in areas where the incidence of tuberculosis is low. Careful and conscientious case histories, accompanied by all the necessary laboratory tests, can obviate the need for many X-rays. Most pediatricians have given up routine X-ray examinations of healthy children. Because they are growing, children are particularly sensitive to radiation, and should be exposed to it only when it is absolutely required.

Like the surgeon who tries to leave the smallest possible scar, the radiologist who is proud of his profession and his own skill watches every detail in order to leave as little radiation "scar" as possible. Other physicians who employ radiation should have the same attitude.

The patient need not fear ionizing radiation in the hands of a skilled practitioner. There is no question that this boon conferred upon us by Roentgen, Henri Becquerel, Marie and Pierre Curie and other workers has been a mighty force for the conservation of life, and will continue to be so. It has also taken a few lives, particularly among the physicians who have used it to benefit others. But as our methods have improved and as more and more physicians apply the latest techniques for minimizing dosage, the dangers have been decreasing and the benefits mounting. The objective in medicine, at least, is to make ionizing radiation an unmixed blessing.

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WHAT'S MAKING NEWS?

If an annual report makes its readers expand with pride, it may be because sales have broken through to new highs. But just as often, it's because management has been able to push operating costs to new lows. This might be the result of a production short cut, an improved process, or a whole new plant. And sometimes, it's as simple as putting a new chemical in the right place at the right time. A few cases in point are reported below.

You may wish to check certain items in this advertisement and forward to those concerned in your company.

ROUTE TO:

New chemicals influence future car designs

Many of the designs planned for the automobiles of tomorrow call for specialized chemicals to make them tick. A peek at the work now in progress in Dow's Automotive Chemicals Development Laboratories shows what will be required of the antifreezes, lubricants and other automotive fluids of the near future.

Wondrous engineering advances await automobile owners of a few years from now. One may be a single unit that combines the present day functions of the transmission and rear axle. Another may cool the engine by boiling a liquid. No one can say for sure which of these and dozens of other innovations will be given the nod by automakers, but one thing is certain: Many new chemical fluids will be needed to make them feasible . . . chemical fluids far different than those used in cars today.

These new fluids are today being developed by creative chemistry, such as the experimental work being carried on in Dow's two new Automotive Chemicals Development Laboratories. Located in Midland, Michigan and Freeport, Texas, the two laboratories comprise extensive research facilities strictly devoted to automotive chemistry. Dow research chemists are currently concerned with many different projects involving the engine, cooling system, transmission, brake system and other important automotive areas.

One interesting area of study concerns viscosity index improvers for lubricating oils. V.I. improvers help extend the range of temperature conditions under which lubricants can operate. For example, an engine oil standing idle at ten degrees below zero is apt to be pretty heavy and syrupy. But at normal engine operating temperatures of 200 degrees and above, the same oil would "thin out" considerably. V.I. improvers give oil better consistency at both temperature extremes—and at all points in between.

Work on synthetic lubricants for transmissions is closely related. Heavier fluids are needed to carry the increased "loads" required of contemplated transmission designs. Fluids of higher density may permit smaller, more efficient transmissions.

Dow has long been active in the important area of antifreeze and cooling system research. This interest comes naturally, as Dow supplies several different formulations of ethylene glycol

Alleviation of rust and corrosion in the cooling system of today's automobile engine is the subject of continuing study in the Dow Automotive Chemicals Laboratories.

antifreeze to major oil companies and automotive manufacturers. Much of this work is concerned with improving the characteristics of today's all-winter antifreeze. Some, however, is on a strictly speculative basis—such as the engine that is cooled by boiling.

Other projects under way at Dow include the development of improved brake fluids, gasoline additives and several other specialized chemicals. Whatever direction automotive designs take in the next few years, Dow hopes to be ready with new chemical fluids that will meet their requirements.

DOW LOOKS TO FUTURE WITH GLYCERINE

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The future for glycerine users . . . very rosy, indeed. In fact, Dow proudly announces that an improvement in manufacturing technique has led to an even finer quality in Dow's synthetic glycerine. Coupled with product improvement is another glycerine plant in Freeport, Texas.

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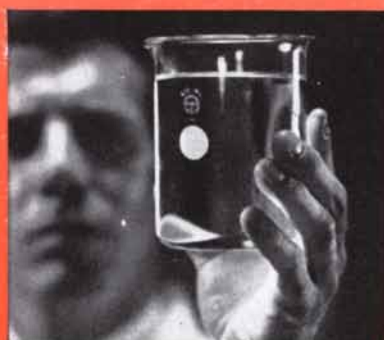

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Ionizing Radiation and Organic Chemistry

In one of its many industrial applications, ionizing radiation is used to break organic molecules into ions and free radicals. These fragments often recombine to form compounds with novel properties

by A. Charlesby

In ionizing radiation the organic chemist has a tool that enables him to tear molecules into reactive fragments. When a high-energy particle penetrates an organic compound, the valence electrons that form the chemical bonds in its molecules absorb minute portions of the huge energy carried by the radiation, and the bonds are broken. For an instant free electrons, ionized and highly excited molecules and finally free radicals pervade the immediate environment of the molecules. The ordered structure of the target substance is powerfully disturbed as these fragments enter avidly into reactions with one another and with molecules not directly affected by the radiation. When equilibrium is restored, the chemical bonds are re-established in new configurations; new molecules have been synthesized and new properties imparted to the substance.

With ionizing radiations available in plentiful supply over the past decade, it was reasonable to expect that they might evoke important innovations in chemistry. Imaginative chemists envisioned the creation of an entire new chemical-process industry and a route to syntheses not otherwise attainable. They saw, for example, how radiation could be used to develop physical properties under precise control in such substances as natural rubber and polyethylene, to produce hybrid materials containing the best features of familiar natural or synthetic materials and to promote reactions that cannot be started by heat, pressure or catalysts.

These possibilities remain as attractive as ever, but their realization on the industrial scale has been rather slow. For the most part other techniques can accomplish the same end results, and the cost of radiation is high. Cheaper sources of radiation will ultimately make more radiation processes economically attractive. The principal advances will come, however, with deeper understanding of what transpires in the chaotic instant between the primary physical impact of the radiation and the final chemical changes observed in the system.

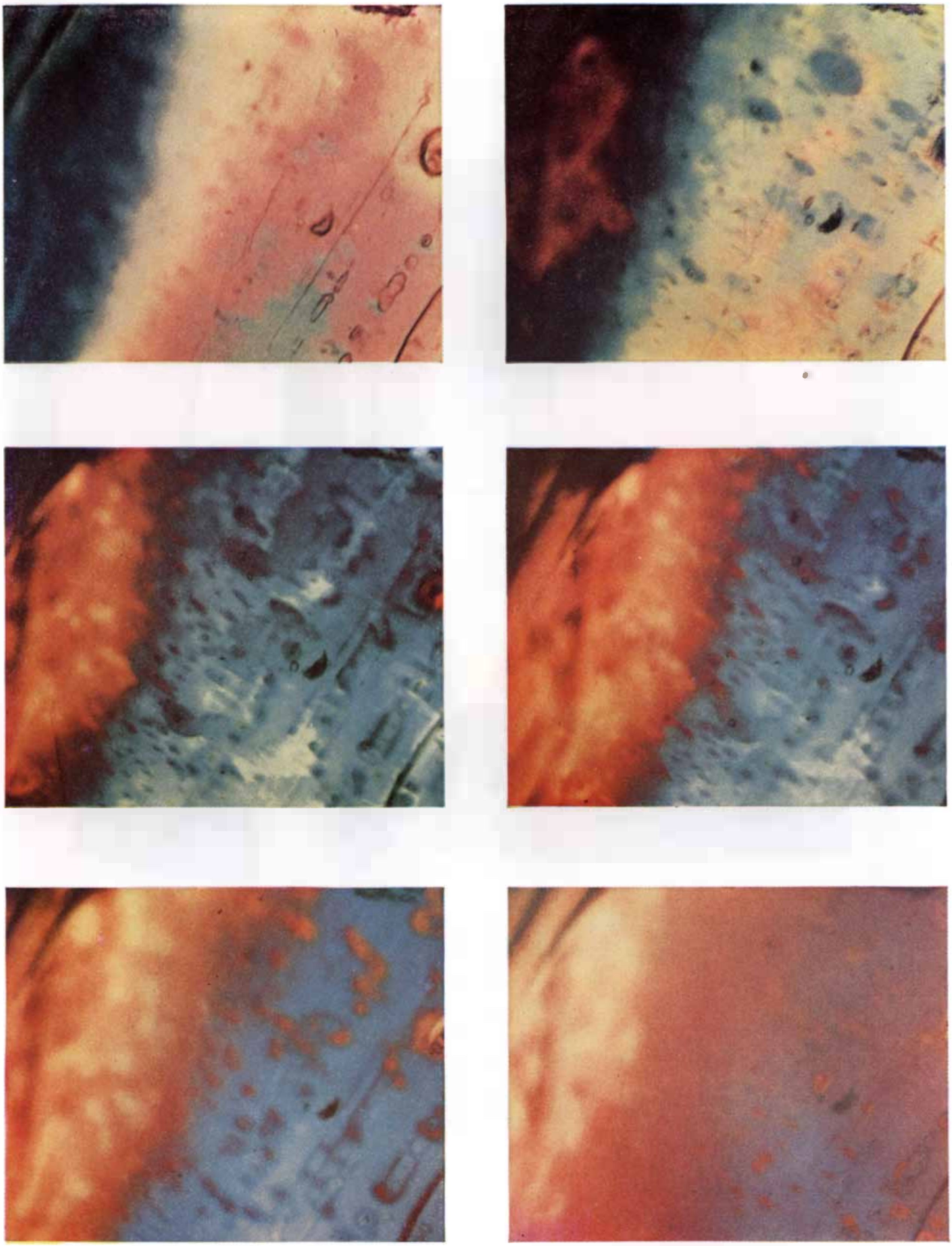
The radiochemist has many questions in common with the radiobiologist. This in itself is testimony to the size and intricacy of the molecules put together by contemporary organic chemistry. Like the giant molecules assembled in the living cell, the polymer molecules of synthetic fibers and plastics consist of repeating chains built up of dozens, hundreds or even thousands of simple units called monomers. Both kinds of giant molecule are highly sensitive to radiation. In a structure containing thousands of chemical bonds the breaking of a single bond—a chemical change as low as .01 per cent—can radically alter such macroscopic properties as viscosity. Man-made polymers have served effectively as models for their considerably more complex natural counterparts in a number of decisive experiments. Much that has been learned about living matter applies also to synthetics.

As Alexander Hollaender and George E. Stapleton have observed in this issue, the presence of either water or oxygen greatly amplifies the indirect effects of ionizing radiation on the large molecules in the cell, via the secondary action of free radicals and peroxides. The same holds true for synthetic polymers. Radiobiologists were puzzled to discover that higher temperatures appeared to increase the number of hits on target molecules in the cells. The finding that the same effect occurs in synthetic polymers made it unnecessary to postulate any elaborate biological mechanism to explain this result. Synthetic polymers have also been used to study ways to increase the resistance of cells to irradiation. Both polymers and cells, it turns out, can be protected by incorporating radiation-resistant groups into their structures; I need hardly emphasize the much greater simplicity of the polymer experiments.

One of the most alluring prospective applications of ionizing radiation in industrial chemistry is in the synthesis of polymers. Certain polymers—among them polyethylene, which is used in the greatest variety of applications—are assembled by the process of "addition" polymerization. In one method the monomer solution is seeded with free radicals of the monomer, that is, a monomer with an unpaired electron, or open chemical bond, at one end. The unpaired electron readily hooks the radical to another monomer. The result is a two-monomer unit that in turn has an unpaired electron at its end; so starts a chain reaction that builds up a polymer of considerable length. Because ionizing radiation produces huge numbers of free radicals in organic compounds, as Robert L. Platzman has explained in this issue, it naturally occurred to many chemists that radiation might be employed to initiate the process of addition polymerization. The process can, in fact, be made to produce polymers that are already widely synthesized by conventional methods. However, attempts to produce new polymers require doses of radiation too large to be economically feasible.

Addition polymerization can also be triggered by ions of the monomer, that is, by electrically charged monomers that have lost an electron as the result of ionization. Here again the use of ionizing radiation remains a laboratory proc-

IRRADIATED ORGANIC MATERIALS such as teflon (*top*) and polyethylene (*bottom*) will combine with solutions of dye-accepting polymers to produce copolymers that can be dyed brilliant colors. Both polyethylene and teflon are normally colorless and very resistant to dyes, as is shown by the weak tints produced by dyeing commercial teflon (*longer strips*). An undyed strip of teflon is shown for comparison at far right. The materials were irradiated and dyed in the laboratory of Radiation Applications Incorporated.



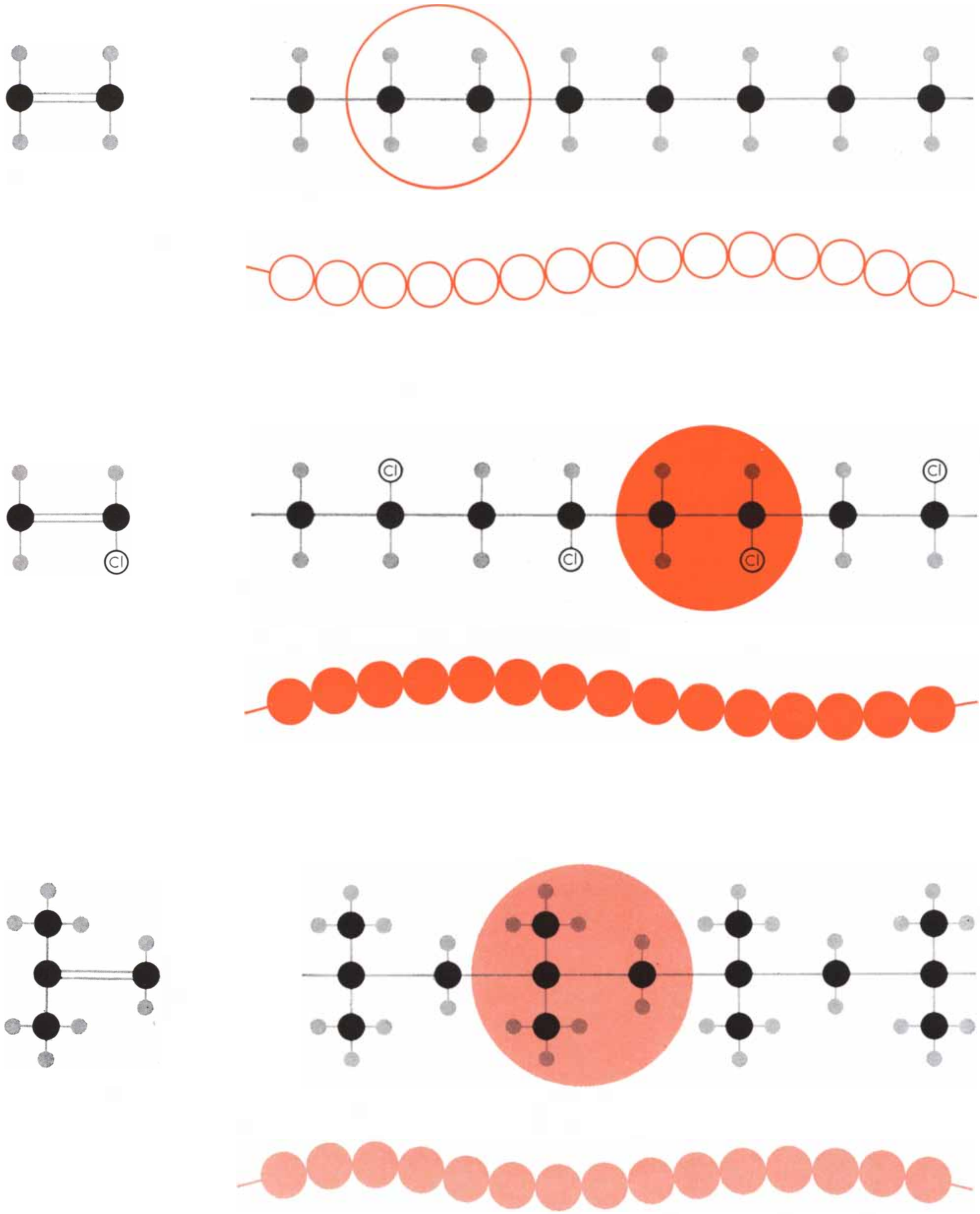
A SOLID POLYMERIZES in these time-lapse photomicrographs of an acrylamide crystal. Frame at top left, made 76 hours after the crystal was exposed to a million rads of gamma radiation, shows dark edge of an almost completely polymerized area. Frame at top right shows the same area after another 48 hours. Frame at middle left, made 13½ hours later, shows small polymerized areas beginning to form ahead of main one. Last frame, made 100 hours later, shows reaction almost completed. Photomicrographs were made by George Adler and Robert F. Smith of the Brookhaven National Laboratory, who used crossed polarizers with a red compensator.

ess. It has been found, however, that irradiation of the monomer produces a much greater yield in the presence of finely powdered zinc or of silica or even of glass beads. This surprising result has instigated research into the question of the influence of surface effects and catalysts on radiation-induced reactions.

Ionizing radiation can also bring about the peculiar phenomenon of solid-state polymerization, which would have been difficult to foresee, let alone study, without such radiation. Under irradiation the molecules of certain crystalline solids (*e.g.*, acrylamide) link to form polymers. Although the substance is not visibly altered, its structure is completely rearranged. The process can be followed microscopically by observing the gradual changes in color fringes as the material polymerizes [*see illustration on opposite page*]. As J. B. Ballantine of the Brookhaven National Laboratory has pointed out, the different rates of polymerization in various regions of a crystal are an indication of its internal strains. This raises the possibility of using such techniques to study irregularities in the structure of certain crystals.

Up to this point we have been discussing the use of radiation to synthesize polymers, a technique that has not been a commercial success. This is not the case, however, with the technique of using radiation to modify existing polymers. When exposed to radiation, all the polymers studied so far are either degraded to form smaller molecules or cross-linked to form larger ones. Which of the two reactions a particular polymer undergoes depends mainly on the structure of its monomer units, although the precise mechanism of both these reactions is still warmly debated. Polymers composed of monomers containing a single chemical side-group tend to be cross-linked, while polymers whose monomers contain two side-groups tend to be degraded. In both types of molecule, radiation apparently breaks the main chain. Chain fragments with no bulky side-groups tend to reunite quickly, but those with two side-groups tend to be pushed apart, making the break permanent.

Generally degradation involves what the term implies: Because the individual molecules are shorter the material becomes more soluble, less viscous and mechanically weaker. In polymethylmethacrylate (Lucite) both the main chain and the side chains that branch from it are fractured. This liberates hydrogen, carbon monoxide and carbon dioxide, which remain trapped in the molecular structure; upon subsequent heating



MONOMERS FORM POLYMERS by linking together in long chains. The three monomers shown here with their respective polymers are ethylene (*top left*) and polyethylene (*top right*); vinyl chloride (*middle left*) and polyvinyl chloride (*middle right*); isobutylene (*bottom left*) and polyisobutylene (*bottom right*). These compounds are composed of atoms of carbon (*black balls*), hydrogen (*gray*) and chlorine (*white*). The large colored circles show the monomer units incorporated into polymers. The strings of small colored circles beneath them show a small fragment of a polymer chain, which may contain thousands of such monomer units.

these molecules come together to form bubbles that foam the plastic into a spongy mass [*see bottom illustration on page 190*].

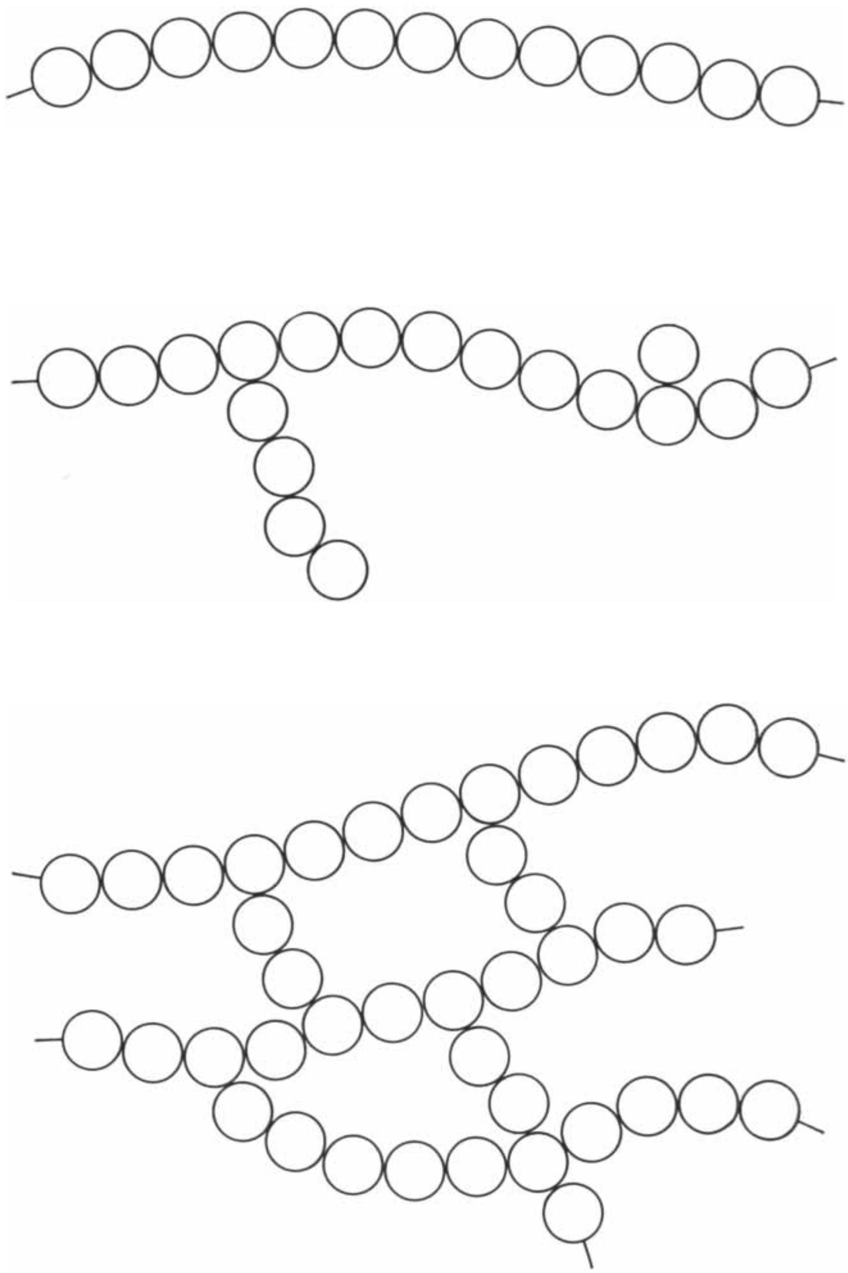
While degradation involves a fracture of the polymer's main chain, cross-linking apparently results from the coupling of the side-chains of two or more polymer fragments. The main chains of two adjacent molecules can also form direct carbon-to-carbon cross-links when radiation removes one hydrogen atom from each chain. Cross-linking profoundly affects the macroscopic properties of a polymer. When the number of cross-links is low (about one link per 100 monomers), and the chains have adequate flexibility, the polymer will form a highly elastic material such as rubber. When the number is high (about one cross-link for every three or four monomers), it will form a more rigid material which fractures readily and has many of the properties of glass.

In the pilot plant, at least, ionizing radiation has served well in the task of cross-linking natural rubber. Cross-linking converts this rather impure polymer into the tough elastic material that serves so many important purposes in our civilization. Ordinarily rubber is cross-linked by vulcanization, a complex chemical process that introduces sulfur links between the rubber molecules. Irradiation accomplishes the same purpose by inducing direct carbon-to-carbon links between adjacent molecules. Since the number of cross-links is directly proportional to the dose of radiation, some parts of a piece of rubber can be made more elastic than others. Rubber can also be given different elastic properties in different directions simply by stretching it and irradiating it in this orientation. Chemically vulcanized rubber, however, is a relatively cheap product, produced by a process that has been developed over many years to a state of high technical efficiency. The curing of rubber by radiation is regarded as commercially unfeasible in the U.S., but the U.S.S.R. has announced that it has the process working on a factory scale.

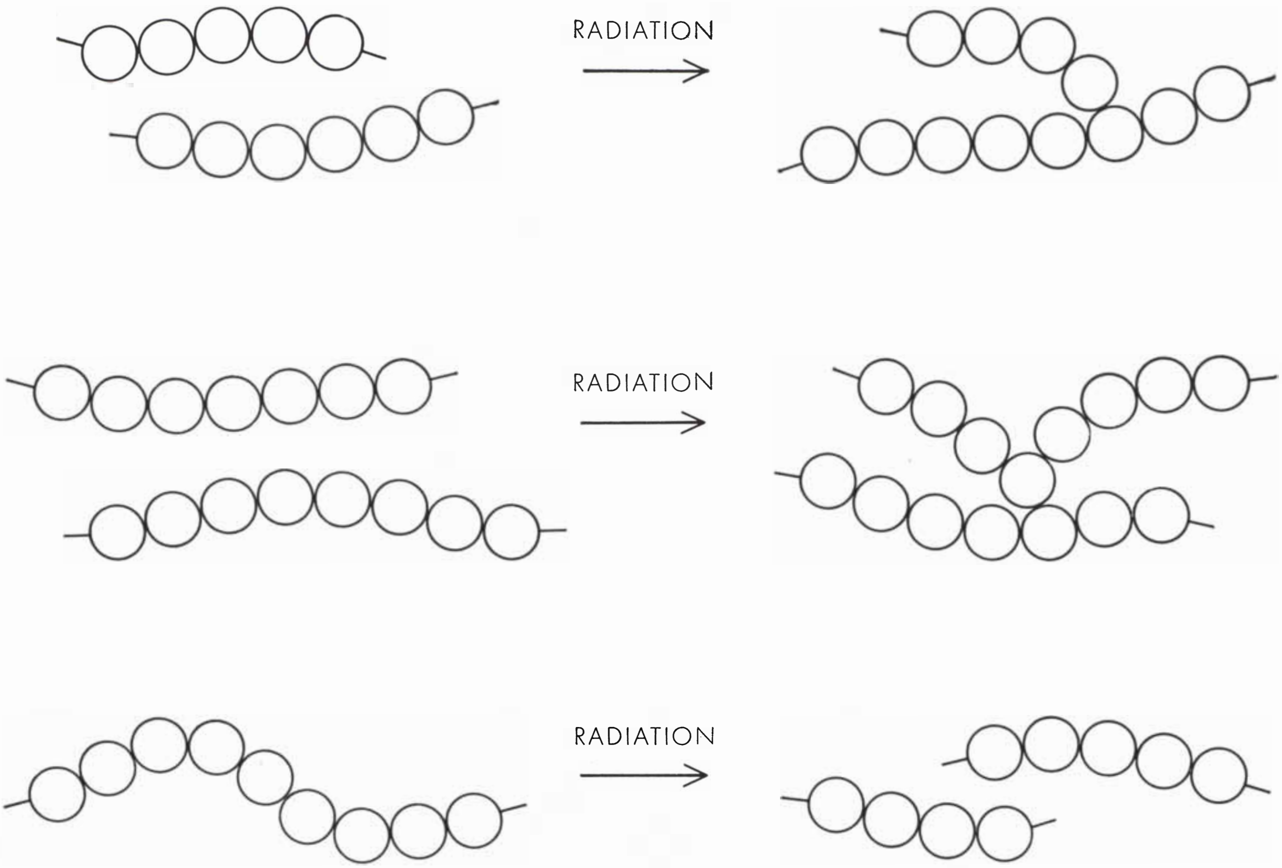
The commercial outlook is brighter for irradiated silicones, the synthetic polymers that are often used as high-temperature rubbers. Silicones are readily cross-linked by small doses of radiation, and because they are expensive to begin with, the cost of irradiating them represents only a small percentage of their final price. There is also strong evidence that irradiated silicones are superior to chemically cross-linked ones.

Irradiation imparts to polyethylene significant properties that fit this ubiquitous plastic for service in certain technical applications. Commercial grades of polyethylene soften and eventually melt to a viscous fluid at temperatures between 240 and 275 degrees Fahrenheit, depending on their degree of crystallinity. Irradiation somewhat lowers this melting point, but improves temperature resistance by inducing the formation of cross-links. The irradiated polyethylene melts to a rubber-like material that does not flow at these higher temperatures and regains its original properties on cooling. In service as an insulator of heavy-duty electrical cables, it withstands temperatures of 300 to 400 degrees F. and justifies its high cost.

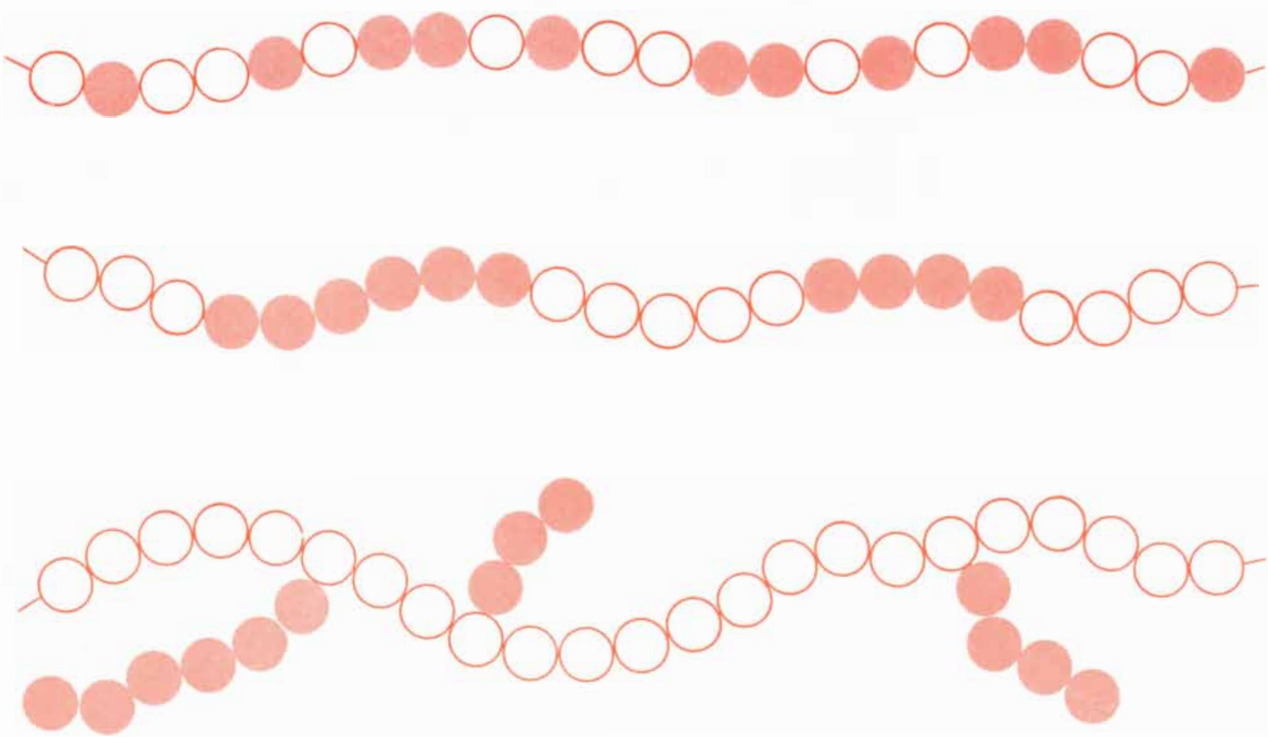
Irradiated polyethylene can also be made into a plastic sheet that is heat-sealable but resistant to melting. Foods can be wrapped in it, cooked and sterilized, and then stored almost indefinitely, with the food visible to periodic inspection. I have prepared and "canned" some excellent omelets with this material, using a pair of scissors to cut the sheet



CHAIN STRUCTURE is one basis for classifying polymers. Linear or one-dimensional polymers such as natural rubber have either straight chains (*top*) or branched chains (*middle*). Such chains can link together to form either two-dimensional sheets or three-dimensional networks (*bottom*). Vulcanized rubber is an example of a three-dimensional polymer.



RADIATION CHANGES POLYMERS by breaking the chemical bonds holding the polymer chain together. The broken chain fragments may then recombine in new arrangements (*top*), be cross-linked (*middle*) or be degraded into smaller fragments (*bottom*).



COPOLYMERS are hybrids composed of two or more different types of monomer. Random copolymers (*top*) consist of monomers linked together in no particular order. Block copolymers (*center*) contain similar monomer units strung together in groups or "blocks." Graft copolymers (*bottom*) have side-chains of one type of monomer "grafted" onto a main chain of a different type.

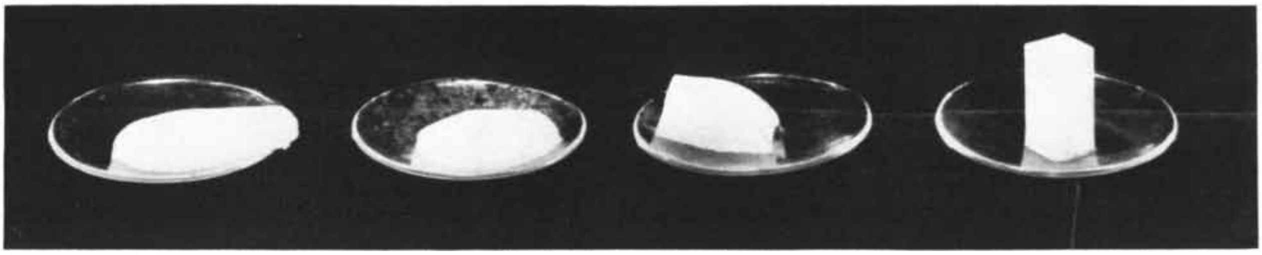
and a flatiron to seal the package and cook the eggs. Even at present radiation costs this particular process is not excessively expensive.

In many applications, however, the use of radiation is limited by its current high cost. One way to reduce the cost of irradiation is to add allyl (C_3H_5) groups to the polymer. When these groups are exposed to radiation, they initiate a chain reaction in which each allyl group, as it becomes linked to the polymer chain, stimulates the formation of another active site on the polymer molecule. The reaction stops only when all the active sites have linked. Such reactions can produce a great number of cross-links with a relatively modest radiation dose.

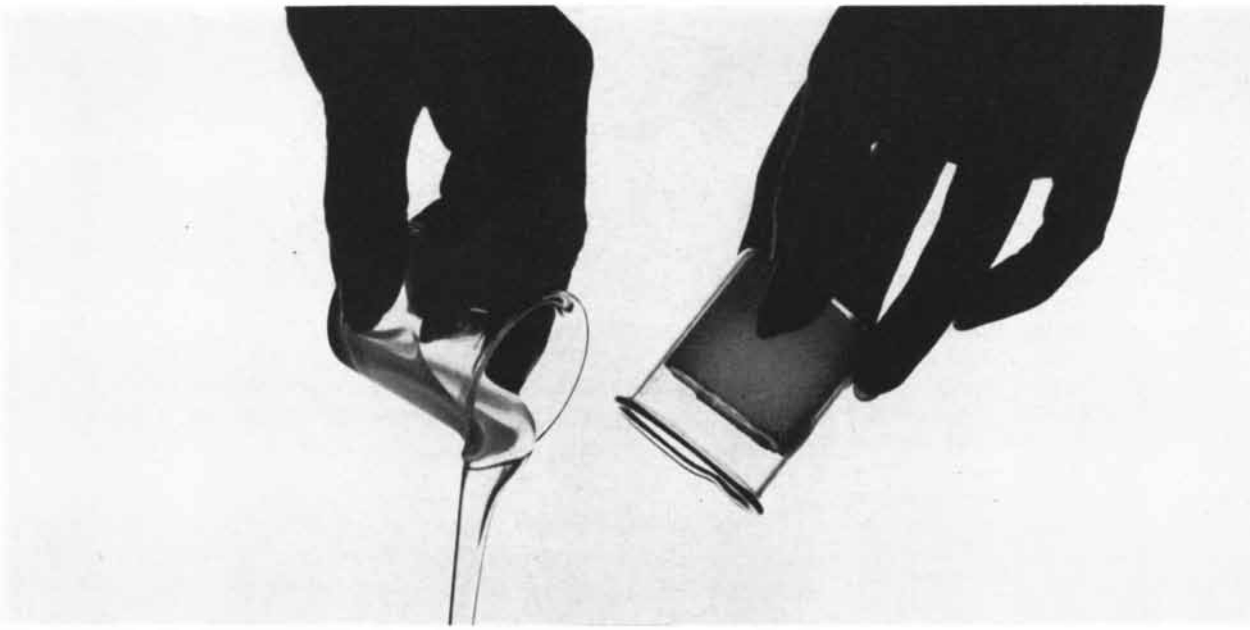
Some polymers are resistant to radiation and cross-link only sparsely. A given dose of radiation induces the formation of only a 20th the number of cross-links in polystyrene, for example, that it does in natural rubber or polyethylene. Characteristically the structures of these polymers include benzene rings, and the benzene ring is distinguished for its stability under irradiation. This refractory behavior may be turned to account by incorporating benzene rings into other polymer structures to produce radiation-resistant materials for use in intense radiation fields. Here the designer must be wary both of the tendency to cross-linking and of susceptibility to degradation. While many polymers degrade into sticky fluids under strong or prolonged radiation, lubricating oils become polymerized and cross-link into gummy residues.

Just as cross-linking can appear on occasion as an undesirable phenomenon, so constructive uses may be found for the process of degradation. The natural polymer cellulose, for example, is easily degraded by radiation. It has been suggested (perhaps jocularly) that a suitable degree of degradation might "predigest" the large cellulose molecules in sawdust to yield a nourishing cattle fodder. Degradation might also be employed to produce a hybrid of cellulose and nylon: By exposing a mixture of the two substances to radiation, it might be possible to produce polymer fragments that would link together to form a hybrid which combined the best properties of both its parents.

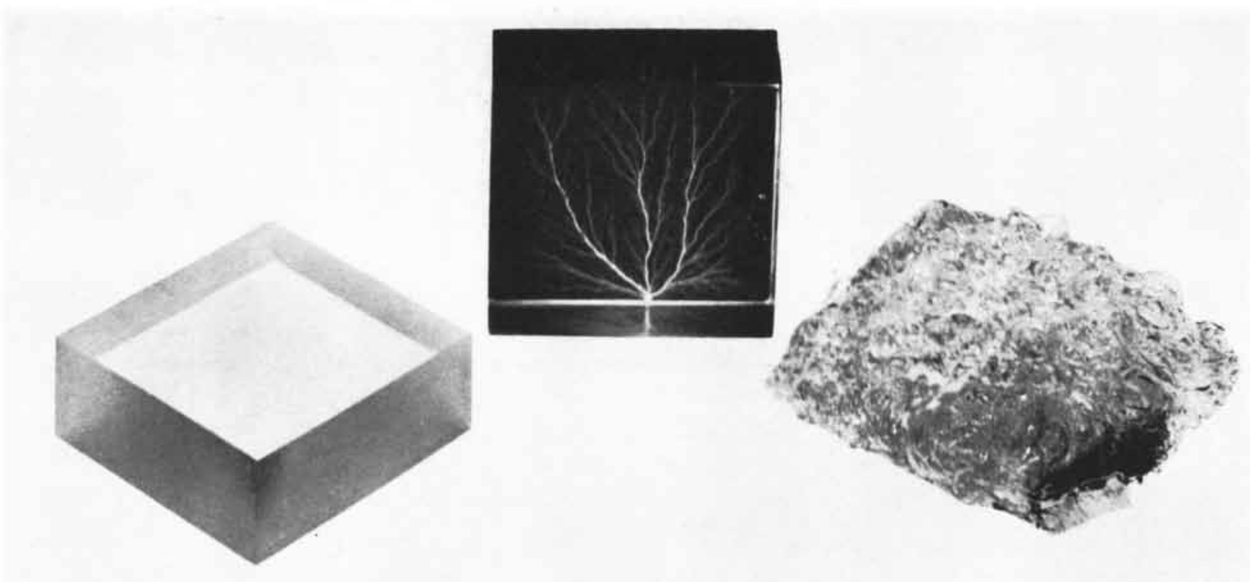
Such a hybrid is known as a copolymer. In the case of the cellulose-nylon combination the idea is that irradiation would fracture the cellulose chain and permit segments of nylon to fit themselves into the backbone of the new



IRRADIATED POLYETHYLENE is more resistant to heat than the unirradiated material. Here four polyethylene blocks were heated for one hour at 390 degrees Fahrenheit. The block at far right was previously exposed to a dose of 20 million rads of cobalt-60 gamma radiation; the block next to it received seven million rads; the next block, two million rads. Block at far left was not irradiated. The plastics photographed in the demonstrations on this page were irradiated by Radiation Applications Incorporated.



IRRADIATED POLYESTER RESIN changes from a syrupy liquid to a hard, tough solid. Resin pouring from the beaker at left has not been irradiated; that in the beaker at right has been exposed to 750,000 rads of gamma rays from a cobalt-60 source.



IRRADIATED LUCITE (polymethylmethacrylate) becomes a foamy mass (*right*) when heated. When exposed to an electron beam, a Lucite block becomes impregnated with free electrons; if the block is then electrically grounded, the sparking of the discharging electrons forms the crack patterns known as Lichtenberg figures (*center*). An unirradiated Lucite block is shown at left.

molecule, forming a "block" copolymer [*see bottom illustration on page 188*].

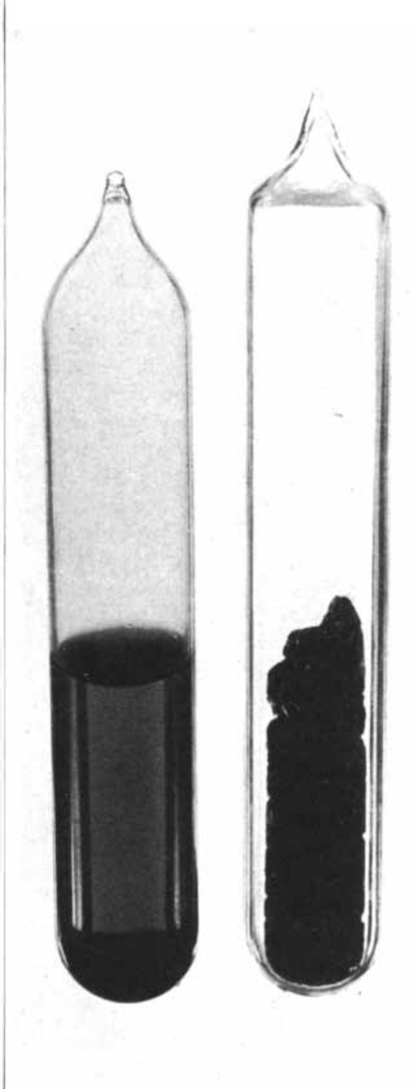
Irradiation can also be used to excite active centers of polymerization on the backbone of a polymer, permitting it to initiate the polymerization of one of its side-chains. In such polymerizations monomers of a different type may be "grafted" on a polymer's molecular backbone. Such graft copolymers have already been successfully produced. For example, irradiation promotes the grafting of dye-accepting monomers to the surface of teflon, a notably tough and chemically inert polymer, making it possible to label this material with colors when it is used to insulate electrical conductors. The grafting of polystyrene to the surface of teflon film similarly permits one side of this otherwise unbondable material to be attached to other substances, while the other side retains its chemical inertness and high temperature-resistance.

Such are the possibilities, hopes and promises of ionizing radiation as applied to chemical technology. Much that is known to be technically feasible remains economically impracticable. To go from the processing of such special-purpose materials as silicones and teflon to the processing of commonplace industrial polymers requires much cheaper sources of radiation. One can envision nuclear-power stations and chemical-processing plants working side by side. One can also envision the difficulty of reconciling the very different interests of the chemical engineer and the nuclear-power engineer. Considerable structural changes would be necessary to accommodate a high flow of irradiated materials through any existing nuclear reactor designed primarily for research or for power production. On the other hand, the fuel rods in nuclear reactors must be replaced periodically and the used rods stored for a while before they can be processed for the extraction of plutonium and fission products. At certain plants the fuel rods are already serving as irradiation sources during this "cooling-off" period; their declining radioactivity must, of course, be allowed for in the scheduling of chemical processes. When the fission products have been extracted, these too may act as radiation sources, especially the long-lived isotopes cesium 137 and strontium 90. Finally elements such as cobalt may be irradiated in a reactor to produce powerful radiation sources.

At present high-voltage electrical machines provide ionizing radiation at much lower cost. Generating two million volts or more, they produce their effects by means of their primary electron-beams, or by secondary X-rays when the electron beams impinge on a target.

For some purposes there are advantages to be gained by using one of these sources of radiation as opposed to the other. But in a wide range of applications they are interchangeable and directly competitive. As the supply of fission products increases and the cost of processing them comes down, one may expect to see an economic battle between the electrical and the nuclear-engineering industries to provide power for the new field of radiation chemistry.

But economics is not the sole barrier to progress in radiation chemistry. Equally important is the great deal that the radiation chemist has yet to learn about his subject. No theory yet ad-



IRRADIATED OIL becomes cross-linked, changing from a liquid (*left*) to a gummy solid (*right*) that does not flow or melt.

vanced explains, for example, the peculiar electrical behavior of polymers under irradiation. Many polymers are very effective electrical insulators, a property they retain even after severe radiation damage. However, at radiation doses and intensities far too low to cause any observable chemical change, they can suffer a considerable reduction in their insulating capacity. They ultimately recover, but the time it takes them to do so varies from polymer to polymer.

One theory states that ionization liberates either electrons or protons which are free to flow as current under the pressure of an external electrical field. It accounts for the gradual decay of these currents by assuming that the wandering electrons must first be trapped by some impurity atom, then released by thermal agitation and finally recaptured by electron-deficient molecules. The experimental conductivity observed, however, is remarkably consistent, and bears no relation to the presence of impurities.

An alternative theory suggests that the conductivity is due to the motion of "holes" of the sort that occur in semiconductors. These holes are simply the charged vacancies left when an electron or proton is ejected from a molecule in a crystal lattice. Another electron or proton may fill the hole, creating another hole in the place it vacates in the lattice; thus, like a wandering proton or electron, the hole appears to move through the material. But there are indications that the hole tends to migrate to certain preferred positions in a given molecule. Here the study runs into the even more fundamental question of "energy transfer," the mysterious process in certain organic molecules by which incident energy absorbed at random migrates to specific sites and produces nonrandom chemical changes.

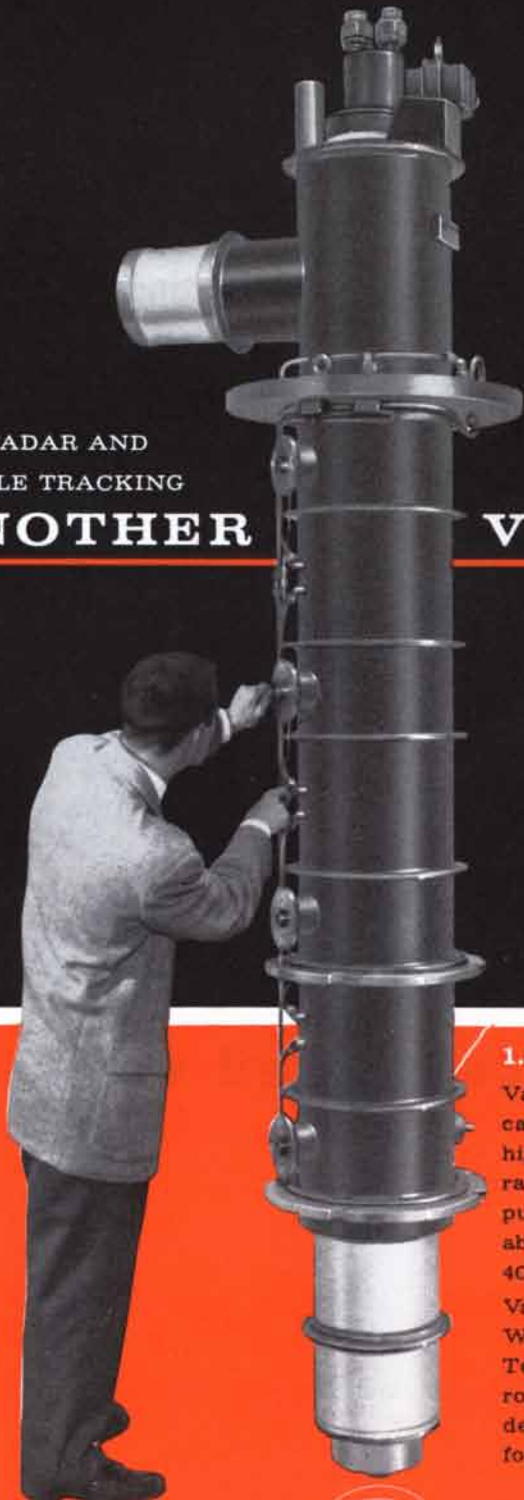
Most studies of irradiated polymers have been carried out on solids in which the polymer molecules are held almost immobile. Comparatively little attention has been paid to the behavior of polymers in solution, in which the chemical groups involved may move about. This is a significant gap in the work of radiation chemistry, because polymers in solution offer much better analogies to biological systems. Moreover, solution studies permit the comparison of the direct effects of radiation on the polymer itself and the indirect effects that are mediated by the action of the radiation on the solvent.

One set of experiments, using water as the solvent, has led to a most surprising result. Certain polymers that do not

cross-link easily and even degrade when they are irradiated as solids have been found to cross-link readily in solution. The molecules link up into a network that gels suddenly, absorbing the water in which they are dissolved to form a jelly-like material. As continued irradiation increases the number of cross-links, the network gradually shrinks, wringing out some of the water. The presence of certain radiation-protective molecules will greatly increase the dose of radiation required to bring the reaction about, and this provides a measure of the degree of protection offered.

In these studies the concentration of the polymer in the solution is especially significant. One might expect that fewer cross-links would be formed at low concentrations, when the polymer molecules are far apart. But instead the dose required for network formation decreases as the concentration is reduced. The explanation lies in the indirect effect of the radiation: Radicals formed in the water react in some way with the polymer molecules, causing them to cross-link. As the polymer concentration is reduced, there is a larger number of radicals available to attack each polymer molecule, and the polymer may be cross-linked by very small doses.

If the concentration is reduced still further, a new pattern of behavior emerges. Instead of forming networks, the polymer apparently degrades. This transition, which occurs in a very narrow range of concentrations, has several possible explanations. One postulates that unspecified active groups are formed on the polymer; if one of these groups meets another in a given time, they will react to form a cross-link. In very dilute solutions, however, such an encounter does not occur soon enough, and the activated polymer molecule degrades by main-chain fracture. Thus radiation initiates a concentration-dependent competition between cross-linking and degradation. Another explanation depends on the fact that networks can be formed only by the linking of active sites on separate molecules. Below a certain concentration this becomes even less probable than the linking of active sites on the same molecule. The latter process tightens up the molecule and reduces its over-all size, making cross-linking with other polymer molecules even less likely. The elucidation of such questions as these will surely enhance the usefulness of ionizing radiation in polymer chemistry. But it will also contribute significantly to our understanding of the effect of radiation on the molecules that conduct the intricate processes of life.



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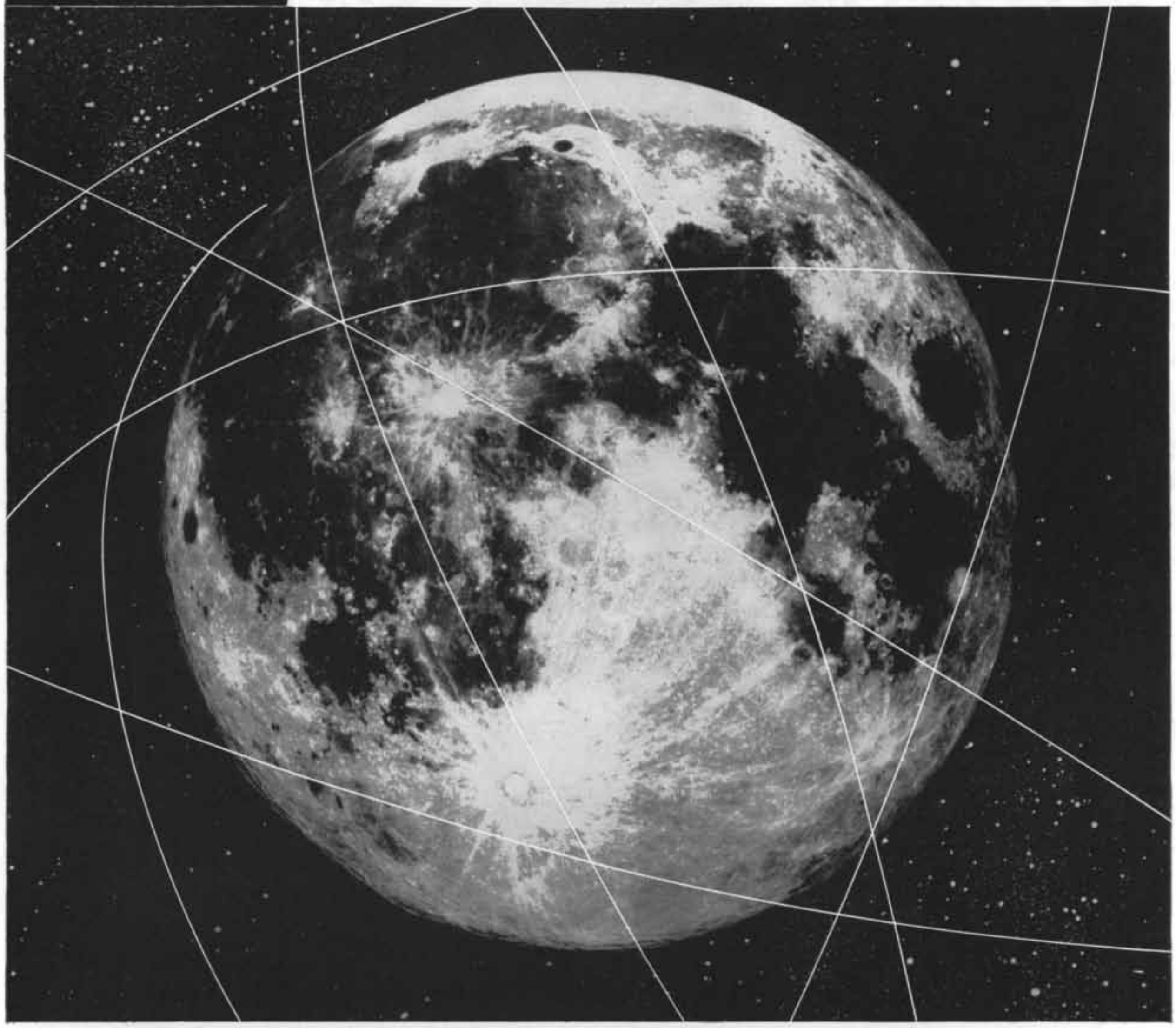

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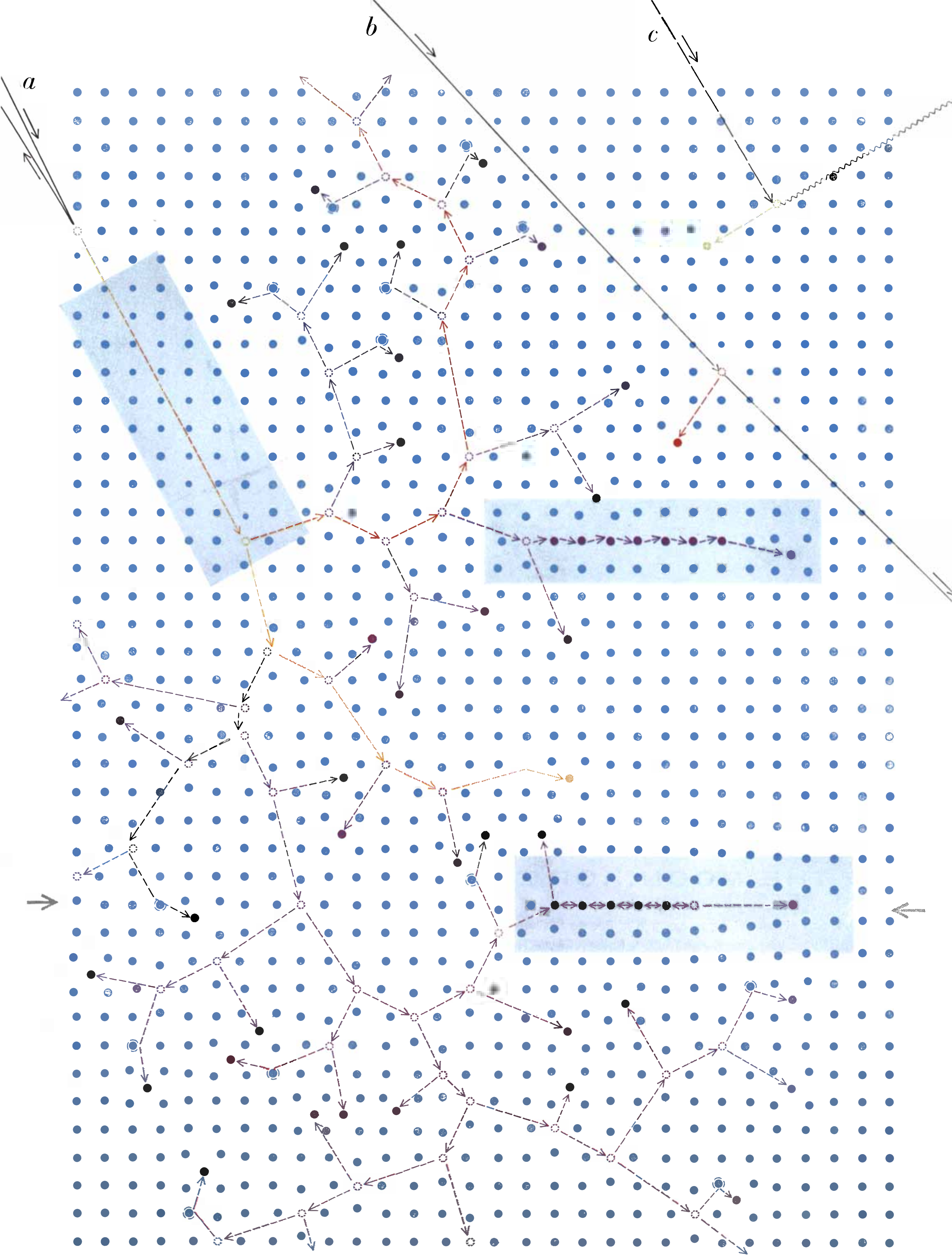

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Ionizing Radiation and Metals

The effects of radiation on metals result from the displacement of entire atoms in a crystal, not from ionization. These atomic displacements yield new insight into the nature of the solid state

by Douglas S. Billington

Long before the uranium in the fuel element of a nuclear reactor has been consumed in fission, the fuel element becomes swollen, elongated, blistered and embrittled by the flux of high-energy particles within. A graphite moderator, which slows down the fast neutrons from the fuel elements to the slower "thermal" speeds needed to support the chain reaction, loses much of its thermal conductivity and suffers dimensional changes under the action of those neutrons. Similar damage is sustained by the metal control-rods that absorb the excess neutrons and so serve to maintain the reaction in a steady state.

Here is ample evidence that high-energy radiation—which so powerfully disrupts living matter and substances composed of organic molecules—may also have significant effect upon inorganic crystalline solids. There is a substantial distinction to be drawn, however, between the effects observed in organic and inorganic matter. John F. Loutit has pointed out elsewhere in this issue that a dose of 300 or 400 r [*see glossary of terms on page 78*] of ionizing radiation to the whole body is nearly always fatal to man. What is the effect of a similar dose of radiation to a piece of metal, or ceramic? The answer, in the case of almost all inorganic crystalline solids, is: No effect is detectable. It is only at the heart of a nuclear reactor that the destructive action of ionizing radiation upon such materials becomes a matter of concern, and even there it primarily affects materials that are involved in the nuclear reaction itself. The uranium-graphite reactor at the Oak Ridge National Laboratory has been in continuous operation for 16 years. The fuel elements and control rods have of course been replaced several times during this period. But the thick walls of concrete that shield the scientists and engineers who work around the reactor remain unaffected by the huge volumes of intense radiation they have absorbed over this long period. All of the structural components of the reactor are still sound and will continue to be serviceable for an indefinitely long time to come.

The stability of inorganic solids under irradiation is best understood in terms of the events that take place on the microscopic scale. Ionizing radiation is disruptive to organic and living matter precisely because it ionizes, that is, tears electrons from their moorings in atoms and molecules and thereby breaks the chemical bond. In the case of most inorganic solids, however, this ability of radiation to cause ionization results in no significant change in properties. The electrons in metals are not bound to any one atom but are shared by all; in other words, metals in the solid state are permanently ionized. However, when a particle or photon of radiation carries sufficient energy, it may, by a simple billiard-ball type of collision, knock atoms out of their positions in the lattice structure of the crystal. Now the displacement of whole atoms does alter the properties of the metal in significant ways. But it takes radiation of considerable energy and intensity to make these changes show up on the macroscopic scale.

Such radiation is available only in the interior of a nuclear reactor, from certain extremely active radioisotopes

SEQUENCE OF EVENTS following bombardment by a fast (one- or two-million-electron-volt) neutron (*a*) in the idealized lattice of a copper crystal is depicted on the opposite page. Red line traces path of atom displaced by neutron; yellow line traces path of second atom in sequence of collisions; purple lines show paths of subsequent atomic collisions. The great majority of displaced atoms (*darkest dots*) come to rest interstitially, distorting the lattice by forcing adjacent atoms out of position. Vacancies left by interstitials (*broken circles*) distort lattice by allowing adjacent atoms to collapse inward. Before stopping, displaced atoms may have only enough energy left to deliver glancing blows in collisions, enhancing thermal vibration of other atoms (*circled dots*) but not displacing them. The 60,000-electron-volt energy of the first atom shrinks the apparent diameter of atoms along its path (*blue area at left*). The arrows in the margins point to extra plane of atoms (a "dislocation") which ends in middle of lower blue area at right. Same area shows a focusing collision: Impact is squarely on axis of travel of displaced atoms, causing each atom to spring forward, collide with the next and return; the last atom is permanently displaced. Upper blue area at right shows defocusing collision. Impact is just off the axis of travel of the displaced atoms, causing atoms to follow jagged path, each one knocking the next out of position and replacing it. Some neutrons pierce the lattice with no effect; others (*b*) may dislocate only one atom. A slower moving (1/40-electron-volt) thermal neutron (*c*) may be absorbed by nucleus of an atom. The atom is thereby transmuted; it emits a gamma ray and recoils to an interstitial position. In a crystal the events charted here in two dimensions occur in three dimensions. The diagram is based on drawings that were prepared by O. S. Oen of the Solid State Division of the Oak Ridge National Laboratory.

and from high-energy accelerators. Particles of sufficient energy can exert even more extreme effects on the microstructure of solids. When the two or more fragments of a fissioning uranium atom fly apart with a total energy of 160 million electron volts, each yields up its share of this enormous energy within .001 inch; the spectacular changes in the fuel rod are the result. The neutrons and other particles in the reactor may cause transmutation of atoms into radioisotopes of their own or other species, thus modifying the properties of a material in a most radical way.

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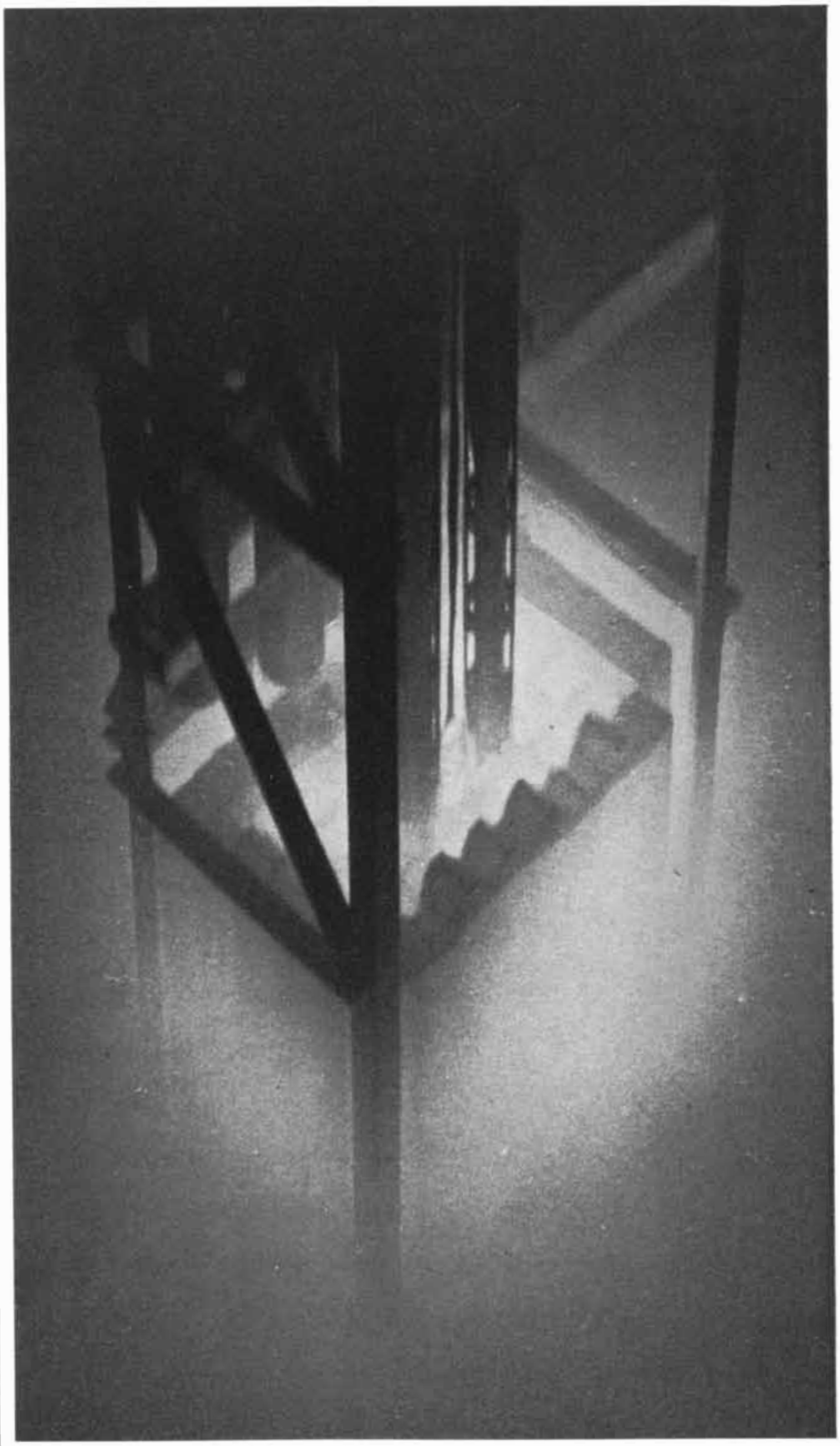

SWIMMING-POOL REACTOR at the Oak Ridge National Laboratory is used for irradiation experiments. Bright glow surrounding the core is Cerenkov radiation, produced by electrons which travel through water of pool at speeds greater than the speed of light in water.

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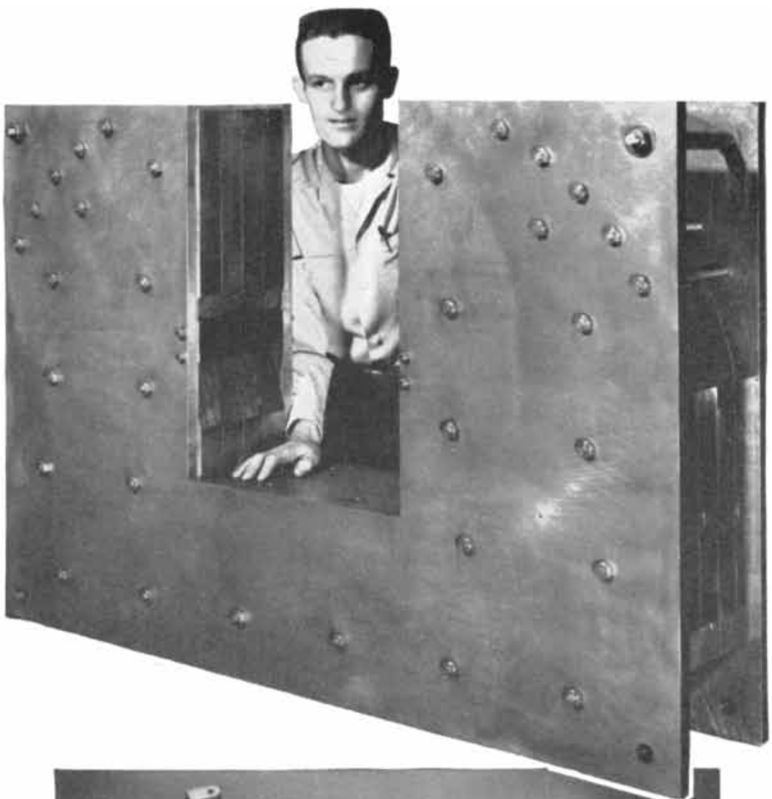

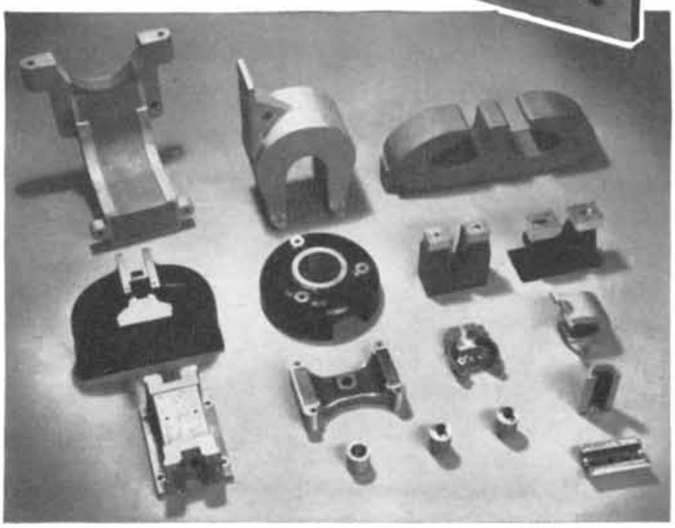

Top: the world's largest permanent magnet, built by Arnold for Argonne Labs, was designed to supply a field of 1100 gausses in a gap of 16½ inches. Bottom: a typical group of the permanent magnet assemblies that Arnold supplies for rotors, traveling wave tube, wave guide and magnetron magnets, mass spectrometer and other measuring applications, etc.

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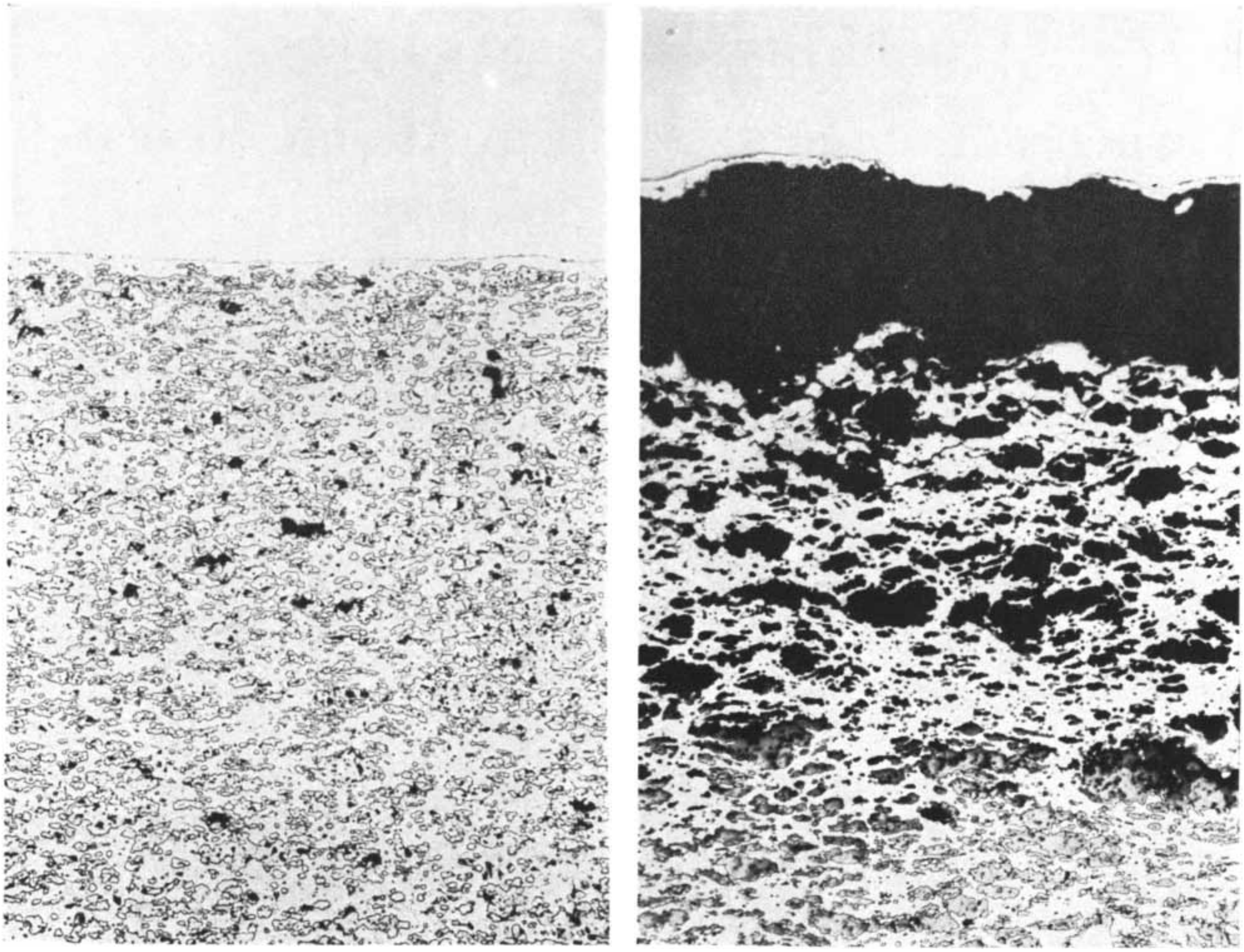


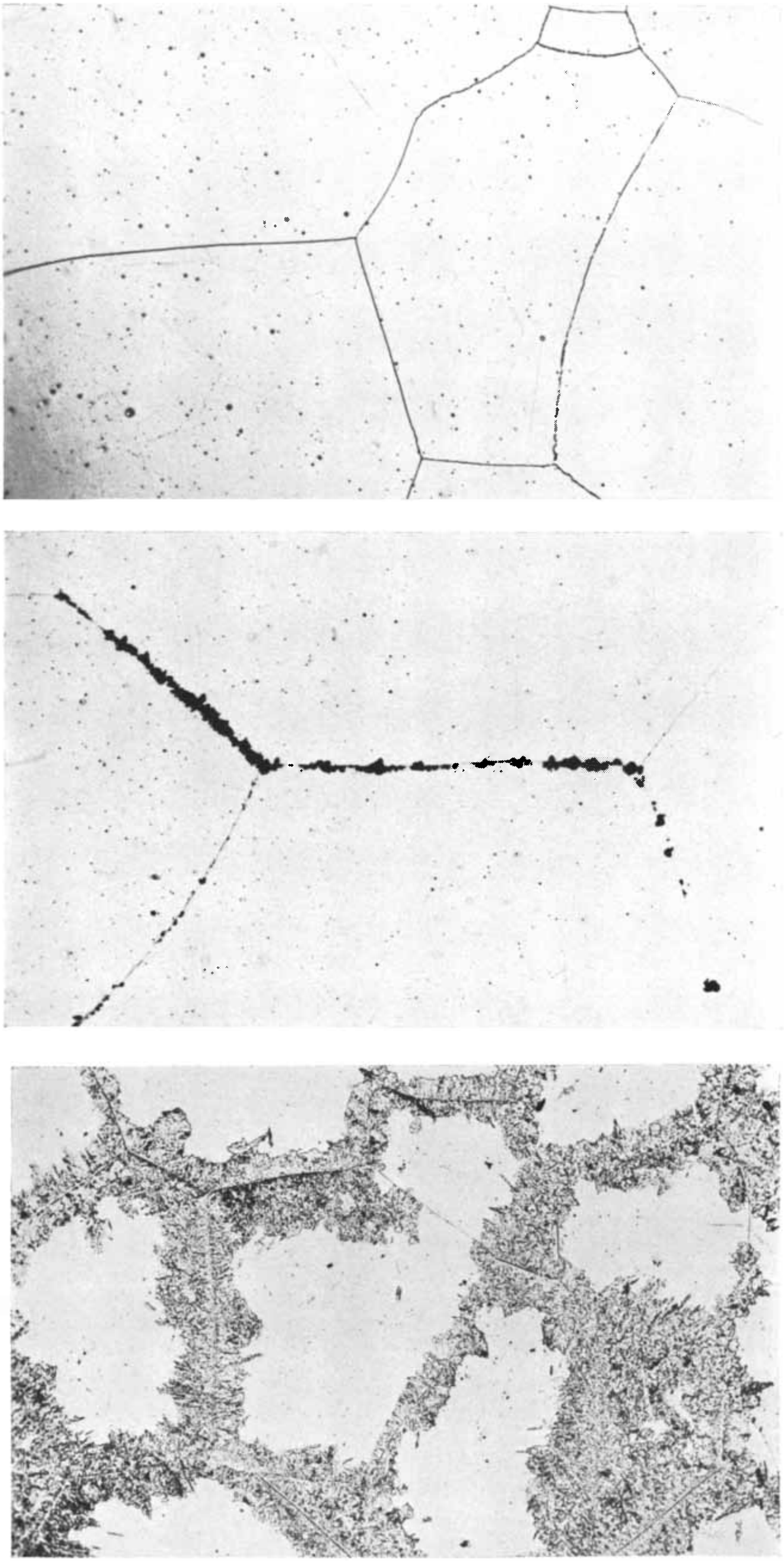
RADIATION DAMAGE to reactor control rod is illustrated in these photomicrographs (*magnification 100 diameters*). Unirradiated rod (*left*) consists of boron granules in iron, encased in a sheath of stainless steel (*top*). Neutrons from reactor transmute boron to lithium and helium (*right*). Expanding helium bubbles (*dark areas*) cause rod to swell and separate steel jacket from it.

of construction, reactor scientists and engineers have had to contend with these effects in materials that must also stand up under extreme conditions of temperature, corrosion and, at times, pressure. From the beginning, therefore, they have been exposing inorganic crystalline solids to the flux of the reactor and studying the consequences in terms of strength, electrical conductivity and other significant properties. These investigations have now laid the basis for an entirely new experimental approach to fundamental questions about the solid state.

Until the advent of the nuclear reactor the metallurgist depended upon the same three methods for altering the properties of his materials that were known to the smiths of the Bronze Age. These are the introduction of impurities, or alloying; plastic deformation, by hot-forging or cold-working; and heat-treating, by slow cooling or fast quenching. Irradiation now gives the art and science of metallurgy a fourth technique, one that can accomplish some of the same effects as each of the others but one that affords unexampled control over the variables in the experiment. In the traditional techniques the entire mass of the material under study is necessarily involved. With high-energy radiation, events involving a single atom or a few atoms at a time may be observed and known degrees of alteration may be effected in the material.

Metals derive their characteristics both from the perfection and the imperfection of their internal structures. Just below the macroscopic level that we see and touch is the so-called microstructure, that is, the small crystals or grains which become visible at magnifications of 100 or 200 diameters. This structure resembles a flagstone pavement. The irregularly shaped crystals fit fairly closely; such impurity grains as may be present appear as pebbles between the flagstones. At the atomic level the internal structure of each crystal is more regular. Here, in the precise geometrical array of the lattice, are ranks and files of atoms in perpetual thermal vibration, and, whirling tightly about each, a complement of electrons. Pervading the entire space of the metallic crystal lattice is a "gas" of free electrons which binds the atomic nuclei together and which also gives the metal its characteristic conductivity. Here and there an atom of an alloying metal or impurity may occupy a lattice site and warp neighboring atoms in the lattice out of position. Elsewhere a lattice site may be vacant, and the surrounding atoms move slightly into the vacancy, partially filling it. An occasional atom may be forced into an interstitial position between the ranks and files of atoms, placing the basic periodic structure under strain and forcing adjacent atoms slightly out of place.

The stage is now set for the action of a high-energy particle. When a fast neutron, traveling with a million electron volts of energy, hurtles into a



PHASE PRECIPITATION of beryllium from a nickel-beryllium alloy is illustrated in these photomicrographs. Crystal grains magnified 250 diameters (*top*) are supersaturated with beryllium. Heating causes excess beryllium to precipitate along grain boundaries. Successive stages of the process are seen magnified 250 diameters (*middle*) and 100 diameters (*bottom*). The same effect can be produced in a copper-beryllium alloy by radiation.

crystal lattice and collides with an atom, it bounces off like a billiard ball. The atom recoils violently (in a typical metal such as copper its energy may be as much as 60,000 electron volts) and leaves behind a vacancy. As it rushes through the lattice, its high velocity reduces the probability of interaction with other atoms, in effect making them smaller [*see illustration on page 200*]. The migrant atom expends a great deal of energy tearing away the outermost electrons from the atoms it fleetingly encounters. This is ionization, but the few electrons thus freed make an insignificant addition to the gas of electrons that pervades the metal. The still-recoiling atom expends more of its energy exciting other electrons, making them jump momentarily from inner to outer orbits around the lattice atoms. These encounters slow its headlong flight sufficiently to give interatomic forces more time to act. The atom now begins a series of collisions with other atoms that sends them recoiling into collisions with still others. With the remainder of its energy the migrant atom sets the last atoms along its path into heightened thermal vibration and thus, in a burst of heat, it forces itself into an interstitial position in the lattice. Meanwhile the neutron has set other atoms in the lattice off on similar careers, directly and indirectly knocking hundreds of atoms out of their positions before it expends its energy.

From this account of the action of a single particle, it is clear that radiation must heighten those properties of a solid which derive from its imperfections, that is, from the presence of vacancies and interstitials in the lattice. Such lattice-defects explain many of the important and interesting properties of metals that are inexplicable in terms of an ideal lattice. The introduction of defects into metals by means of irradiation is now confronting theory with a rich new realm of observation.

One phenomenon in metals which depends upon vacancies and which is affected by irradiation is diffusion, the process by which atoms of various kinds mix. When copper and zinc, for example, are placed in good contact and heated, the atoms of the two metals intermingle in the zone of contact, with the result that the two metals may even be welded together. The concept of a perfect, rigid lattice had indicated that the energy required for one atom to force its way past another was too high to account for the rapidity with which welding takes place. The notion of the vacant lattice-site, however, furnishes an excellent mecha-

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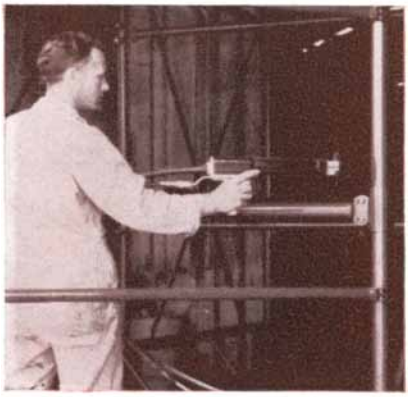

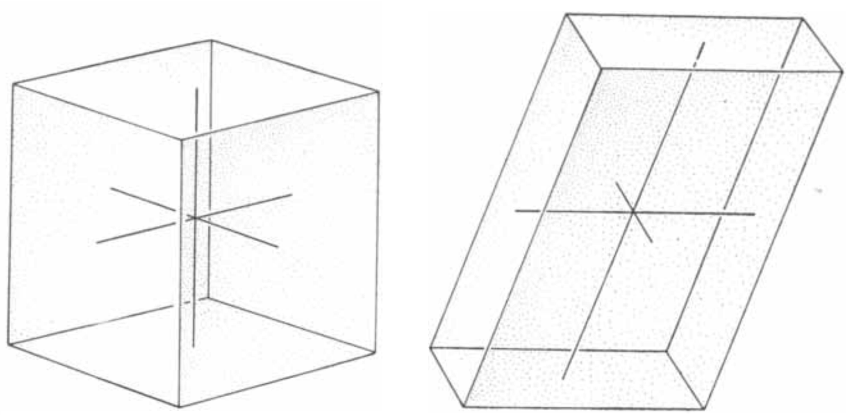

CRYSTAL LATTICE consists of repetitions of a basic atomic arrangement, or unit cell. Two of the possible structures are shown here: cubic (*left*) and monoclinic (*right*).

nism for diffusion. Instead of forcing its way past the next atom, an atom has merely to move into a vacancy left by that atom; in doing so, it creates a vacancy for the atom in line behind it, and so on. Since heat increases the vibrations of atoms at their lattice sites and thereby encourages them to create vacancies, it is easy to see why heat promotes the welding of copper and zinc. In fact, zinc diffuses into copper about 100 million million times faster at 300 degrees centigrade than it does at room temperature. Irradiation similarly enhances diffusion. During nuclear bombardment at low temperatures, the intermingling of the atoms of zinc and copper proceeds at a rate characteristic of much higher temperatures. In other words, under bombardment the solid acts hotter than it really is.

Another property that may be modified by the creation of vacancies is the geometry of the crystal structure itself. If copper is alloyed, for example, with beryllium in the ratio of seven copper atoms to each atom of beryllium, the solid solution of the two elements at room temperature contains two distinct cubic lattice-structures, or phases. One, the so-called alpha phase, is a face-centered cubic crystal (a cube with atoms at the center of each face and at each corner): the other, the beta-prime phase, is a body-centered cubic crystal (one with an atom in the center of the cube and others at each corner). When the temperature of this alloy is raised to 850 degrees centigrade, all the beryllium atoms go into solution with the copper, joining with them in the alpha phase. If the alloy is now rapidly cooled, as by quenching, the solution becomes supersaturated and the alloy is "frozen" in the alpha phase. The atoms will not move from their positions because their thermal vibrations at room temperature do not give them enough mobility to rearrange themselves into the beta-prime phase in less than 1,000 years. But if the material is now exposed to neutron bombardment in a reactor, the introduction of vacancies causes the excess beryllium to leave the alpha phase and precipitate in the beta-prime phase, as though 1,000 years had passed or heat had been applied.

At the Oak Ridge National Laboratory and other centers a similar process has been demonstrated in an alloy containing three atoms of copper to one of gold. The alloy is exposed to irradiation in the "disordered" condition, that is, with the atoms of copper and gold occupying random positions in the face-centered cubic lattice. Under irradiation the copper atoms take positions on the faces of the cubes, while the gold atoms assume corner positions. The same transformation can be achieved by heating. But the alloy assumes this "ordered" configuration at much lower temperatures under neutron bombardment. Investigations at the Brookhaven National Laboratory have shown that the crystallographic rearrangement that converts white tin into gray tin can also be accelerated by irradiation. There now seems to be no doubt that irradiation introduces vacancies in crystal structures. Thus a process that is either too slow to observe at room temperature or too fast to observe at higher temperatures may now be brought under experimental control and observation.

The interstitial atoms, as well as the vacancies they leave behind, play a decisive role in the behavior of metals, notably in their plasticity. Crystals owe this quality in part to the presence of extra and incomplete planes of atoms in their lattices. Under shearing stress, which itself may multiply their number,


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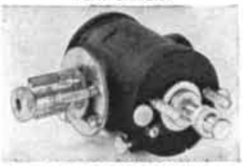
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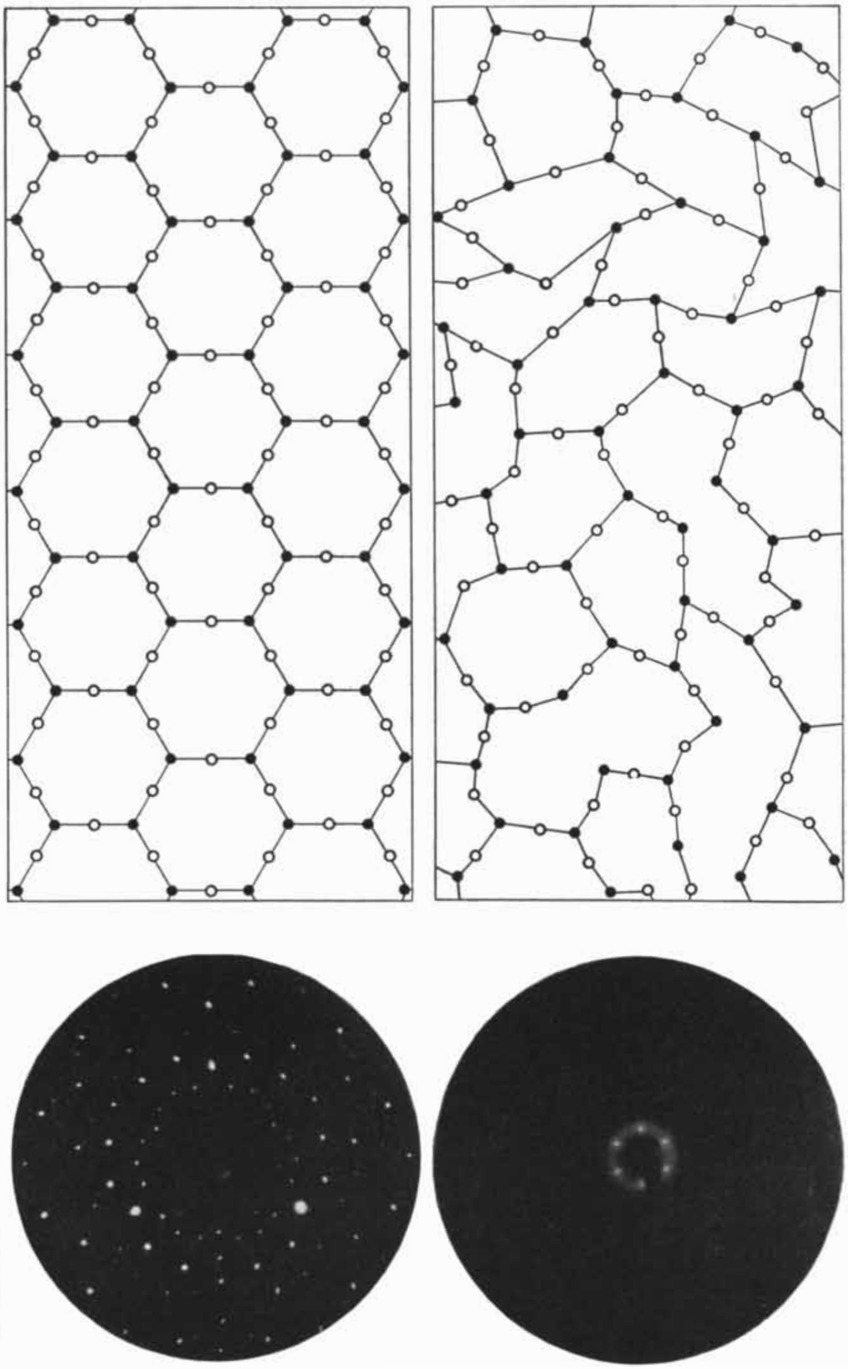
these "dislocations" travel through the lattice by successively displacing adjacent planes, thus permitting the stress to be exerted against one lattice plane at a time. In the absence of dislocations, the stress would have to move all the lattice planes simultaneously. Now lattice defects may cancel the effects of dislocations. An interstitial or vacancy in the plane along which the dislocation moves will impede the movement of the dislocation and thus will tend to strengthen the crystal. Neutron bombardment introduces interstitials and vacancies, and by doing so can increase the strength of metal crystals—in the case



QUARTZ CRYSTAL-LATTICE is destroyed by radiation. Orderly arrangement of silicon atoms (*solid dots*) and oxygen atoms (*open dots*) in a normal crystal (*top left*) produces the X-ray diffraction pattern of bright spots in the photograph (*bottom left*). Irradiating the crystal breaks some interatomic bonds and displaces atoms (*top right*). Because disordered structure can no longer diffract X-rays coherently the pattern disappears (*bottom right*).

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Melt Index	D-1238-52T	—	0.2	0.7	2.5	5.0
Heat Distortion Temp. (66 psi)	D-648-45T	°F.	185	185	180	180
Brittleness Temp.	D-764-52T	°F.	—200	—180	—160	—100
Impact Strength, izod (1/8" x 1/2" injection-molded bars)	D-256-54T	ft. lb./in. notch	23	18	13	3
Tensile Strength, Max., 0.2 in./min.	D-638-52T	psi.	3700	3600	3500	3300
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Refractive Index	D-542-50	n_D^{25}	1.54
Hardness, Shore D	D-676-49T		65
Stiffness	D-747-50	psi.	150,000
Water Absorption (1/8" specimen, 24 hr. immersion @ room temp.)	D-570-54T	%, wgt. gain	<0.01
Flammability	D-635-44	in./min.	1.0
*Mold Shrinkage, length		in./in.	0.03 to 0.05
width		in./in.	0.02 to 0.04

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But at the same time that irradiation increases the strength of metals, it decreases their electrical conductivity. Any departure from perfect order in the crystal lattice—such as impurity atoms, interstitials or vacancies—increases the scattering of electrons and thus interferes with their ordered flow in an electric current. The effect of irradiation is demonstrated by the results of experiments performed at low temperature in a reactor at Oak Ridge. Ordinarily reduction of the temperature of copper, or other conductors, increases their conductivity; with the thermal vibrations of the lattice atoms reduced, the scattering of electrons is correspondingly reduced and current flows more freely. Neutron irradiation reverses this low-temperature effect. The conductivity of copper at four degrees absolute (degrees centigrade above absolute zero) has been reduced by 90 per cent under neutron bombardment in the reactor.

Subsequent warming of the metal restores most of its conductivity. Because the interstitials are in the most unstable configuration, their increased thermal vibration gives them enough mobility to return to the normal, and more stable, positions in lattice sites, annihilating the corresponding vacancies. In effect the interstitials introduced by irradiation at low temperature are frozen in. Careful reheating "thaws" them slowly, making it possible to observe the return of conductivity.

Atoms of an impurity or alloying metal have an effect on conductivity similar to that of interstitials or vacancies. All alloys of copper, for example, exhibit a conductivity lower than that of copper itself. The different electronic structure of the impurity atom distorts the regularity of the lattice, causing electron scatter.

Impurities have the opposite effect in semiconductors, which have a paucity of free electrons to begin with. A properly selected impurity (a "donor") will contribute extra electrons to the number of the electrons in the material and thus enhance conductivity. Certain semiconductors, by the same token, show a large change in conductivity when they are irradiated; interstitial atoms may ionize, thereby increasing the number of electrons free to move in an applied electric field. In those semiconductors which carry current by the organized motion of "holes," irradiation generates free electrons by ionization which disorganizes the motion of the holes and decreases conductivity in much the same way as crystal defects scatter the current-carrying electrons in a conductor. Thus though the ionizing effect of radiation is of small consequence in metals, it does significantly affect the properties of semiconductors.

The ionizing effect of radiation is important also in ionic and covalent crystals. When sodium chloride, an ionic solid, is exposed to X-rays, the crystal rapidly darkens and may even become opaque. The effect can be explained in part by other factors, but one must conclude that ionization also plays a role. Ionization causes a pronounced change in the structure of covalent crystals such as quartz and diamond. These crystals are bound together by valence electrons that form a precise pattern of bonds, producing highly symmetrical lattice structures. Neutron bombardment knocks whole atoms from their lattice positions, and these atoms, by ionizing the covalent bonds, disrupt the orientation of other atoms in the lattice. Macroscopically the crystals remain unchanged, but X-ray diffraction photographs show that the ordered structure of the crystalline solid has given way to an amorphous structure; quartz comes to resemble silica glass and diamond is converted to a graphite-like solid.

Certain transformations that occur in the crystal structure of uranium-containing solids demonstrate another way in which irradiation may alter the properties of solids. In this case the process turns on the behavior of a single fragment ejected in the fissioning of an atom of uranium. Such a fragment is many times heavier than a neutron and it carries an electrical charge. As a result it expends most of its enormous energy ionizing and exciting the lattice atoms along its path and gives up another portion in billiard-ball collisions. The rest of its energy it transfers to a large number of atoms in near-collisions and glancing blows that do not displace them from their positions but set them in violent thermal vibration. Together these atoms act as if they had suddenly been heated to an extremely high temperature, well above 1,000 degrees C. This "thermal spike" lasts no more than one ten-billionth of a second and may involve as few as 1,000 atoms. Though its duration is short, the thermal spike lasts long enough, by the time-scale of the vibrational frequencies of atoms, to permit many processes to occur. In zirconium oxide that contains uranium as a minor impurity, tiny crystals characteristic of a high-temperature phase appear; the quick cooling of the spike apparently

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prevents reversion to the low-temperature phase. What is more interesting, X-ray diffraction studies show that the crystallites of the converted phase may contain several million atoms, many more than could have been directly involved in interaction with the fission fragment. Apparently the tiny crystal that first condenses from the spike in the high-temperature phase acts as a center of nucleation which grows as adjacent atoms are incorporated into its lattice structure.

It is highly unlikely that any of the experiments thus far conducted with the effects of radiation on solids can ever be engineered into industrial processes. One can perfectly well make some metals harder and stronger by neutron irradiation. However, this is an expensive way of doing what metallurgists learned to do cheaply long ago. Even if one could afford it there would remain the hazard of radioactivity due to the transmutation of the metal or one of its impurities to a long-lived radioactive species. Residual radioactivity could be avoided by the use of electrons or gamma rays, but then one would have to settle for mere surface-hardening. This effect can be accomplished more cheaply and surely by such chemical processes as carburizing or nitriding.

It appears, then, that the principal use of radiation in industries that process inorganic solids will be X-ray photography. The future may, of course, bring uses we cannot foresee.

Meanwhile radiation promises to become an ever more productive research tool in the hands of the solid-state physicist. Great interest centers at present upon the use of radiation in combination with low temperatures. The introduction of excess vacancies and interstitials at room temperature and below makes it possible to speed up solid-state reactions that are otherwise too slow to observe. The introduction of defects at temperatures near absolute zero followed by slow-heating permits correlation of their behavior with change in any selected characteristic, under ideally controlled conditions.

Already irradiation studies have shown that some commonly accepted ideas about the nature of solids are incomplete and in some cases erroneous. They have accordingly inspired new lines of study in unirradiated solids. Since the demands of technology now exceed our basic understanding in this field, it is plain that every addition to knowledge achieved by radiation techniques will find speedy application in industry.

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Crystal structure	Face-centered tetragonal
Density at 20°C (68°F)	
g/cc	7.31
lbs/cu. in.	0.264
troy ozs./cu. in.	3.85
Electrical resistivity (microhm-cm)	
(solid) 20°C (68°F)	9
(at melting point) 156°C (313°F)	29
Electrochemical equivalent	
In +++ (mg/coulomb)	0.39641
Electrode reduction potential	
In +++ (H_2 = 0.0 volt)	0.34
Latent heat of fusion (cal/g)	6.8
Latent heat of vaporization (cal/g)	468
Linear coefficient of thermal expansion/1°C	33×10^{-6}
Mechanical properties:	
Tensile strength, psi	380
Elongation (% in 1")	22
Brinell hardness	0.9
Modulus of elasticity, psi	1,570,000
Melting point	156.17 ± .05°C (313.1 ± .1°F)
Nuclear Data	
Stable Isotopes (113,115)	2
Thermal neutron cross section (2200 m/s)	
Absorption (barns)	190 ± 10
Scattering (barns)	2.2 ± 0.5
Solidification shrinkage	2.5%
Specific heat (cal/g/°C)	
(solid) 20°C	0.057
Specific volume (cc/g)	
20°C (68°F)	0.136
Thermal conductivity (cal/sq. cm/cm/°C/sec)	
20°C	0.057
Valence	Usually 3, but also 2 and 1
Vapor press. (mm Hg)	
1249°C (2280°F)	1
1466°C (2671°F)	10
1756°C (3193°F)	100
1863°C (3385°F)	200
1982°C (3600°F)	400

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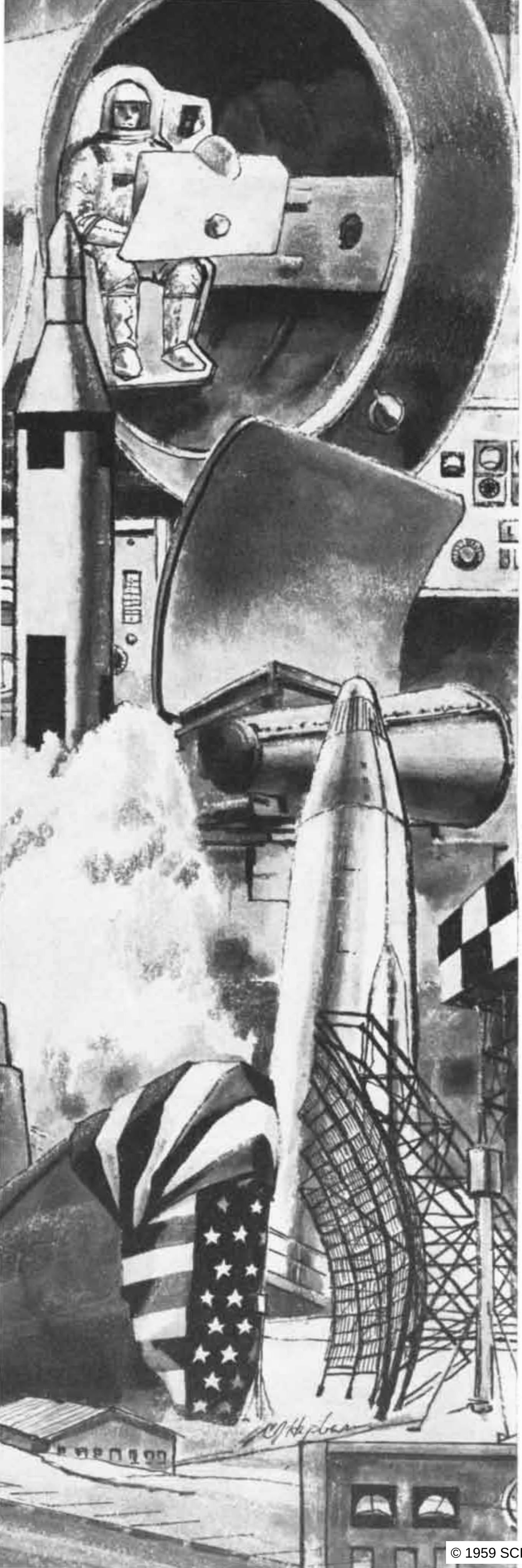

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- **Pinpointed authority, responsibility**
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Ionizing Radiation and the Citizen

How can mankind secure the demonstrated benefits of radiation and minimize the hazards that attend it? The question assumes that the species will not exterminate itself in a nuclear war

by George W. Beadle

In a few short years the science and technology of nuclear physics have come to affect the lives of all men. As the authors of the preceding articles in this issue have made abundantly clear, the nuclear age is attended by unprecedented new risks and hazards.

By far the greatest hazard, as everyone knows, is the threat of nuclear war. Nuclear weapons could bring civilization to a catastrophic end. Yet no one seems able to find a workable formula for avoiding this danger that is at once foolproof and acceptable to all nations. To many men the complete abolition of nuclear weapons is the only sure solution. This must remain an unrealistic hope until ways are found for extending the ban to armed conflict itself. What is to prevent nations that have not renounced war from rebuilding their armories of nuclear weapons?

In their failure to settle their differences by peaceable agreement the major nations are engaged in a mad nuclear arms race. Each hopes to deter potential enemies by the threat of instantaneous and annihilating retaliation. All know the danger of the game. None appears to see how to stop in a manner that will guarantee security for all.

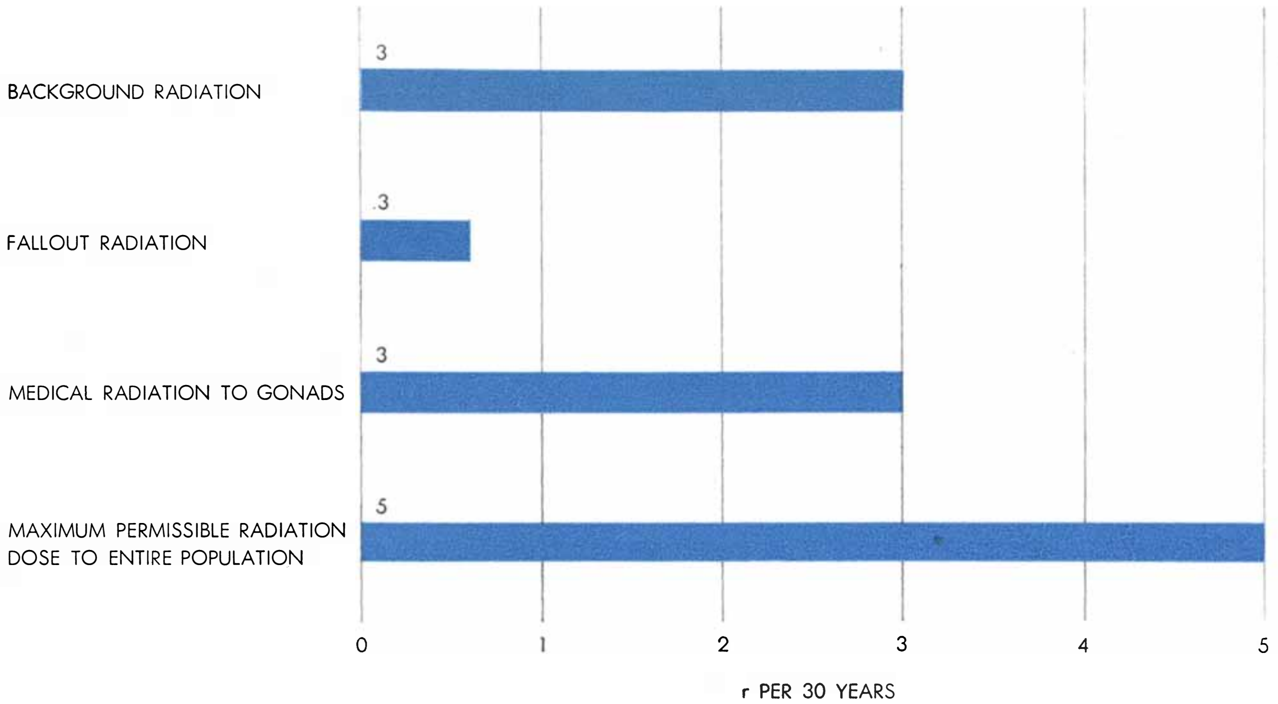
Meanwhile the hazard of nuclear armament becomes progressively more grave. Existing weapons are more widely dispersed, and the responsibility for using them is delegated to lower ranks of command. The risk of accident or poor judgment increases correspondingly. In the recent report issued by the American Academy of Arts and Sciences (*The Nth Country Problem: A World-Wide Survey of Nuclear Weapons Capabilities*) it is made clear that at least a dozen nations, in addition to the Big Three, have economic resources and manpower sufficient to arm themselves with these weapons. Will they not be tempted to enter the race in increasing numbers for national prestige if not for defense? Can they be dissuaded by any real hope of a just and effective solution? Failing this,

UNITED NATIONS SCIENTIFIC COMMITTEE on the Effects of Atomic Radiation meets periodically. A U. S. representative at this March, 1959, session was Shields Warren (*at left, chin in hand*), author of "Ionizing Radiation and Medicine" in this issue.

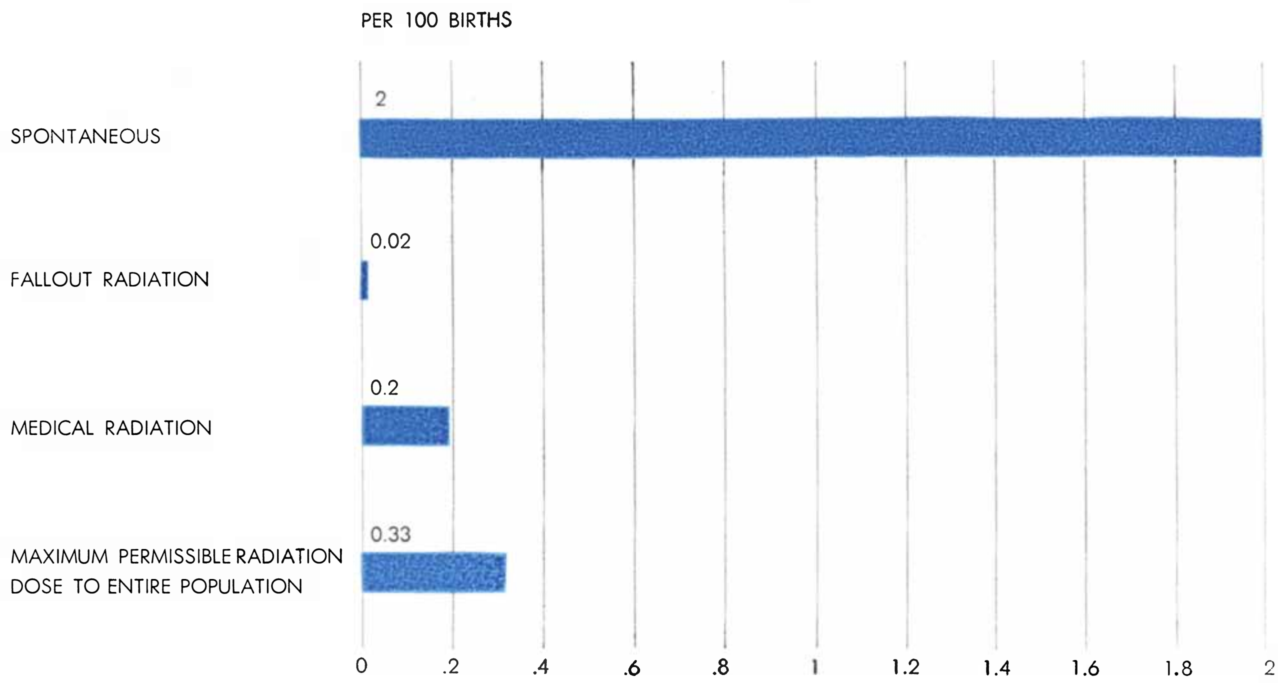
can they be convinced that they will be better off if they do not join the competition? It is true that capability of small-scale retaliation is a highly vulnerable intermediary position along the road to full retaliatory power. But will this argument carry conviction, coming from nations that have already arrived at the latter stage, or think they have?

The only practicable solution may lie in a pedestrian step-by-step approach. Certainly the present attempts to effect a permanent ban on the testing of nuclear weapons deserve full support, if only because this is the sole first step that appears to have a reasonable chance of acceptance.

Termination of the tests, which have increased exponentially in number for 14 years, will eliminate one nuclear hazard. The hazard of fallout is quantitatively



ESTIMATED RADIATION DOSE for average U. S. resident during reproductive years is represented by top three bars. Fallout estimate applies only if nuclear weapons tests cease. Permissible dose at bottom is in addition to medical and background doses.



INDIVIDUALS BORN WITH NEW MUTATIONS, per 100 births, and causes of mutations are charted at left. At far right are totals of new mutations. Background radiation is responsible for some of the spontaneous mutations. All the figures on this chart are very

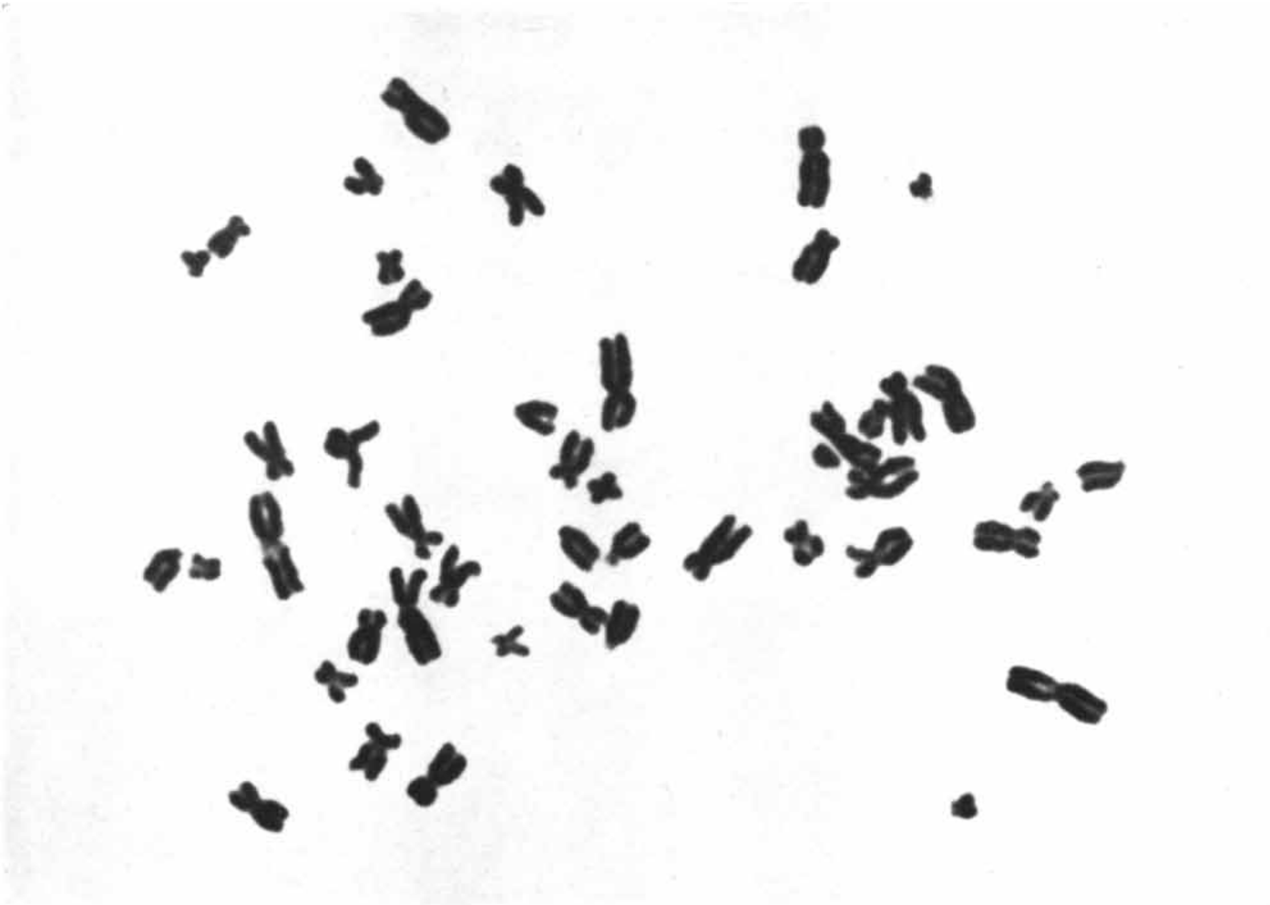
small but qualitatively large, because of its embarrassing moral aspects. In addition, the mere fact of agreement will encourage negotiation on other issues.

But even if we succeed in taking this step and all the ones that must follow to achieve permanent peace, we will by no means be done with the hazards of radiation. We will have greatly reduced the risk of exposing large segments of the world population to high-level radiation. But there will remain the delayed effects of fallout and the increasingly important hazards of the peacetime uses of radiation. Power-reactor accidents may occur, as they already have; the radioactive by-products and spent fuels of reactors will need to be contained and safely disposed of; radiation and radioisotopes will be finding wider use in technology as well as in scientific and industrial research. The medical profession must continue its evaluation of the risks attending diagnostic and therapeutic irradiation of patients and its efforts to reduce these risks to the essential minimum.

What are the hazards to health of ionizing radiation and how great are they in given situations? After the millions of words that have been written and spoken there remain much uncertainty and confusion in public understanding. Why is

IN U. S. PER YEAR PER 4,000,000 TOTAL BIRTHS	IN WORLD PER YEAR PER 80,000,000 TOTAL BIRTHS	IN WORLD PER GENERATION PER 2,400,000,000 TOTAL BIRTHS
80,000	1,600,000	48,000,000
800	16,000	480,000
8,000	160,000	4,800,000
13,000	270,000	8,000,000

rough estimates, and are subject to at least a five-fold uncertainty in either direction.



HUMAN CHROMOSOMES are enlarged some 2,000 diameters in this photomicrograph made by J. H. Tjio and T. T. Puck at University of Colorado Medical Center. The chromosomes are from a female body cell grown in tissue culture. There are 46 of them.

it not possible to give simple answers to straightforward questions?

We are told at various times and by investigators of repute that fallout does no biological harm; that there is some damage but that it is negligible with respect to our defense needs; that present fallout levels, by producing several hundred thousand genetic mutations per generation on a world-wide basis, do enormous biological harm. Whom shall we believe?

We read in a reputable scientific journal that present and foreseeable levels of strontium 90 in human bone are unlikely to produce a single case of leukemia. But in another issue of the same journal we find it argued that the concentration of strontium 90 may already be approaching harmful levels in the bones of some individuals and may well be responsible for hundreds of new cases of leukemia in the next generation. Is there a "right" answer?

Should school children be given annual X-ray examinations? The truck continues to make its rounds and many schools still request its services. Do the advantages outweigh the risks?

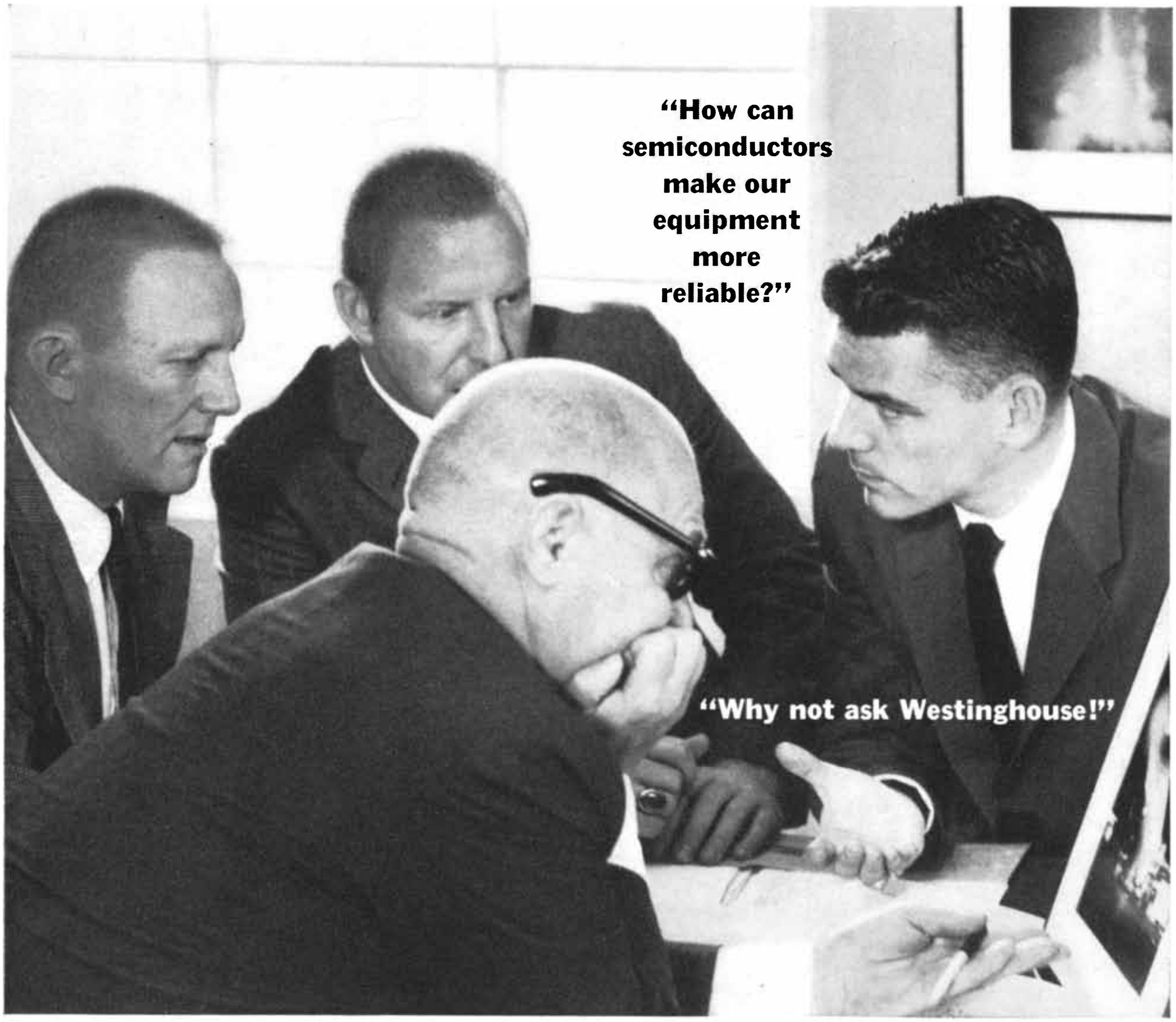
In occupational exposure to ionizing radiation, is there a zone of greater danger as exposure approaches "permissible" levels? "Permissible" implies no risk, but the maximum permissible occupational exposure is several hundred times larger than fallout exposure per given period. Is this not inconsistent with the statement that even low exposure—as from fallout—produces mutations?

To arrive at sensible assessments of radiation hazards it is necessary to understand the reason for the conflict in opinion and information. Such assessments are imperative; the health and survival of hundreds of thousands of individuals are at stake. As for succeeding generations, if we now seriously underestimate genetic hazards, the harm that is done will persist, in some degree, for centuries to come. Nor can we postpone decisions until we have final and complete answers.

It is not in the nature of science to give final and complete answers. The probability is that there will always be diverse, tentative or contradictory answers to fundamental scientific questions. The best that can be hoped is that responsible citizens will make a greater effort to understand the knowledge at our disposal at any given time and to comprehend the social implications of this knowledge.

The preceding articles in this issue have presented a review of the state of knowledge of ionizing radiations. To place this knowledge in the perspective of public policy it will be useful to summarize here the biological aspects of the situation.

Whole-body exposure of man to penetrating ionizing radiation in large doses of 400 to 600 or more r units [*see glossary of terms on page 78*] delivered over a short period of hours or days causes cell and tissue damage so extensive that successful repair may be impossible. Death results within days or weeks, the interval depending on the exposure. On the other hand, the same amount of



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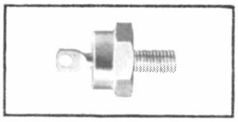

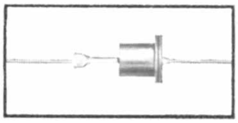

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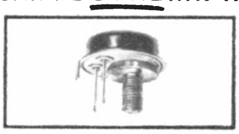


radiation received over a much longer time, say months or years, permits such recovery processes as the replacement of cells by the division of still-viable cells and the successful resorption and elimination of breakdown products. Consequently the individual may survive and show little direct evidence of injury.

The chance of death after exposure to lethal radiation doses may be greatly reduced by certain therapeutic measures now under development. Of these the replacement of blood-cell-forming tissues by means of bone-marrow transplantation is one of the most promising. Nonlethal doses of something like 100 r units given at one time produce immediate damage, but it is to a considerable extent reparable. Such symptoms as change in the number and proportion of blood cells of various types, subcutaneous bleeding and loss of hair provide means of estimating exposure where this is not otherwise known.

In experimental animals, the mouse for example, sublethal doses of radiation appreciably reduce the life span. It is almost certain that this also occurs in man. Most investigators agree that there is no threshold below which ionizing radiation has no effect on living matter. On the other hand, some believe that there may be a minimum effective dose or dose rate for particular effects such as life-shortening, as John F. Loutit points out elsewhere in this issue. Unfortunately the quantitative relation between the degree of exposure and the reduction in longevity is difficult to determine even in experimental animals. If the relation is linear—that is, directly and simply proportional to exposure—down to low levels of radiation, and if the reduction of longevity in man is proportionately the same as in the mouse, the life-span reduction per r of total-body exposure could be something like one to 10 days.

In mice and in men heavy radiation-exposure increases the incidence of various forms of cancer. Radiologists and heavily irradiated survivors at Hiroshima and Nagasaki, for example, show an incidence of leukemia 10 or more times higher than that of roughly comparable but unexposed individuals. Here again the exact relation between dose and incidence is not known; measurements are subject to large sampling errors. Even in mice the data are ambiguous. It may well be that the relation differs for different types of malignant disease. The most pessimistic assumption holds that the relation of disease to exposure is linear down to the lowest possible doses, and that the effect of intermittent and slowly delivered radiation is strictly cumulative. If this is the case, the probability that a person will develop leukemia appears to be approximately one in one million for each r of exposure per year. There is some evidence that prenatal exposure results in an even higher incidence of leukemia per r during the childhood years.

In several respects the genetic hazard is the most difficult and serious aspect of the problem of radiation. Genetic mutations are almost always harmful. Transmitted to descendants, they may express themselves over many successive generations.

It is now almost certain that in all cellular organisms (and in some viruses) molecules of deoxyribonucleic acid (DNA) bear the primary hereditary directions for the numerous processes that interact in development and function. Thus in man the DNA molecules in the chromosomes of the fertilized egg-cell are believed to carry the specifications by which the egg cell grows into an individual.

These specifications are "written" in a kind of molecular code; its basic symbols are the four kinds of units called nucleotides. Genetic directions are somehow spelled out by the sequence of these units, of which there are about 200 million in the 46 chromosomes of a human body-cell. Each grouping of 1,000 or so units of DNA is called a gene; each gene "tells" the body how to conduct some vital function; for example, how to assemble the proper amino acids (from the 20-odd kinds available) in the proper sequence to make an essential protein constituent of hemoglobin.

The individual's total DNA code is multiplied many times in the course of his life cycle and is ultimately passed on to the next generation. The details of this replication process are beginning to be understood; in fact, the process will proceed under relatively simple conditions in a test tube. Its precision is high. The probability of a genetically significant and easily detectable mistake during the 20 to 40 successive replications per generation is estimated at about one in a million for each gene. If there are 10,000 kinds of genes (an estimate subject to a large error), the chance that there will be a mistake of any kind in a given egg or sperm is only about one in 100.

Such mistakes are, like typographical errors, changes in the sequences of symbols in the code. The replication of DNA molecules is purely mechanical; therefore a sequence of incorrect symbols will be replicated as faithfully as if it were a correct sequence. Errors of this sort—

mutations—are not repaired except by the rare reversal of the process by which they occurred. There is no proofreader in the system. And such errors are likely to lead to significant errors of development or function; for example, defective hemoglobin. Since there are many ways to make hemoglobin incorrectly and only one way, or possibly a few ways, to make it correctly, mutations are much more likely to be deleterious than neutral or favorable.

If the mutant genes are replicated faithfully, with no correcting mechanism in the system, they should accumulate progressively generation after generation. Why then do species not mutate themselves out of existence? The answer is that natural selection rejects those individuals in whom deleterious mutations occur. Selection is a kind of inspector that discards the bad sets of specifications. This rejection of unfavorable mutations has been called "genetic death" by H. J. Muller. In man it may occur in many ways: death in the embryonic stage, death near or after birth, death prior to reproduction, failure to produce an average number of offspring, or failure to reproduce at all. L. S. Penrose of the University College London has estimated that in Europe and the U. S. the members of a given generation are the offspring of only 50 per cent of the members of the preceding generation. Thus "genetic death" may not mean literal premature death of individuals; it may, and frequently does, mean elimination of a particular line of descent on the instalment plan over many generations, without anyone being quite aware that it is happening.

The genes of all species, including man, are subject to varying rates of "spontaneous" mutation of which we do not know the cause. There are many ways, however, to increase the frequency of mutation, among them high temperatures, a variety of chemical treatments, and high-energy radiation. Ionizing radiation sufficiently penetrating to reach sperm and egg cells or their precursors is a particularly effective way of increasing mutation.

We may now summarize with some assurance the genetic hazard of radiation as follows: Radiation-induced mutations, like other mutations, however induced, are mostly deleterious. Under a given set of conditions, mutations appear to be induced in linear proportion to exposure; thus there is probably no threshold below which radiation will produce no mutations. Since there is no repair mechanism, once the mutation process is complete, mutations induced at different times will tend to accumulate in a line of descent until this tendency is just counterbalanced by natural selection. Ultimately, therefore, each new deleterious mutation must be compensated for by genetic death in the Muller sense.

From data on mice, fruit flies and other organisms it is estimated that the level of exposure of sperm and egg cells or their precursors to ionizing radiation sufficient to double the spontaneous-mutation rate probably lies between 10 and 100 r. Taking 30 r, the geometric mean, as a reasonable guess for the doubling dose in man, it is possible to estimate in a very rough way the number of mutations for various levels of exposure to radiation.

If there is one spontaneous mutation in each 100 egg or sperm cells per generation, as suggested above, there will be two such mutations in every 100 individuals. Exposure to 30 r would double this. The exposure from fallout to date is liberally estimated at a cumulative .3 r in the 30 years of the average human reproductive lifetime. According to this estimate, fallout would increase the spontaneous-mutation rate by 1 per cent. The mutation rate calculated in a similar way for medical radiation runs considerably higher: at 10 per cent of the spontaneous rate, as shown in the bottom chart on pages 220 and 221. The maximum permissible occupational exposure allows for an increase of more than 50 per cent over the spontaneous rate. It should be emphasized that these are exceedingly rough estimates and may be too high or too low by a factor of five or more.

Although most geneticists will agree that the foregoing statements about radiation-induced mutations are reasonably well established, and that the estimates of the number of new mutations resulting from given amounts of radiation are at least plausible guesses, there remain many unanswered questions. For example, are malignant diseases the result of mutations in ordinary body cells, as contrasted with those that occur in germ cells? Although there is sufficient circumstantial evidence to convince many geneticists that some malignant diseases are the result of mutations in body cells, the answer is in most cases not positively known. Until recently no effective techniques were available for the genetic investigation of body cells. In whatever way malignant diseases arise, however, there is no doubt that high levels of radiation induce them effectively. As for low levels of exposure, the question of exact relation of exposure to incidence must remain open until better data are available.

A difficult question is: What is the magnitude of the burden added to society by a given increase in mutation rate? Suppose, for example, that fallout were to add 5,000 to 120,000 additional mutations and perhaps five to 40 additional deaths from leukemia in each generation in the U. S. What would this mean in terms of social burden?

The answer is not known. Perhaps it cannot be, for social burden consists of diverse components that cannot be summed. The cost of caring for a mentally defective person in an institution may be calculable in dollars, but how does one assess the unhappiness and mental anguish of the victim and the victim's family? Furthermore, even though we have some notion of the manner in which genetic deaths occur, and even if we could evaluate them in terms of social burden, we still could not arrive at a proper accounting, because we do not know in what relative proportions the various kinds of genetic deaths occur. It is also important to remember that the more considerate of its unfit individuals a society becomes, the greater will be the burden of a given mutation rate. On the other hand, there is a correction of unknown magnitude for coincidental elimination of two or more unexpressed mutations in single individuals who merely fail to reproduce. What we do know with some confidence is that the social burden of mutation will be increased by radiation in approximate proportion to the increase in mutation.

In view of these uncertainties about the harmful effects of exposure to low levels of radiation, is it possible to arrive at safe "permissible" upper limits of exposure for such groups as industrial workers, X-ray technicians and the public at large? If there is no threshold, the answer is clearly that it is impossible to establish any "safe" exposure other than zero, in the sense of having eliminated all risk. The best alternative is to establish permissible levels for which risks are below specified levels. This is exactly what the various commissions and committees responsible for setting permissible exposures attempt to do. The task is not an easy one, for adequate data are difficult to obtain even with animals.

A recent study by Carol W. Buck of the University of Western Ontario will serve to illustrate some of the difficulties. Let us suppose that the relation of leukemia to radiation is linear at all levels, and that for each r of total-body exposure the annual increase in deaths

from this disease is one for every million individuals. This is a value that appears reasonable for high levels of exposure. If a population were exposed prior to age 30 to an average of five r above the natural and medical background, how many individuals would have to be observed to establish a statistically significant increase in leukemia?

The answer is six million people, and they would have to be observed for a period of at least a year. In this number there would be, on the average, 30 new cases of leukemia each year attributable to the five r. This additional number, over and above the 200 cases expected without those added by radiation, would be just statistically significant. To be certain that the added radiation was responsible, there would of course have to be a control rate based on an unirradiated population similarly observed and comparable in all other respects. Even if one observed a smaller population for a correspondingly longer time, say 600,000 people for 10 years, the difficulties in meeting these requirements in human populations are formidable. They are so great that the study has not been done at this level of radiation even with an animal as favorable as the mouse.

It is obvious that we cannot for a long time arrive at better than the roughest kind of approximation in establishing permissible exposures. Right now it is difficult to see how we can improve on what the International Commission on Radiological Protection has done. This agency defines the maximum permissible dose for an individual as "that dose, accumulated over a long period of time or resulting from a single exposure, which in the light of present knowledge carries a negligible probability of severe somatic or genetic injury." It recommends that the total permissible genetic dose prior to age 30 "to the whole population from all sources additional to the natural background should not exceed five r plus the lowest practicable contribution from medical exposure."

Buck's calculations show how difficult it would be to establish whether this level of radiation to the general population would increase the incidence of leukemia by as many as five cases per million persons per year. If the entire population of the U. S. were to be exposed for generations to the maximum permissible level, it would be exceedingly difficult to exclude the possibility that the incidence of leukemia would increase by as many as 850 cases per year, or 50,000 per generation.

In addition to these difficulties, it should be remembered that ionizing radiation cannot be detected by the unaided human senses. Furthermore, overt signs of its harmful effects are often delayed for many years.

From the beginning of man's experience with ionizing radiation he has consistently underestimated its hazards. In fact, the tendency has been to underestimate not only the effects of a given exposure but often the amount of exposure as well. The exposures due to medical radiation have often been found to exceed estimates. And more recently there has been underestimation of the radiation from strontium 90 and carbon 14, two of the biologically most significant radioisotopes produced in tests of nuclear weapons. Permissible exposures have been revised downward repeatedly. Have we now reached the end? Many informed persons think not.

Incomplete knowledge thus plays a large part in public confusion and misunderstanding. It is easy to see why a qualified investigator inclined to look at the matter in the most favorable light could reasonably say that the number of persons genetically affected by fallout per year in the U. S. population might be less than 200; that the majority of these might be counterbalanced by such factors as early embryonic deaths and slight reductions in fertility; that genetic deaths of this kind would be largely undetected, even in individual cases; that the added social burden could be negligibly small. He might reason: Why worry until more compelling evidence requires it?

At the other extreme an equally qualified worker could easily feel obligated to emphasize the least favorable possibility: that fallout might well be producing as many as 800 or more new mutations per year in the U. S., or 400,000 or more per generation on a world-wide basis. On this basis he could well argue that the fallout hazard is by no means an unimportant problem for society.

It is clear that the tendency to take one or the other of these extreme positions with regard to genetic and other hazards will be strongly influenced by attitudes toward the problem of world peace. The individual who is convinced that national defense through massive build-up of nuclear weapons is at the moment the only tenable safe position will be likely to regard the development and testing of such weapons to be of such overriding importance that the uncertain, unmeasurable and possibly small damage to the population seems of relatively little importance. In contrast, another individual who is convinced that the only completely safe position will be attained through nuclear disarmament, and that we must get on with it immediately, tends to look for all possible arguments against nuclear weapons and will therefore be likely to cite the grimmer estimates.

There is no effortless way for the concerned citizen to arrive at an opinion. He must consider all aspects of the problem—risk of nuclear war included—hear all arguments, weigh all evidence and hope to arrive at a conclusion that makes sense to him. The scientist with special knowledge has a responsibility to make the facts available in as objective a manner as possible. As a citizen he has the obligation to help interpret them in terms of public policy.

The area of scientific confusion regarding radiation hazards can of course be greatly reduced by the direct procedure of adding to present knowledge. This work now engages many investigators in government agencies, industry and academic institutions. The process can and should be speeded up in all reasonable ways. Additional manpower is needed and, above all, new ideas. For example, the application of the techniques of microbiology to human-cell populations *in vivo* and *in vitro* promises a new approach to questions about human genetics. Existing manpower can be used to better advantage and at little additional expense.

Members of the medical profession are in an especially favorable position for learning about human genetics. Collectively they have occasion each year to examine millions of individuals. Unfortunately most physicians are not sufficiently well prepared to ask the right questions and make the right observations to add to the store of genetic knowledge of man. With only a little effort they could be equipped for the task. For example, medical records as kept by private practitioners, by clinics and by hospitals could be enormously improved from the standpoint of their genetic information.

In the long run more nearly adequate genetic training in medical schools will be the answer. Entirely aside from radiation hazards, this is necessary and desirable; it is increasingly apparent that the relative importance of genetic disease is great and will become greater as other diseases are conquered. Already some 160,000 infants are born each year in the U. S. with significant genetic defects, many of which constitute important medical problems.

For these reasons census procedures

and records should also be revised to encompass genetic data. A pilot study is now under way in Canada, designed to find out how this might best be done. There is every reason for other nations to consider such actions.

It is well known that unambiguous communication is difficult even among investigators in the same scientific discipline. This is true especially in the area of radiation hazards, where probability arguments are so often involved. Since the incidences of radiation damage are often very low, the evaluation of their significance usually involves statistical methods of the most sophisticated kind. Scientists, who should understand statistics, have been known to be confused about them.

Consider a specific example. Shortly after World War II geneticists were asked whether long-term studies of the survivors of the bombing of Hiroshima and Nagasaki should be made to see if evidence of genetic damage could be found. Simple preliminary calculations suggested that significant results would be hard to obtain. On the assumption that man is about as mutable per unit of radiation as the fruit fly or mouse, the detectable genetic effects would be near the borderline of statistical significance —maybe just over, maybe just under. Despite this and other difficulties the study was made, for there was both a clear obligation and an opportunity to add significantly to knowledge of the genetic hazards of radiation.

The results were pretty much as predicted: There were at first no demonstrable effects that were statistically significant. What did this mean to laymen—and, it should be added, to some scientists? The result was often taken to mean that there was no effect. The correct interpretation was that from this study alone it could not at the time be said whether the effect was zero, or as great as that expected in mice, or at a level between the two. We are not in any way justified in concluding that radiation is less effective in producing mutations in man than in mice. The data do indicate that the genes of man are not more sensitive than those of the mouse by any large amount, and that is gratifying to know.

World-wide radioactive contamination by the testing of nuclear weapons raises moral problems of a new kind. It has not previously been possible for any one nation to alter the global environment in a manner clearly harmful to other nations. A nation accused of such contamination is naturally reluctant to face the issue squarely. The temptation is rather to avoid the issue by alleging that the harm does not exist or that it is insignificantly small. Once significant harm is admitted, the issue can no longer be evaded, for morality is qualitative, not quantitative.

During war, standards shift. Mutual harm is then inflicted in the name of self-defense or rightful causes. Neutrals inadvertently caught between belligerents may then accept injury that would not otherwise be tolerated. There is a close analogy in the case of individuals. Society permits individuals to commit acts in self-defense that would not otherwise go unpunished. Again, innocent bystanders may be hurt in the process.

A large portion of the confusion that arises in disagreements about nuclear weapons results from failure of the adversaries to make clear whether they are arguing on the basis of a peacetime or wartime moral standard. Which moral standard is applicable during a cold war? Does the potential enemy follow the same standard? Although attempts to define moral standards may not help in arriving at final agreement, they may nevertheless establish that the basic issue is not one of science at all.

What should the citizen conclude about ionizing radiation? Having heard what the scientist has to say about it, and having checked a few references to be sure that what he has been told is good science, he might find the following considerations decisive in his thinking: Ionizing radiation has always been with us and will be for all foreseeable time. Our genetic system is probably well adjusted by natural selection to normal background-radiation. Added radiation will increase the frequency of mutations; most of these will be harmful. Exposure to radiation in large amounts will increase malignant disease; small amounts may possibly do the same, in proportionately lesser degree. In view of these potentially harmful effects every reasonable effort should be made to reduce the levels of ionizing radiation to which man is exposed to the lowest levels that can reasonably be attained.

As to fallout from nuclear-weapons tests, the citizen will conclude that it contributes in a small way to world-wide levels of radiation. For this reason alone the tests should be discontinued, or conducted in such a way as not to lead to atmospheric contamination. Additionally, as a hopeful first step toward a final solution of the problem of nuclear war, every possible effort should be made to discontinue the tests altogether.

Medical radiation, if properly used, is of great benefit to man. The citizen will accordingly support the investigation of ways to reduce the exposure, especially to the gonads of persons who may still reproduce, without sacrifice of clearly established diagnostic or therapeutic benefits. Radiologists estimate that progress in this direction can be expected before many years to reduce medical radiation to the gonads by a factor of five to 10—perhaps to an average value for the entire population of .5 r per reproductive generation. For the same reason exposure from industrial and experimental radiation sources should be held at minimum levels. This means that adequate shielding must be engineered into power reactors and other sources of radiation. Safe, permanent methods of waste disposal can and must be developed.

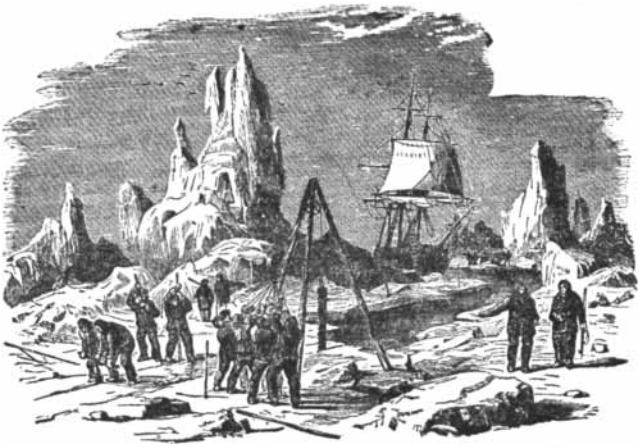
If all reasonable measures are taken, it does not seem an unreasonable hope that present levels of radiation exposure in the U. S. can be appreciably reduced —perhaps to an average level of less than one r above natural background.

With the millennium—when the citizenry has achieved sophistication in science, when wars have been abolished, when populations are stabilized at levels compatible with food supplies, when medicine has conquered the last infectious disease and corrected most genetic ailments—it may at last become essential to take a hard look at man's long-term evolutionary past and his prospects for the future.

Painful questions will have to be asked. It may become important, for example, to determine whether conquest through war, with subsequent replacement of one population by another, has been important in man's evolution. Did the conquerors differ genetically from the conquered? If so, was the effect favorable for the species (assuming that man will by then have arrived at some sensible definition of "favorable")? For the same reasons it may become essential to ask whether man's evolution has been held back because his system of controlling populations has made insufficient provision for natural selection.

Finally, assuming that medicine will have become highly successful in circumventing genetic death, will the net effect of medical practice have been unfavorable to the genetic capital of mankind? It is not inconceivable that by asking such questions man may one day find himself in the paradoxical position of searching for wiser and more humane ways than he now knows to counteract the undesirable evolutionary effects of too much success.

ON TO M^c^MURDO S^d^!



[VOL. II Nº VI]

Yes, the first Irish Geophysical Year Expedition is preparing to push off to Antarctica or so we [The Whiskey Distillers of Ireland] understand. Good news, good news to know our spirit of scientific enquiry at last will crystallize, if only into ice. ✠ The purpose of the expedition—we explained it last time but it will do no harm to cover it again, we suppose—is the study of "How Today's Man Relates To The Irish Whiskey Around Him." And why some relate more than others. And how to encourage this healthy inter-action. Call it an anthropological expedition, except there are no native cultures down there and you must bring along your own; otherwise it would be a wild penguin chase don't you see? ✠ You'll note that the Recruitment and I. D. Card Application Form shown asks you to state whether you are Irish Whiskey Drinkers or *Non*-Irish Whiskey Drinkers. The latter will form the Control Group once at McMurdo but should [for scientific reasons] proceed there on their own independent of the various south-bound parties of burnished, emphatic Irish Whiskey Drinkers, attractive travelling companions though they may be. ✠ Once you have arrived at Little Ireland the following time table may be useful:

First Day:	Set up camp; divide party as follows: Wood Gatherers, Irish Whiskey Drinkers, Control Group, Nurses.
Second Day:	Set up scientific instruments.
Third Day:	Turn scientific instruments "on."
Fourth Day:	Irish Whiskey Drinkers pair off with Control Group for one-teach-one indoctrination.
Fifth Day:	Control Group report to Canteen; buy Irish Whiskey. Unsupervised activity.
Sixth Day:	Organize softball league, Irish Coffee Fanciers vs. Irish Whiskey Purists; Control Group vs. Canteen Staff; or Nurses against the rest of the camp. Losers stand treat.
Last Day:	Police area; Wood Gatherers pick up empties.

Bon voyage! Meanwhile, the paper work:

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EXPEDITION RECRUITMENT FORM

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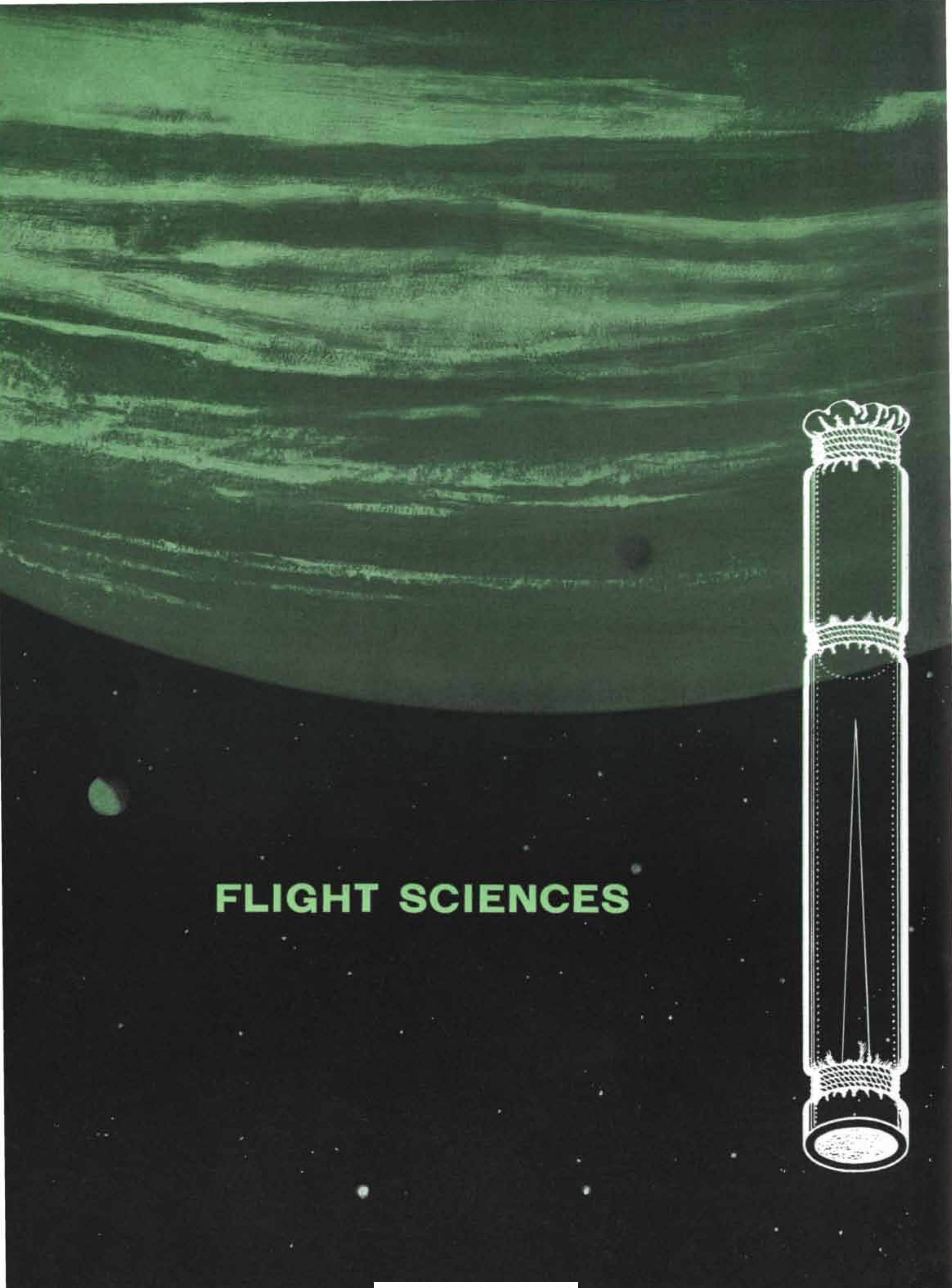
☐ Wood Gatherer; ☐ Nurse; (other) ☐ ____________

Name ____________

Address ____________

City ____________ *State* ________ *Country* ________


FLIGHT SCIENCES

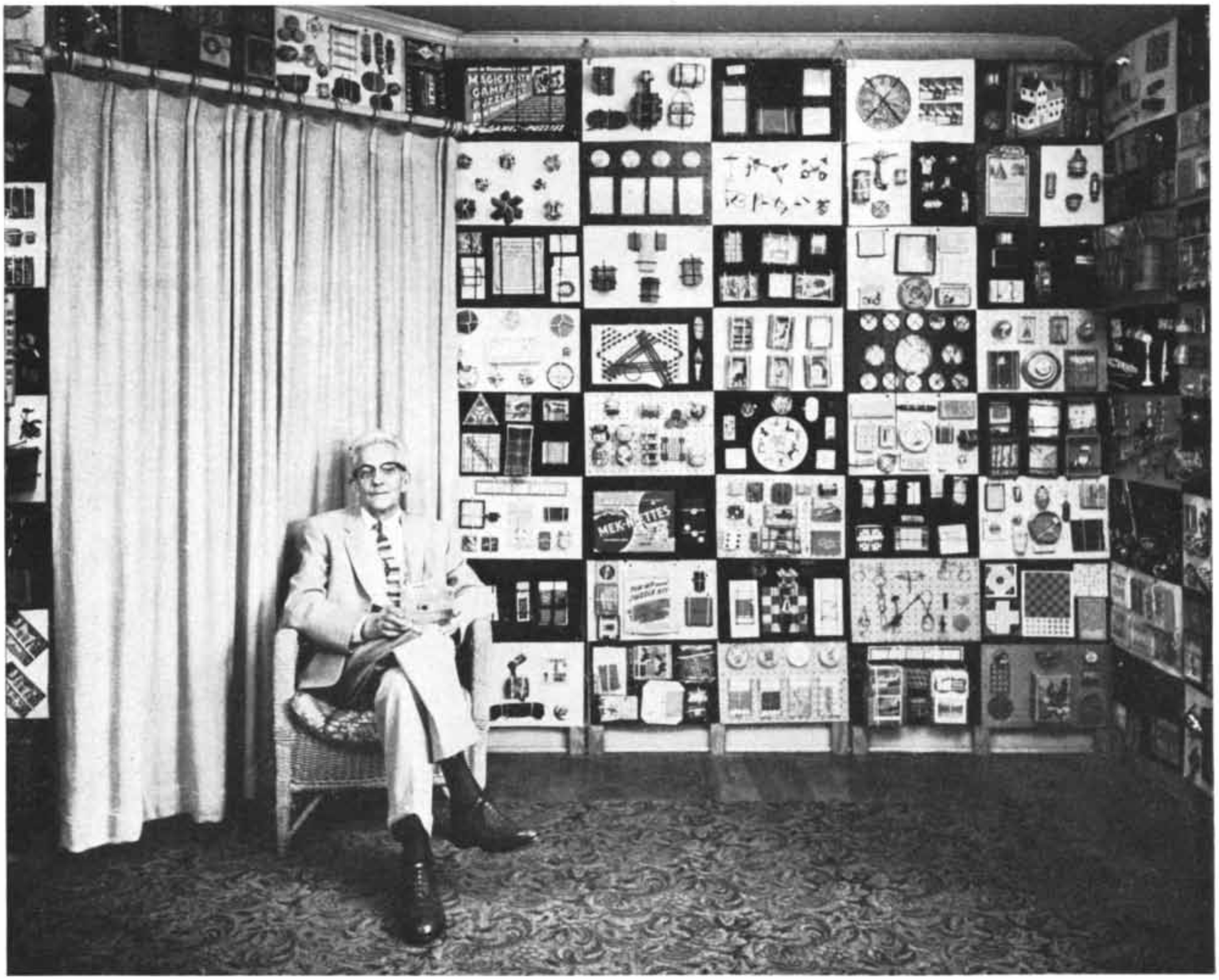
MATHEMATICAL GAMES

Concerning mechanical puzzles, and how an enthusiast has collected 2,000 of them

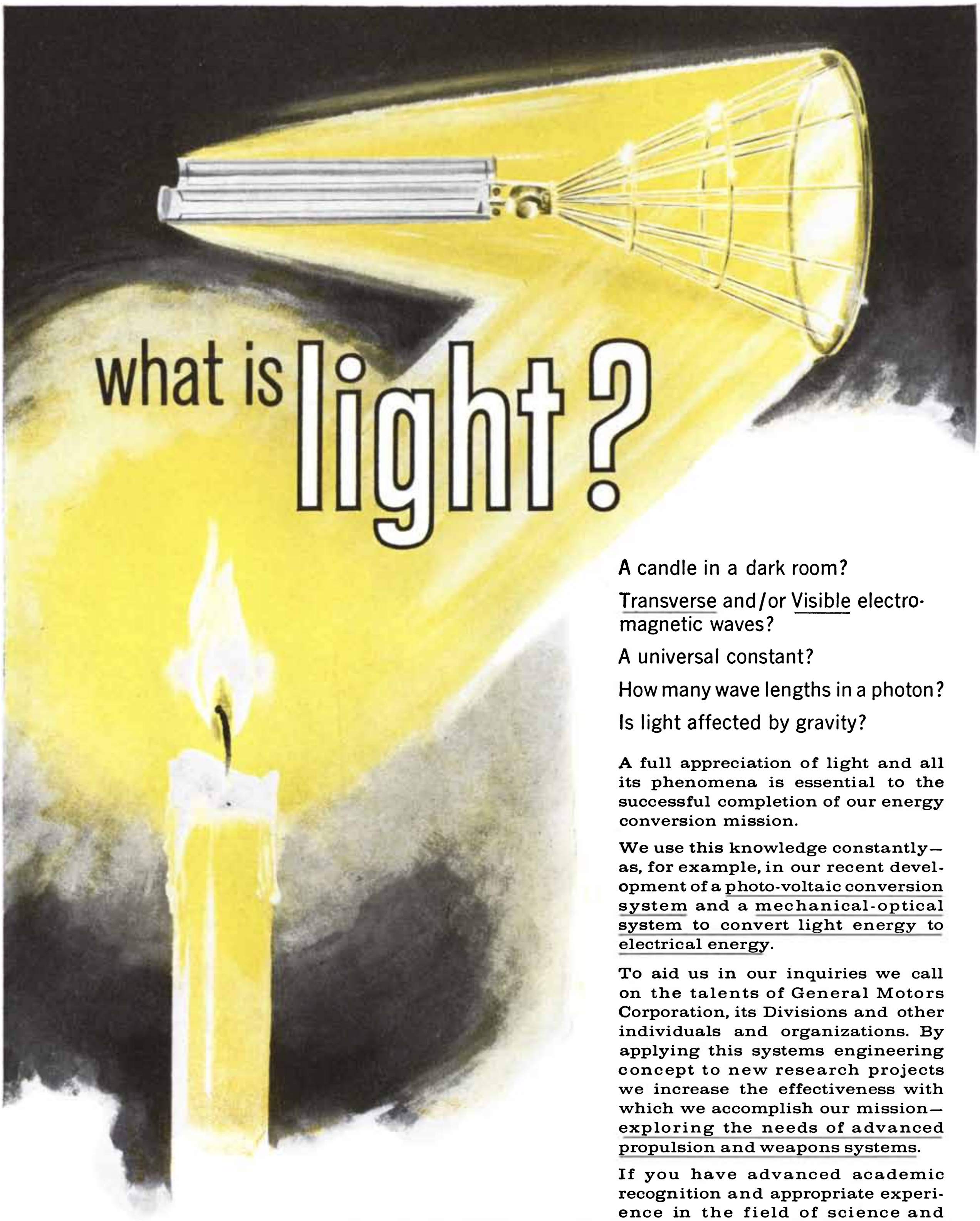
by Martin Gardner

Mechanical puzzles, in contrast to the pencil-and-paper variety, are puzzles requiring some sort of special equipment that must be operated by hand. The equipment may be nothing more than a few pieces of cardboard, or it may be an elaborate construction of wood or metal that is beyond the ability of most home craftsmen to duplicate. Manufactured puzzles of the mechanical type, sold in toy and novelty shops, are often extremely interesting from a mathematical standpoint, and for this reason are sometimes collected by students of recreational mathematics. The largest such collection known to me is owned by Lester A. Grimes, a retired fire-protection engineer who lives in New Rochelle, N. Y. (A smaller collection, though stronger on 19th-century items and old Chinese puzzles, is owned by Thomas Ransom of Belleville, Ont.) Grimes's collection numbers about 2,000 different puzzles, many of them exceedingly rare. The following account is based largely on this collection.

No history of puzzles has been written, but there is little doubt that the oldest mechanical puzzle is the ancient Chinese puzzle-game of tangrams. Known in China as the *ch'i ch'iao t'u* (meaning "ingenious seven-piece plan"), it has been a popular Oriental pastime for several thousand years. In the early 19th century it became a fad in western countries, and it is said that the exiled Napoleon whiled away his hours with a set. The name tangrams (unknown in China) seems to have been coined by an anonymous U. S. or British toy manufacturer in the mid-19th century. Many books of tangram figures



Lester A. Grimes of New Rochelle, N. Y., and some of his 2,000 mechanical puzzles



what is light?

A candle in a dark room?

Transverse and/or Visible electro-magnetic waves?

A universal constant?

How many wave lengths in a photon?

Is light affected by gravity?

A full appreciation of light and all its phenomena is essential to the successful completion of our energy conversion mission.

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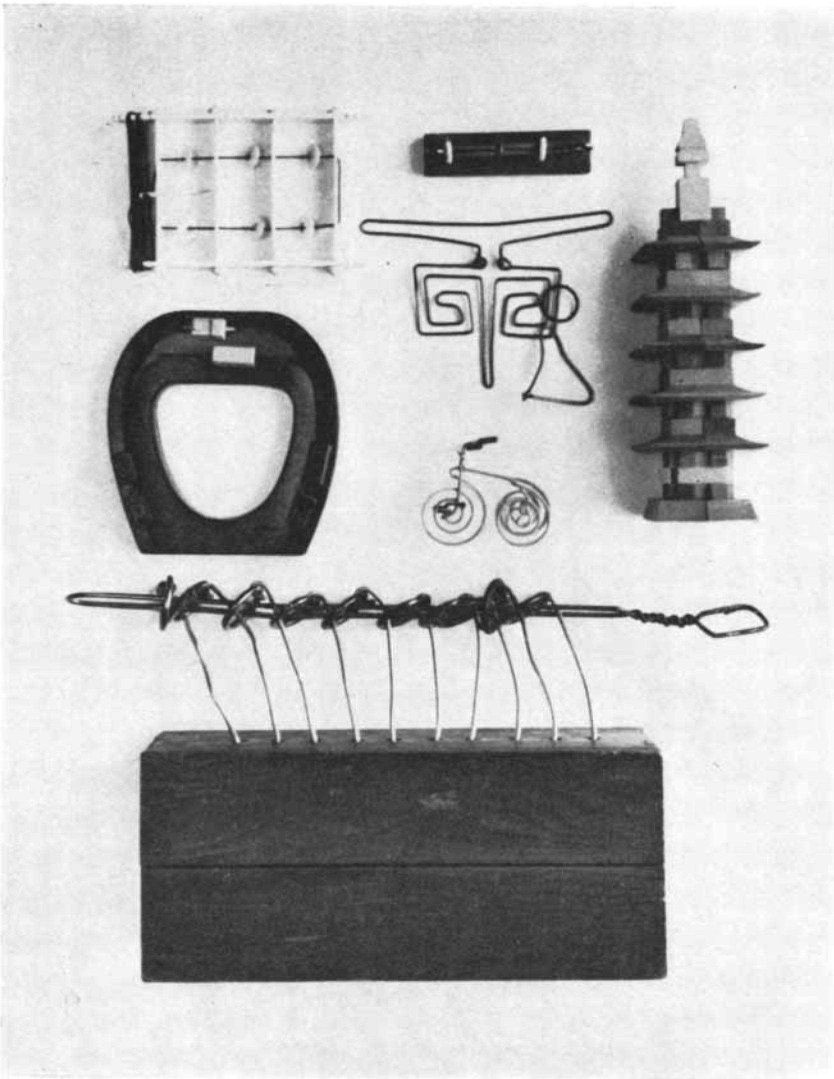
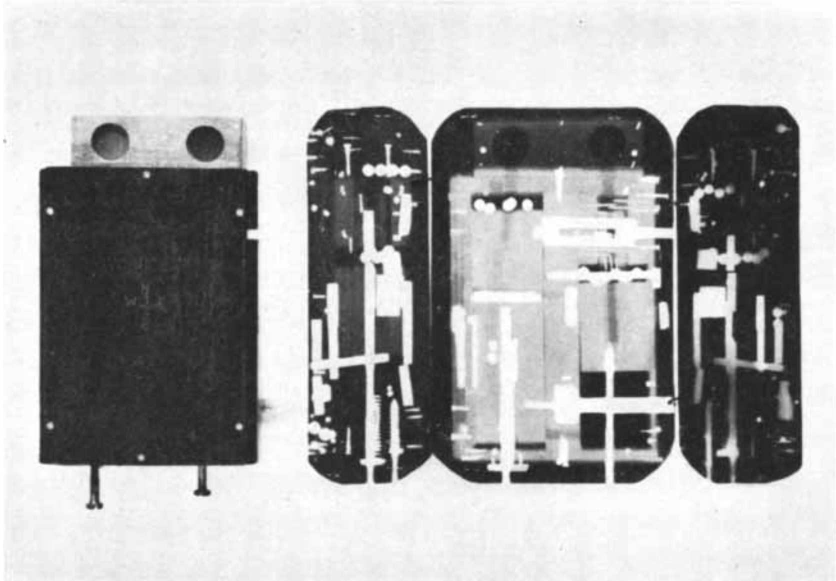


A small sampling of Grimes's puzzles



To solve and keep one of his puzzles (left) *Grimes had to have it X-rayed* (right)

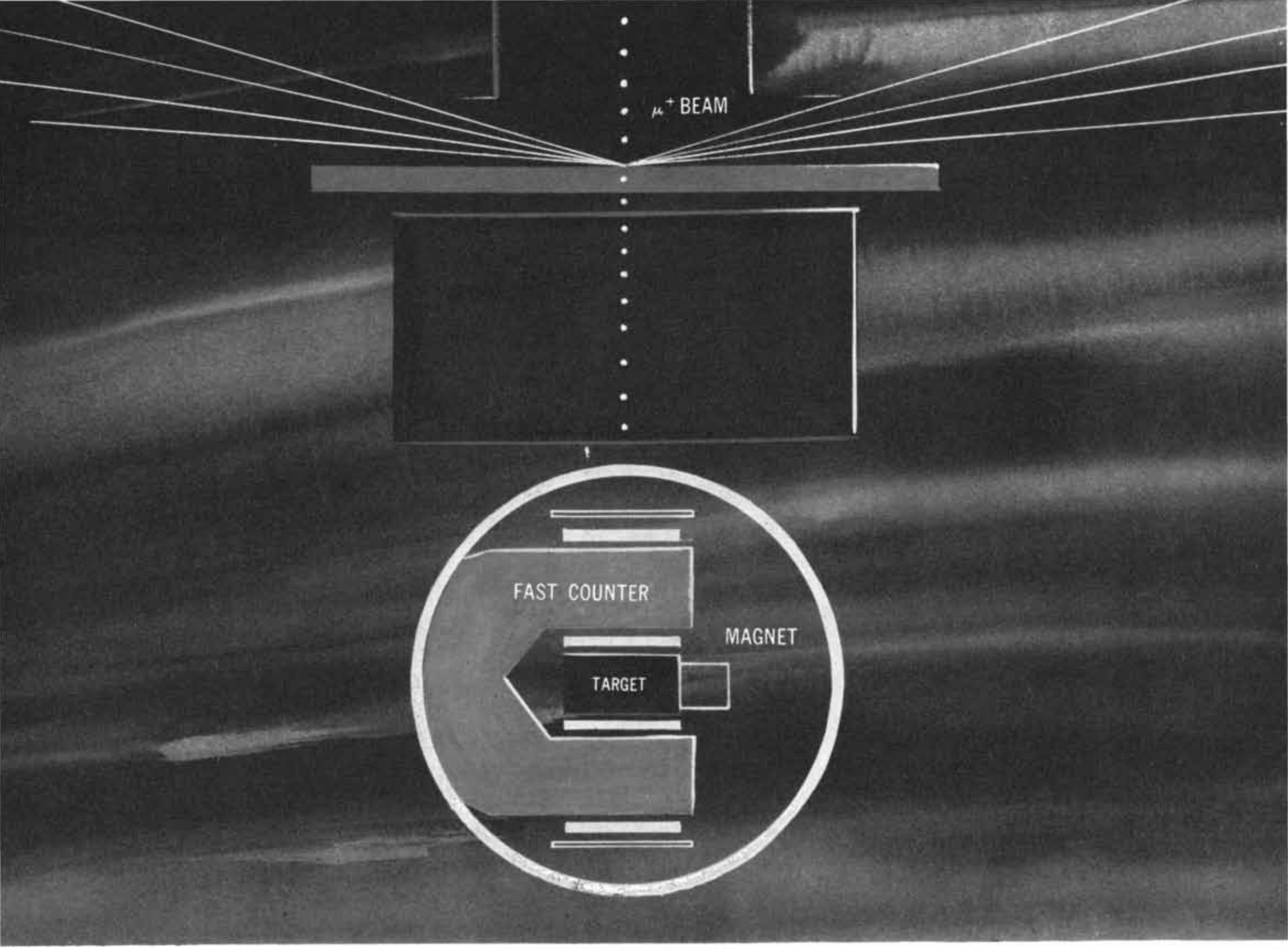
have been published, one of them a booklet by the famous U. S. puzzlist Sam Loyd that is highly prized by collectors.

Dissection puzzle-games similar to tangrams have appeared from time to time (the ancient Greeks and Romans amused themselves with a 14-piece dissection of a rectangle), but tangrams has outlived them all. To understand why, you need only cut a set of "tans" from a square of heavy cardboard, then try your skill at solving a few tangram puzzles or devising some new ones. The illustration on pages 240 and 241 shows how the square is dissected. The rhomboid should be colored black on both sides so that it can be turned over if desired. All seven tans must be used in every figure. Only the geometrical patterns require a bit of effort to solve; a variety of picture-figures are included to show the graceful effects that can be achieved.

Simple dissection-puzzles of this type occasionally provoke mathematical problems that are far from trivial. Suppose, for example, you wish to find all the different convex polygons (polygons with no outside angles less than 180 degrees) that can be formed with the seven tans. You might find them by prolonged trial and error, but how can you prove that you have indeed discovered all of them? Two mathematicians at the National University of Chekiang—Fu Traing Wang and Chuan-Chih Hsiung—published a paper in 1942 on just this problem. Their approach was ingenious. Each of the five largest tans can be divided into isosceles right-angle triangles congruent with the two small tans, so that altogether the seven tans are made up of 16 identical isosceles right-angle triangles. By a clever chain of arguments the two Chinese authors show that 20 different convex polygons (not counting rotations and reflections) can be formed with 16 such triangles. It is then easy to prove that exactly 13 of these 20 polygons are tangrams.

Of the 13 possible convex tangrams, one is a triangle, six are quadrilaterals, two are five-sided and four are six-sided. The triangle and three quadrilaterals are shown in the illustration. It is a pleasant but by no means easy task to discover the other nine. Each can be formed in more than one way, but there is one hexagon that is considerably more elusive than the other 12 figures. Its construction will be depicted in this department next month.

Another popular genus of mechanical puzzle, species of which can be traced back many centuries, involves counters or pegs that are moved across a board according to prescribed rules in order to



Report from IBM *Yorktown Research Center, New York*

THE IMPORT OF POLARIZED MESON BEAMS

Study of meson decay has led to further confirmation of parity nonconservation in "weak" interactions of high-energy particles by a group of scientists of the Columbia University Physics Department and the IBM Watson Laboratory at Columbia. Their work has also uncovered important new knowledge of the meson particle itself.

When T. D. Lee and C. N. Yang first proposed their now famous hypothesis of parity nonconservation, they pointed out that it implied a polarization of the spin of the μ meson emitted from stopped π mesons. About two years ago, precise experiments by R. L. Garwin and L. M. Lederman verified this predicted polarization with meson beams extracted from the Columbia University Nevis Cyclotron. More recently, polarized meson beams were used to measure accurately the magnetic moment of the μ meson. This experiment required apparatus for measuring time to 2/10,000 of a microsecond.

As a result of these studies and other independent investigations, the meson is now probably better understood than any particle except the electron. In fact, polarized meson beams have become a powerful tool for exploring magnetic fields in nuclei, atoms and interatomic regions.

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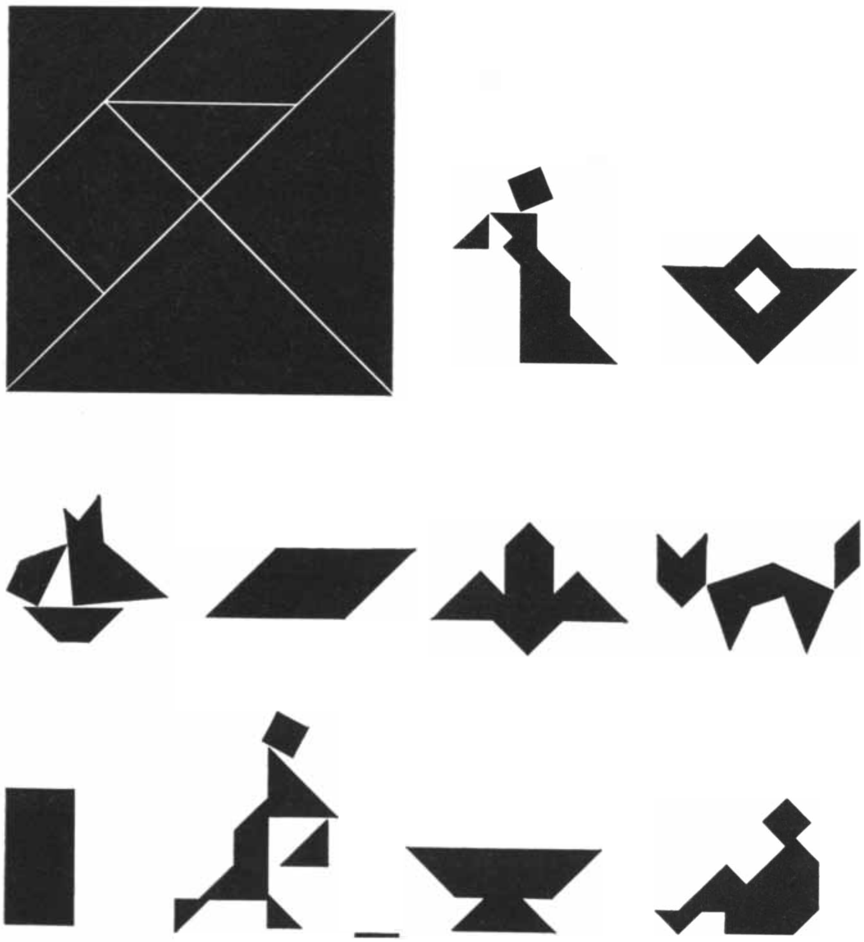
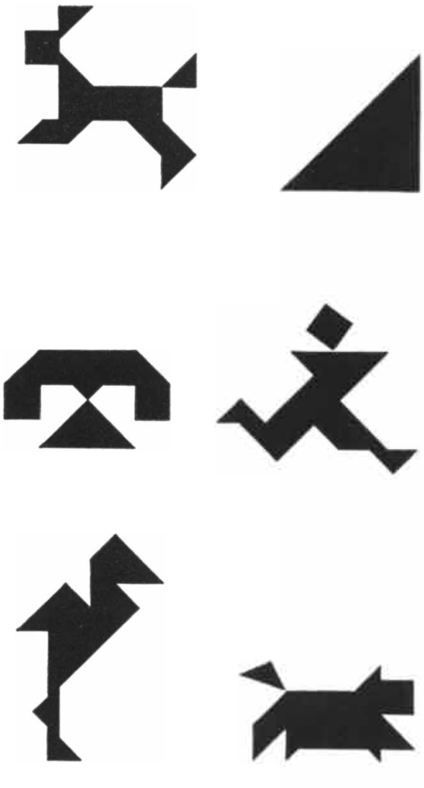
achieve a certain result. One of the best puzzles of this type, widely sold in Victorian England, is shown in the illustration at the top of page 242. The object of the puzzle is to exchange the positions of the black and white pegs in the fewest number of moves. A move is either (1) from one square to an adjacent vacant square, or (2) a jump over an adjacent peg to a vacant square. A peg may jump a peg of the same or opposite color. All moves are "rook-wise"; no diagonal moves are permitted. Most puzzle books give a solution in 52 moves, but Henry Ernest Dudeney, the English puzzle expert, discovered an elegant solution in 46 moves that will be explained here next month. Perhaps a reader will find a still simpler one, but this is unlikely because 46 moves has been the record for many decades. The puzzle can be worked by placing small counters on top of the pegs in the illustration. The squares are numbered to facilitate recording the answer.

This and the preceding puzzle were singled out because the reader can construct them with little effort. Most of the puzzles in Grimes's collection cannot be made easily; since they must be handled to be appreciated, I shall content myself with a brief description of their variety. There are puzzle boxes, purses and other containers to be opened by cleverly hidden methods, hundreds of odd-shaped wire puzzles to be taken apart, silver bracelets and finger rings made of separate pieces that interlock ingeniously, cords to be removed from objects without cutting or untying, glass-topped dexterity puzzles containing objects that are rolled or shaken into desired positions, rings to be removed from rods, eggs to be balanced on end, mazes in three dimensions, Chinese puzzles of interlocked wooden pieces, and hundreds of curious puzzles that defy all classification. Who invents such toys? To trace them back to their origins would be an impossible task. In most cases it is not even known in what country a puzzle originated.

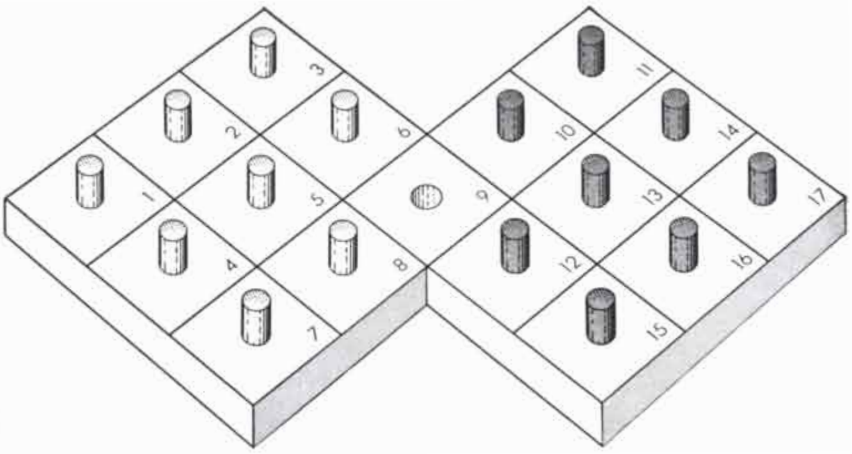
There is one happy exception. A section of Grimes's collection is reserved for about 200 remarkable puzzles invented and constructed by L. D. Whitaker, a



Chinese tangrams (top left) *and some of the figures that can be made* retired veterinarian of Farmville, Va. The puzzles are beautifully made of fine woods (Whitaker turns them out in a basement workshop), and many of them are enormously complicated and diabolically clever. A typical puzzle is a box with an opening at the top into which you drop a steel ball. The object is to get the ball out through a hole in the side of the box. One is allowed to manipulate the box in any manner, provided, of course, it is not damaged or taken apart. Much more is required than just tipping the box to roll the ball through concealed passageways. Certain impediments must be removed by tapping the box in certain ways. Other barriers have to be lifted by applying magnets or blowing through small holes. Interior magnets are so placed that they grab the ball and hold it. You are unaware of this because there are dummy balls inside that you hear rattling about. On the outside of the box there may be wheels, levers and plungers of various types. Some of them must be manipulated a certain way to get the ball through the box; others are there



with the seven "tans"

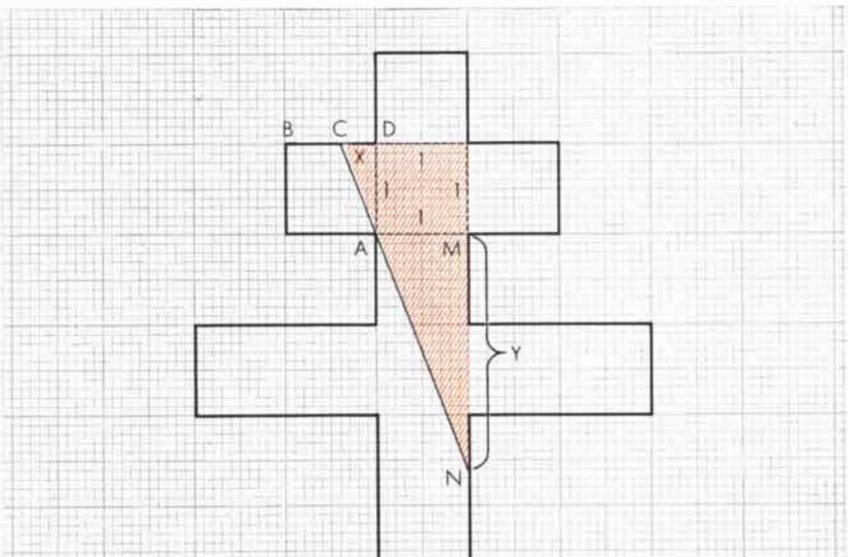


How can the black and white pegs be transposed in the smallest number of moves?

just to confuse you. It may be necessary at some point to push a pin through an inconspicuous hole.

For several years Grimes and Whitaker had an arrangement whereby Grimes received a new puzzle at regular intervals. If he solved it in a month, he was permitted to keep it; otherwise he had to buy it. In some instances the challenge was accompanied by vigorous side bets. Once Grimes worked for almost a year on a Whitaker puzzle without cracking it. He had gone over it with a small compass to locate all concealed magnets. He had carefully probed all the openings with bent wires. The bottleneck was a plunger that had to be pushed in, but apparently some interior steel balls prevented this. Grimes correctly deduced that these balls were to be tilted out of the way, but all his attempts to do this were unsuccessful. He finally solved the puzzle by having it X-rayed. The prints disclosed one large cavity into which four balls had to be rolled, and a smaller cavity into which a fifth ball had to be maneuvered. When all five balls were out of the way, the plunger yielded.

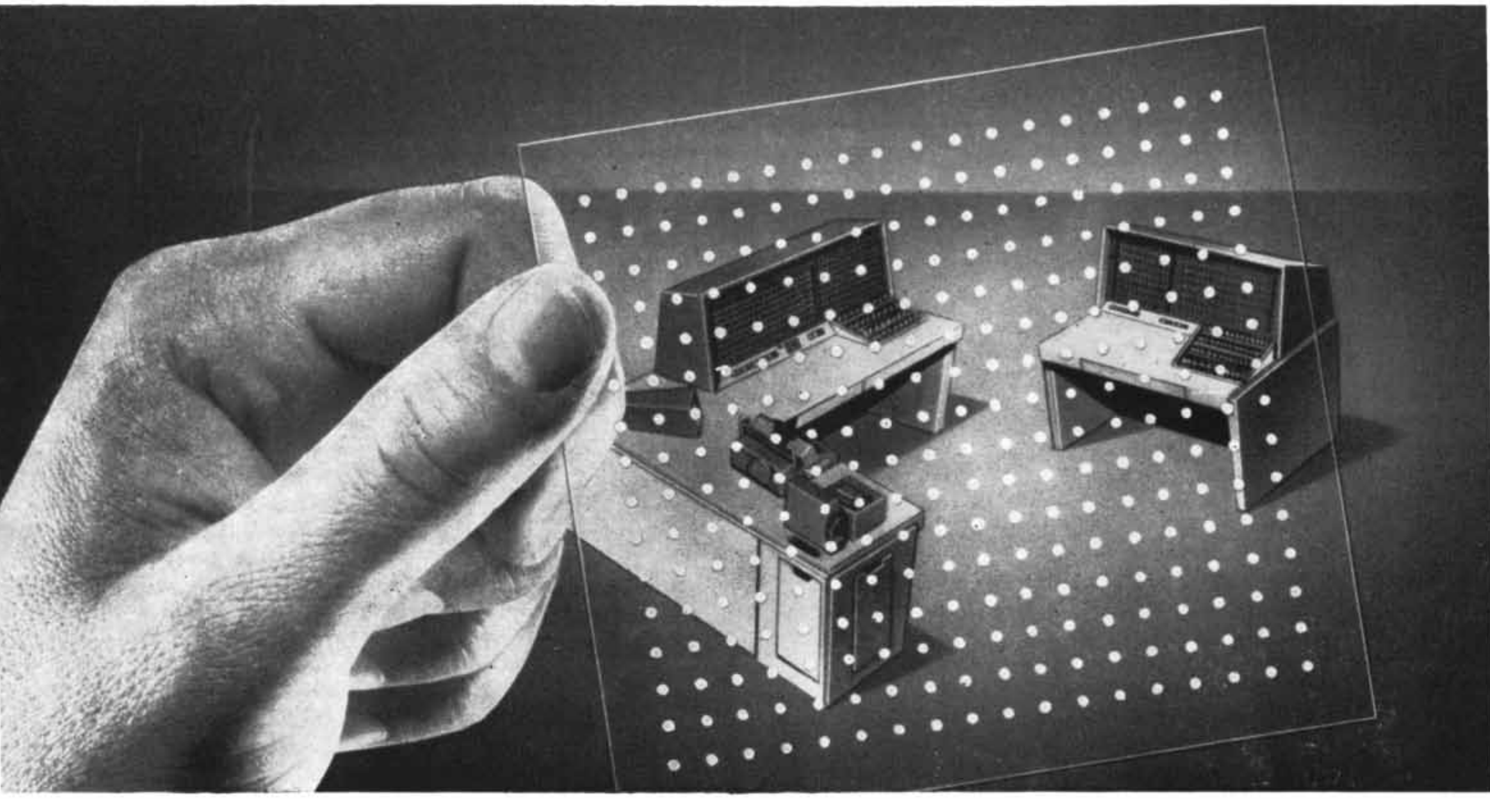
The rest of the puzzle was not so diffi-



Solution to last month's problem of bisecting the Cross of Lorraine *(see also page 244)*

Deposited Memory Cores

One of the many areas of advanced research and development now open to engineers and scientists at Remington Rand Univac



In the very composition of matter lies the key to a whole new range of digital computer capabilities. Solid state research has been vitally important to the outstanding reliability of Univac® military computers. One of the most interesting current programs involves a searching study of ferro-magnetic domain behavior as applied to computer memory elements. An important result of this program is the use of thin film memory cores produced through vacuum deposition of molten metals. Switching time of deposited cores is in some instances as fast as 1/40 to 1/50 microsecond. Use of these thin (.1 microns) deposits is an important step toward micro-miniaturization of computer components. The evaporative process also promises to greatly simplify and speed up quantity production of memory units.

This is one example of a variety of programs currently in progress at Remington Rand which offer opportunity for advanced work in your field of interest. In all of them you will find the advanced facilities and the favorable environment which foster original, imaginative research and development.

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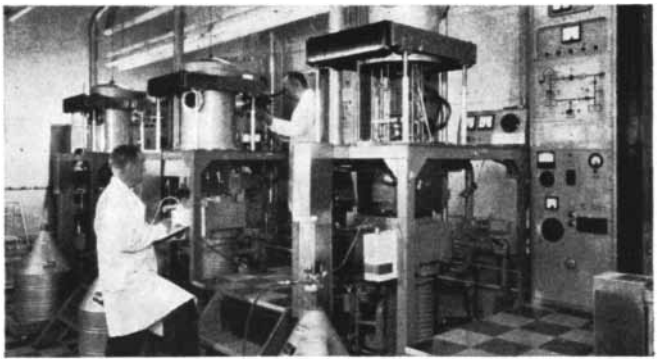

ADVANCED EXPERIMENTAL equipment for production of deposited core memory elements employs vacuum chambers utilizing both oil and mercury diffusion pumps.

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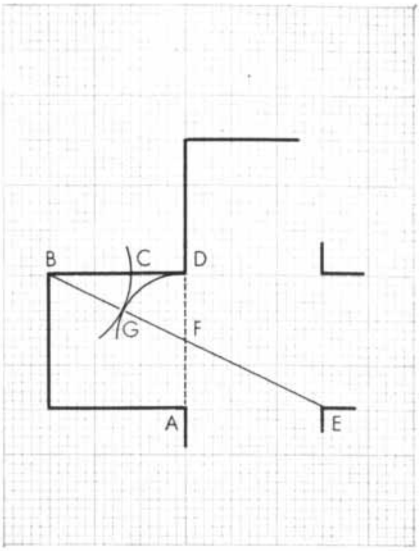


More on the Cross of Lorraine problem

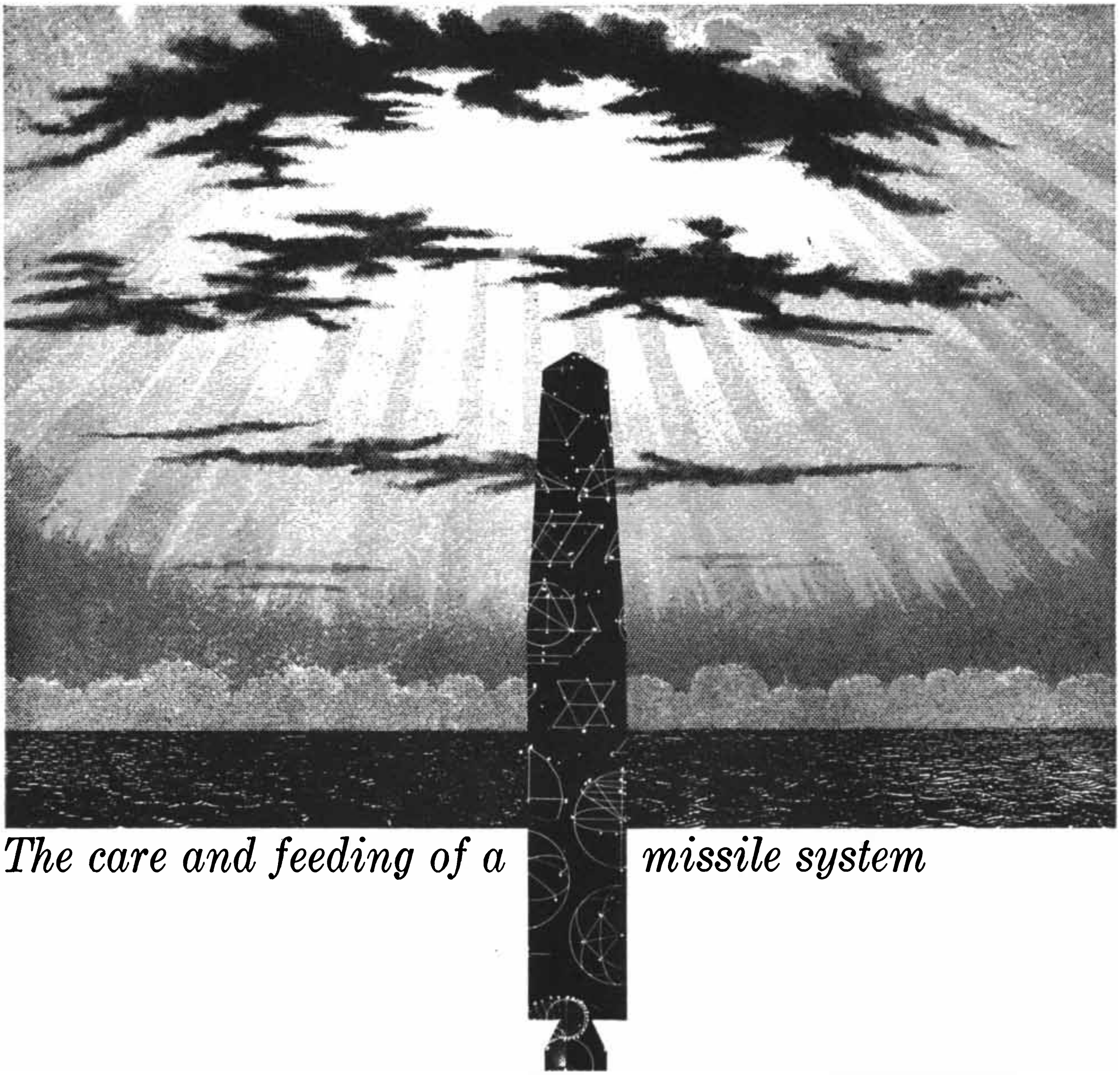
cult, though at one point it required three hands. While the right and left hands applied pressure at certain spots, another plunger, attached to a strong spring, had to be pulled out. Grimes finally managed it by tying one end of a cord to the plunger and the other end to his foot!

Last month's problem of bisecting the Gaullist cross can be solved algebraically by letting x be the length CD [*see illustration at the bottom of page 242*], and y be the length MN. If the diagonal line bisects the cross, the shaded triangle must have an area of 2½ square units. This permits us to write the equation $(x + 1)\ (y + 1) = 5$. Because triangles ACD and AMN are similar, we can also write the equation $x/1 = 1/y$.

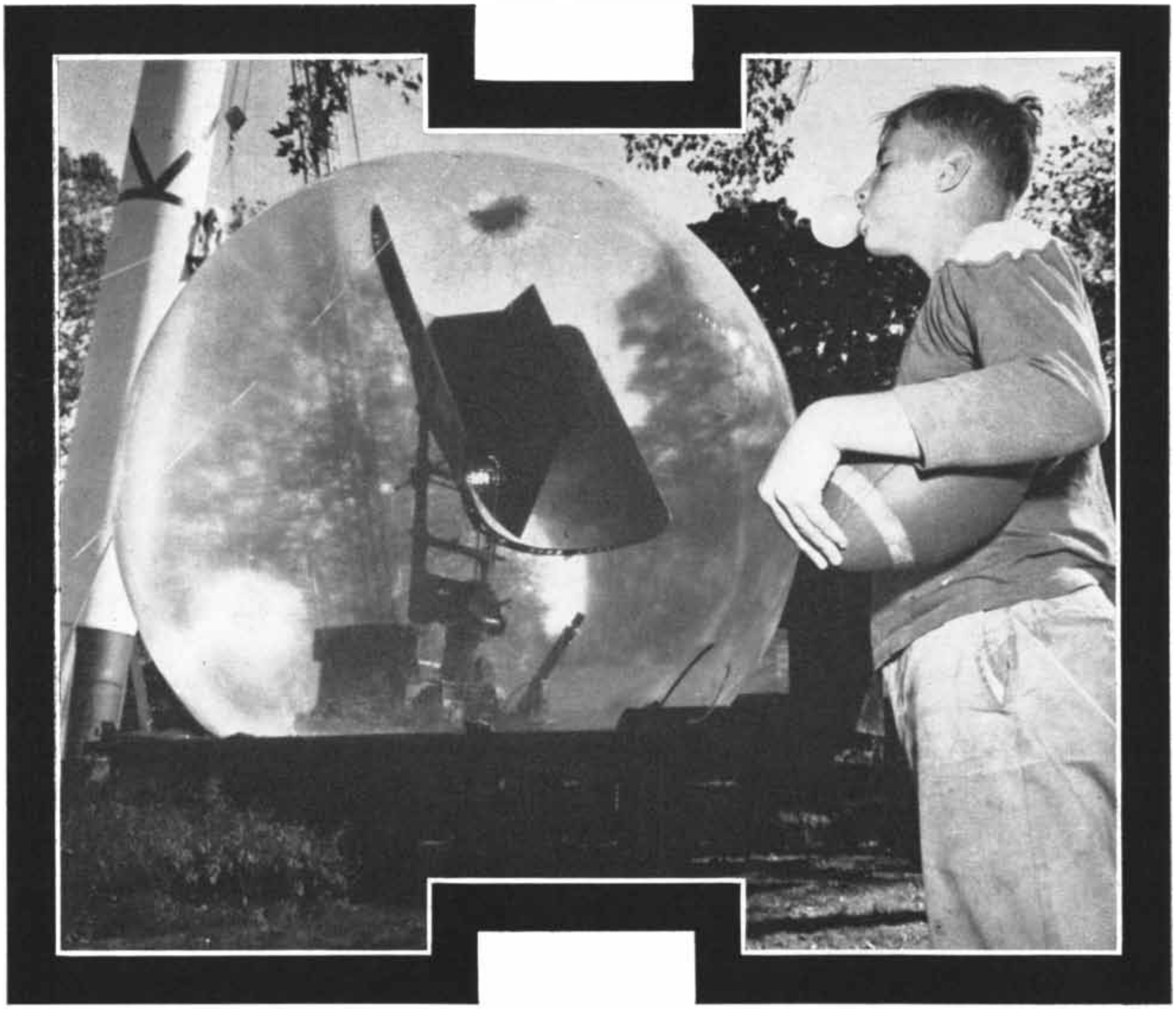
The two equations combine to give x a value of $\frac{1}{2}(3-\sqrt{5})$. BC therefore has a length of $\frac{1}{2}(\sqrt{5}-1)$, or .618+, which is the reciprocal of phi (1φ). In other words, BD is divided by C in golden ratio. The lower end of the diagonal line similarly divides the side of the unit square in golden ratio. The bisecting line has a length of $\sqrt{15}$.

To find point C with compass and straight-edge we can adopt any of several simple methods that go back to Euclid. One is as follows:

Draw BE as shown in the illustration above. This bisects AD, making DF one half of BD. With the point of the compass at F, draw arc of circle with radius DF, intersecting BF at G. With point of compass at B, draw arc of circle with radius BG, intersecting BD at C. BD is now divided into the required golden ratio.



A new dimension in



bubble blowing

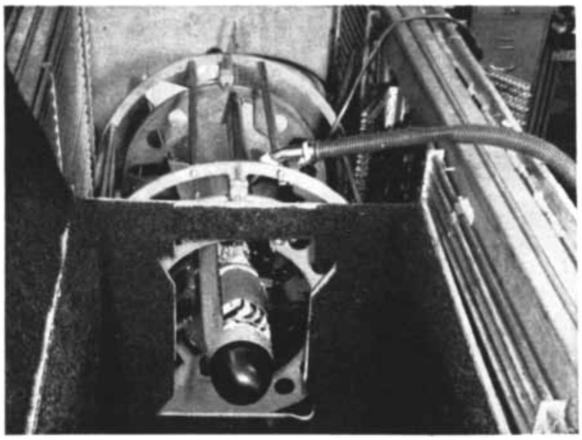
This plastic bubble protects the antenna of a radically new aerial three-dimensional radar defense system.

Sensitive to the inadequacies of conventional radar systems, engineers at Hughes in Fullerton devised a radar antenna whose pointing direction is made sensitive to the frequency of the electromagnetic energy applied to the antenna. This advanced technique allows simultaneous detection of range, bearing and altitude...with a single antenna.

Hughes engineers combined this radar antenna with "vest-pocket sized" data processors to co-ordinate antiaircraft missile firing. These unique data processing systems provide:

1. Speed—Complex electronic missile firing data was designed to travel through the system in milliseconds, assuring "up-to-date" pinpoint positioning of hostile aircraft.
2. Mobility—Hughes engineers "ruggedized" and miniaturized the system so that it could be mounted into standard army trucks which could be deployed to meet almost any combat problem—even in rugged terrain.
3. Reliability — By using digital data transmission techniques, Hughes engineers have greatly reduced any possibility of error.

Result: the most advanced electronics defense system in operation!



Falcon air-to-air guided missiles, shown in an environmental strato chamber are being developed and manufactured by Hughes engineers in Tucson, Arizona.

Reliability of the advanced Hughes systems can be insured only with the equally advanced test equipment designed by Hughes El Segundo engineers.

Other Hughes projects provide similarly stimulating outlets for creative talents. Current areas of Research and Development include advanced airborne electronics systems, advanced data processing systems, electronic display systems, molecular electronics, space vehicles, nuclear electronics, electroluminescence, ballistic missiles...and many more. Hughes Products, the commercial activity of Hughes, has assignments open for imaginative engineers to perform research in semiconductor materials and electron tubes.

Whatever your field of interest, you'll find Hughes diversity of advanced projects makes Hughes an ideal place for you to grow... both professionally and personally.

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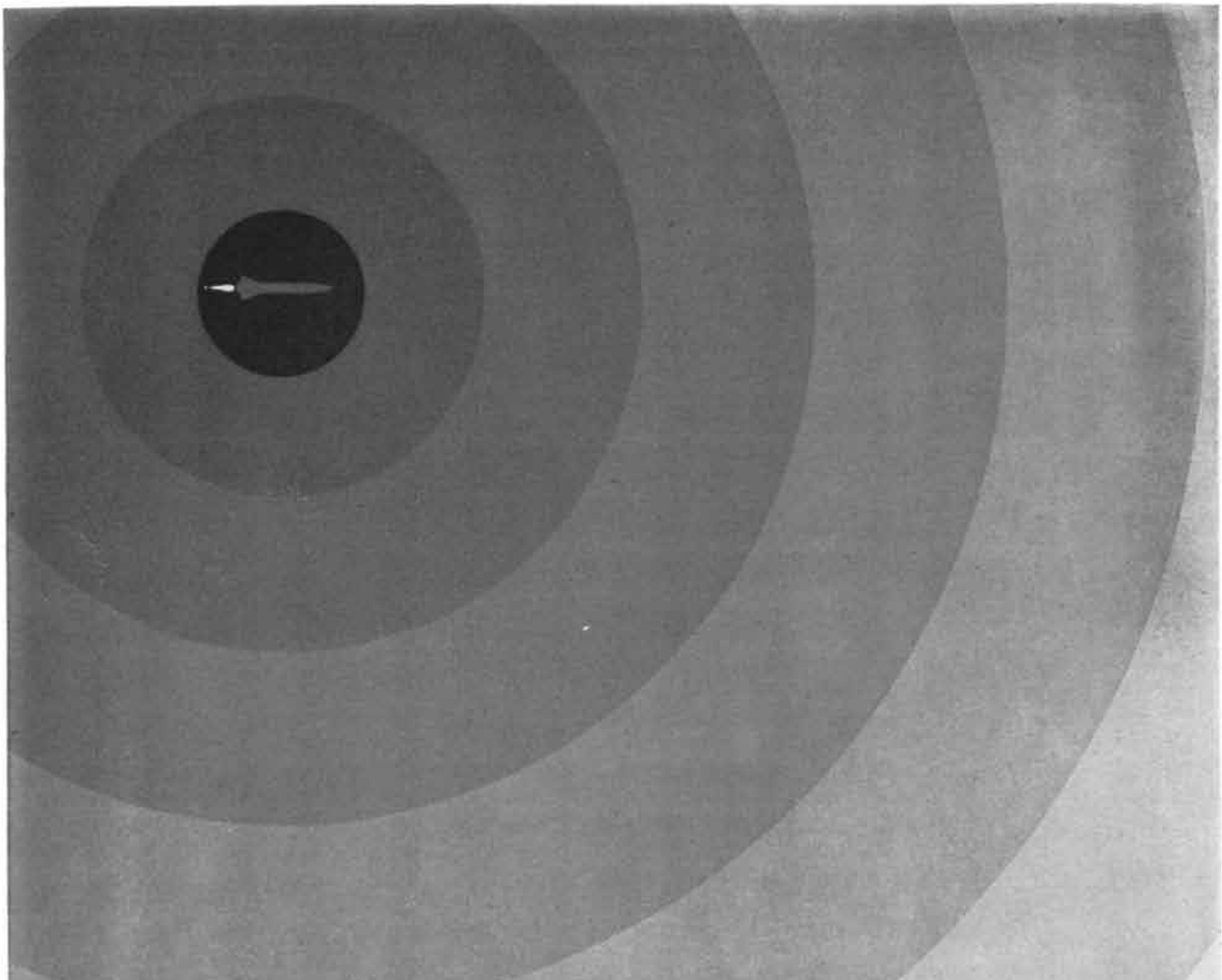


THE AMATEUR SCIENTIST

An amateur's controlled experiments measure the effects of a tranquilizing drug on rats

Conducted by C. L. Stong

How is it that so many new drugs have been added to the armamentarium of medicine in recent years? A large part of the answer lies in the intensified application of the art of the controlled experiment. In an earlier epoch of medicine useful drugs were simply handed down from one generation to another, that is, they had been discovered by virtually accidental experiments on human patients. Today the process is vastly accelerated not only by our advanced knowledge of microbiology and human physiology but also by controlled experimentation on large numbers of laboratory animals. The scope of such experiments is ambitious, but the principles involved are relatively simple, and can even be applied by the amateur. A nice example is submitted by Sarah E. Southwick of Midland, Mich., who is presently a student at the University of Michigan.

"For my science fair project during my senior year in high school," Miss Southwick writes, "I set up a controlled experiment to test the effect on rats of chlorpromazine, one of the new tranquilizing drugs. Tranquilizers were making news at the time, particularly in the treatment of mental disease, and this caught my interest. According to medical reports, the side effects of the tranquilizers had not been fully catalogued, and it seemed likely that a science fair project based on one of them would have a good chance of scoring high on originality.

"Chlorpromazine has the property of quieting mental patients who are restless, overactive and abnormally elated. Would the drug have a similarly depressing effect on normal animals? If so, how would it affect other aspects of their functioning?

"As subjects for the experiment I obtained six white rats, all males from the same litter. During the first phase of the experiment three rats were selected at random for treatment and the remaining three were reserved as controls. Each animal was tagged for identification. Midway through the experiment the treatment was switched; the controls were put on the drug, and the group previously treated became the controls. I called this the 'crossover' phase. It served as a check against previous results. Otherwise all animals were maintained under identical conditions as closely as possible, and each was given a standard ration of food and water on a fixed schedule. The experiment continued for five months as a spare-time activity.

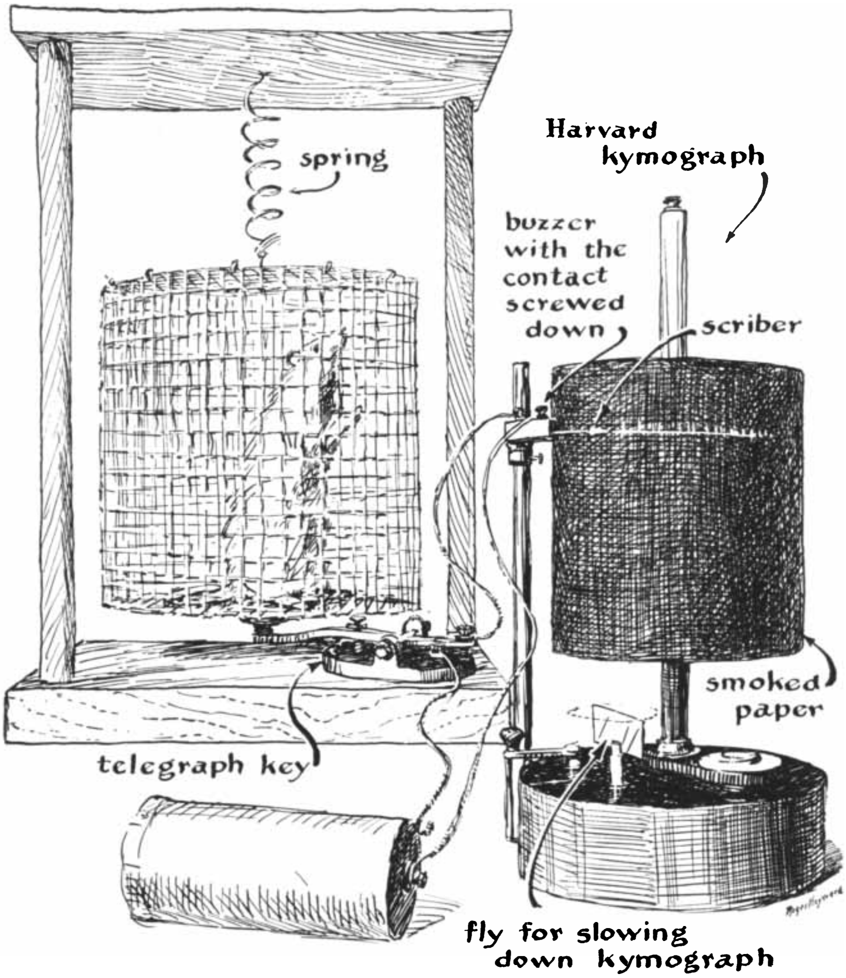
"A thorough physical examination was made of each animal at the beginning of the experiment, both to assure that the animals were in good health and to provide comparison data for subsequent use. The effects of the drug were then observed by measuring changes in activity, intelligence, blood composition, pulse rate, body temperature, weight, respiratory rate, external features, sexual behavior, internal organs and metabolism. The animals were treated by administering chlorpromazine along with their food, initially at the rate of five milligrams of the drug per kilogram of body weight. After one week the dose was increased to 15 milligrams; somewhat later, to 20 milligrams.

"Reaction to the drug was immediate. The treated rats became quieter than the control group. Their movements were slower and more deliberate. To measure the difference I designed a 'jiggle cage' consisting of a box of quarter-inch wire mesh covered at the bottom with a sheet of heavy aluminum foil of the kind used by bakers. The cage was suspended by a weak spring from the bottom of a small table consisting of a seven-inch square of half-inch plywood fitted with legs of wooden dowel stock. The movements of the caged rat caused the cage to jiggle up and down and actuate the handle of a telegraph key in contact with the bottom of the cage. The key closed an electrical circuit between a battery and the coils of a modified buzzer. The buzzer contacts were closed; a wire stylus was attached to the armature. The stylus pressed against the smoked drum of a kymograph on which the movements of the rat registered as sharp vertical pips in an otherwise smooth trace. I borrowed the kymograph from the biology department of the Midland High School. It is not too difficult, however, to make such a drum recording-device. One is described, in fact, in 'The Amateur Scientist' for July, 1957. A recording speed of some three inches per second, equivalent to the speed of a six-inch drum turning at about one revolution per minute, is adequate for this experiment.

"The activity of each rat was measured daily for one hour in darkness (when rats are commonly most active). Copies of two recordings are shown in the accompanying illustration [*bottom of next page*]. These show the activity of the same rat before and after the drug had been administered.

"The effect of chlorpromazine on intelligence was tested by means of a changeable maze in which both the pattern of the paths and the obstacles (rectangular partitions) could be altered. The animal was required to crawl under a partition or jump over it, depending on whether the partition was turned so that its opening was at the top or at the bottom. The maze was covered so the animals would not be distracted during the run. To test the adjustment of the rats to change the maze was altered four times for each group of animals during the course of the experiment. In the beginning the control rats required about seven runs to learn the maze, during which the time of the run dropped from eight minutes to 30 seconds. The treated group required substantially more practice to achieve comparable performance; at first these rats actually lost ground. The reaction of the rats was even more significant during the crossover phase of the experiment.

"During the crossover phase the rats in the control group learned to run the maze, with practice, in five seconds. When they were under the influence of



Cage, telegraph key and kymograph to measure the activity of a rat

chlorpromazine, however, none of these rats could do better than one minute. In contrast, the previously treated rats, after recovering from the drug, learned to run a new pattern in five seconds. Furthermore, when the crossover phase was started, the drug caused the controls to forget a maze pattern they had mastered. From this it would appear that the drug has a depressing effect on memory as well as on intelligence.

"Does the drug similarly depress organic functions? This was investigated in part by examining changes in the blood of the rats. The blood was taken by clipping the tip of the rat's tail. Incidentally, I quickly learned that rats are not as cooperative in all parts of the experiment as one could wish; blood sampling is a case in point. I first tried to hold the animals in one hand while taking the specimen with the other, but soon adopted the technique of wrapping them in a towel. Later I borrowed a glass vessel especially designed for the purpose. Standard clinical pipettes were used for withdrawing two specimens of blood from each rat: one specimen to ascertain the number of red blood cells; the other to test for the number of white

Top record reflects activity of untreated rat; bottom record, activity of treated rat

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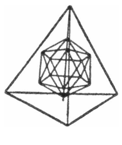

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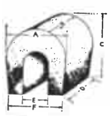

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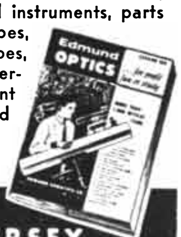

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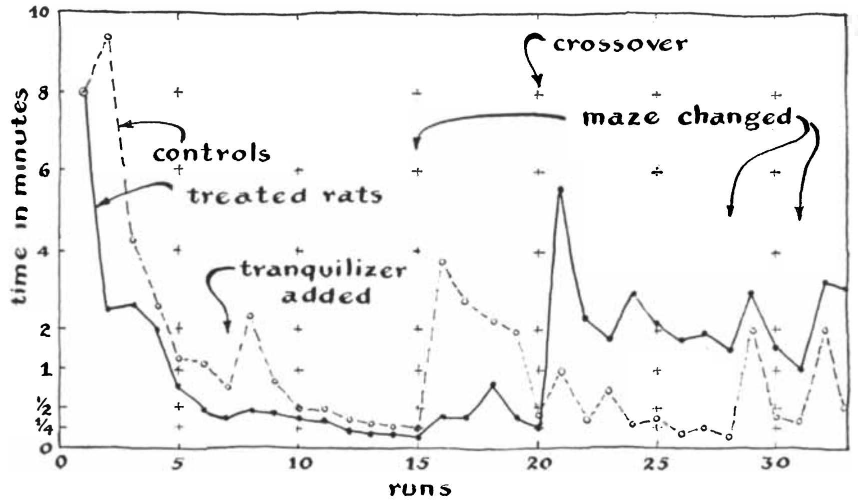
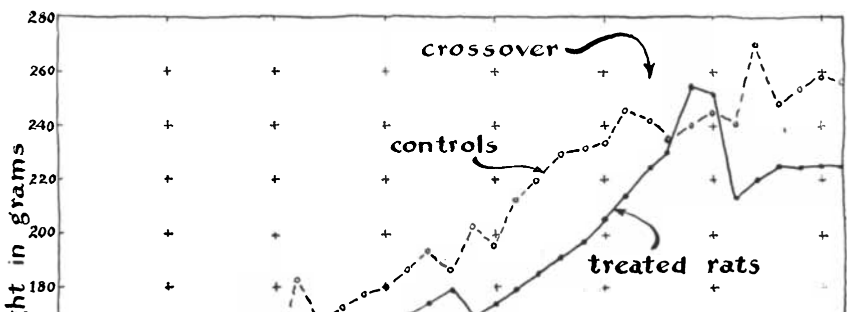


Graph compares the performance of treated and untreated rats in a maze

blood cells. The pipettes are fitted with a short length of suction tubing; one simply places the glass tip in the fluid and withdraws enough to reach the .5 mark etched in the glass. Sufficient diluting fluid is then drawn into the pipette to reach the top mark. When one is sampling white cells, the top mark is 11; in the case of red cells the mark is 101. The diluting fluid for white cells (which causes the red cells to disintegrate) consists of one part by volume of hydrochloric acid to 100 parts of distilled water. The red-cell specimen is diluted by a fluid consisting of .5 gram of mercuric chloride, five grams of sodium sulfate and one gram of table salt dissolved in 200 cubic centimeters of distilled water. This solution causes the white cells to disintegrate.

"Blood cells are counted with the aid of a special chamber that divides the field of view into a pattern of uniform squares, somewhat like a sheet of graph paper. If one encounters difficulty in procuring a counting chamber, a rough estimate of change in the relative number of white cells and red cells can be made by comparing stained specimens. I borrowed a chamber.

"The red-cell count remained constant throughout the experiment for both treated and untreated rats. But the white-cell count increased substantially during the time the animals were on the drug, averaging 22,000 cells per cubic millimeter during treatment as against a normal count of 14,000. Counts were taken of all rats once each week for the first three weeks after the beginning of treatment. Measurements made during the crossover phase were identical with those recorded at the beginning of the experiment. In one exceptional case, however, both groups yielded identical counts. This occurred after the experi-



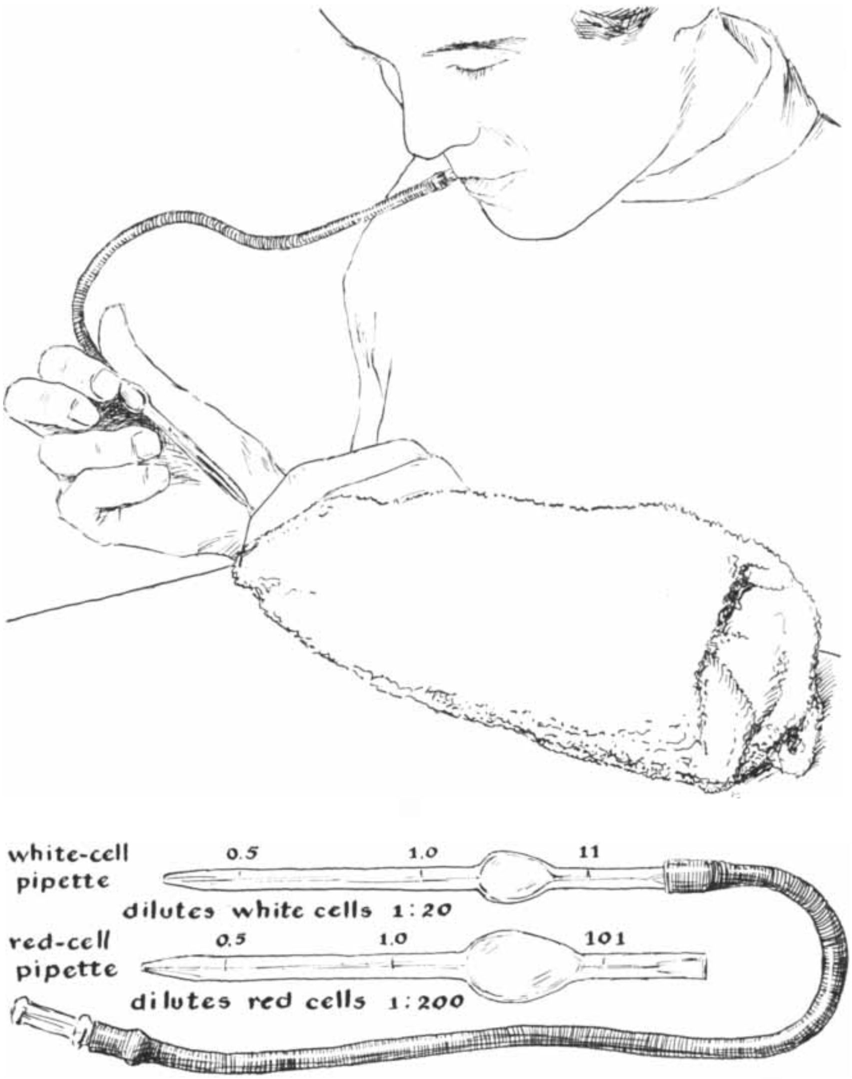
Graph compares the weight of treated and untreated rats

ment had been running two months and suggests that the rats may have developed some tolerance for the drug.

"Stained blood-specimens were examined with the aid of a microscope equipped with a 10-power eyepiece, an oil-immersion objective of 97 power, and dry objectives of 10 power and 43 power. The combinations of eyepiece and objectives gave magnifying powers of 970, 100 and 430 diameters. The instrument was borrowed from the Midland Hospital.

"The technique of making differential smears is not difficult if one carefully follows a standard procedure. The microscope slides must be cleaned thoroughly. Ordinary household detergents, particularly those containing a soft abrasive powder, make a satisfactory cleaning agent. A drop of blood is first placed near the end of a freshly cleaned slide. The end of a second slide is then held at an angle of about 45 degrees at a point between the drop and the center of the second slide, so that the drop wets the lower surface of the upper slide. The fluid will immediately spread by capillary attraction across the line of contact between the two slides. The second slide is then quickly pushed forward toward the far end of the first. This distributes the specimen *behind* the top slide in a film which adheres to the lower slide. Do not place the drop in front of the top slide and push it with the end of the glass; the cells will be forced to flow between the two slides and may be broken.

"The smear is allowed to dry until it becomes tacky, and then is stained. I used Wright's stain, which can be procured through most drugstores. It is made into a solution consisting of .3 gram of powdered stain mixed with three grams of glycerin and 97 cubic centimeters of methyl alcohol. A drop of



Pipetting a specimen of rat blood

the solution is applied to the slide and allowed to stand for three minutes. A drop of buffer solution is then added. This consists of 1.63 grams of potassium phosphate and 3.2 grams of sodium phosphate dissolved in a liter of distilled water. The ingredients of both formulas, incidentally, may be cut in proportion if smaller quantities are desired. After the buffer has worked five minutes the slide is washed gently with distilled water, permitted to dry in open air and then placed under the microscope for examination.

"The differential smears from rats under treatment showed a 20-per-cent increase in the white cells known as lymphocytes, and an equal decrease in neutrophil white cells. Again, however, one measurement made two months after the beginning of the experiment proved exceptional and suggested the development of tolerance to the drug.

"As another index of reaction to the drug the pulse rate of all animals was taken twice during each phase of the experiment. This proved somewhat difficult because the pulse rate of a healthy rat is about 375 beats per minute, and, as I discovered, this rate is almost doubled by the administration of chlorpromazine. Accordingly accurate counts could not be made by listening to the rats' heartbeats with a stethoscope. I solved the problem with the aid of an ordinary magnetic-tape recorder. The rat was held against the microphone and a recording of the heart sounds made at a tape speed of 7.5 inches per second. The record was next played back at 3.25 inches per second and the beats counted by ear against a stop watch. The count was then multiplied by two. (The absolute tape speed, which varies with the make of the machine, is not important. One is only concerned with the ratio of speeds.) Rats tend to become excited when placed against the microphone, so they should be permitted to settle down for a few minutes before the recording is made. The pulse rate of tranquilized rats averaged 639.6 beats per minute, as against 389 beats per minute for the controls. The slightly higher-than-normal rate of the controls is explained by the excitement of the rats at being handled.

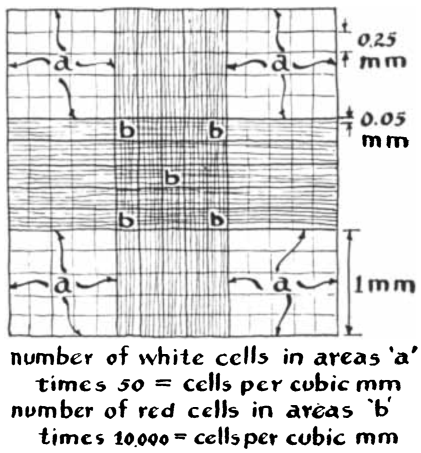
"The body temperature of tranquilized rats was also found to be abnormally high, averaging 100.1 degrees Fahrenheit as against an average of 99.7 degrees for the controls. The average difference is not great. But in every instance the lowest temperature observed in a treated animal was above the highest temperature among the controls. This fact, when considered together with the elevated lymphocyte and neutrophil counts, suggests that the tranquilized rats had contracted an infection of some sort. This was further indicated by their behavior. Some appeared to be sick part of the time. The temperatures were taken with a conventional rectal thermometer.

"A careful record of body weight was made daily, along with the weight of food and water consumed. Early in the experiment the ratio of water to total body weight changed in a direction that suggested that the drug was causing dehydration, but this was not supported by the crossover observations. Both groups made comparable gains in weight throughout the experiment, as indicated by the accompanying graph [*bottom of page 252*].

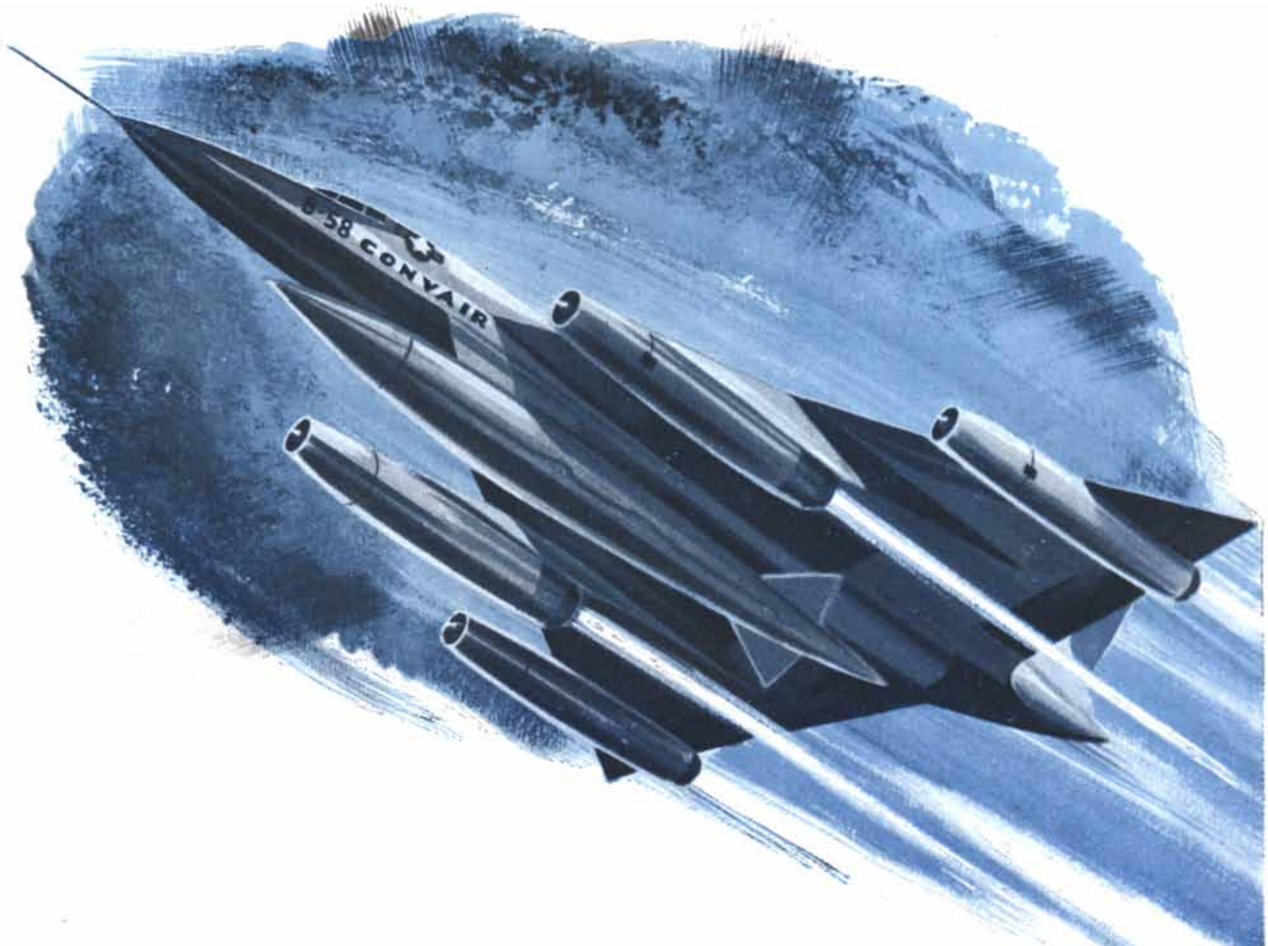
"Chlorpromazine lowers the respiratory rate of rats substantially. Tranquilized rats average 72 inhalations per minute as against 95 for the controls. The rates coordinate well with the relative activity of the two groups. Counts were taken three times during each phase of the experiment.

"A close check was made throughout the experiment of the external appearance of the rats in both groups. I observed a number of obvious differences. Minor skin eruptions developed within a few days after each animal was put on the drug. In addition, the hair of the treated rats became rough and shed readily. In the case of the first group to receive the drug, violent muscle tremors occurred when the animals awakened from sleep. This, however, was not observed in the group treated during the crossover phase. The behavior of the groups also suggested that, at least in rats, chlorpromazine acts as a sexual stimulant.

"Tendencies to jaundice sometimes



Pattern of chamber for counting blood cells



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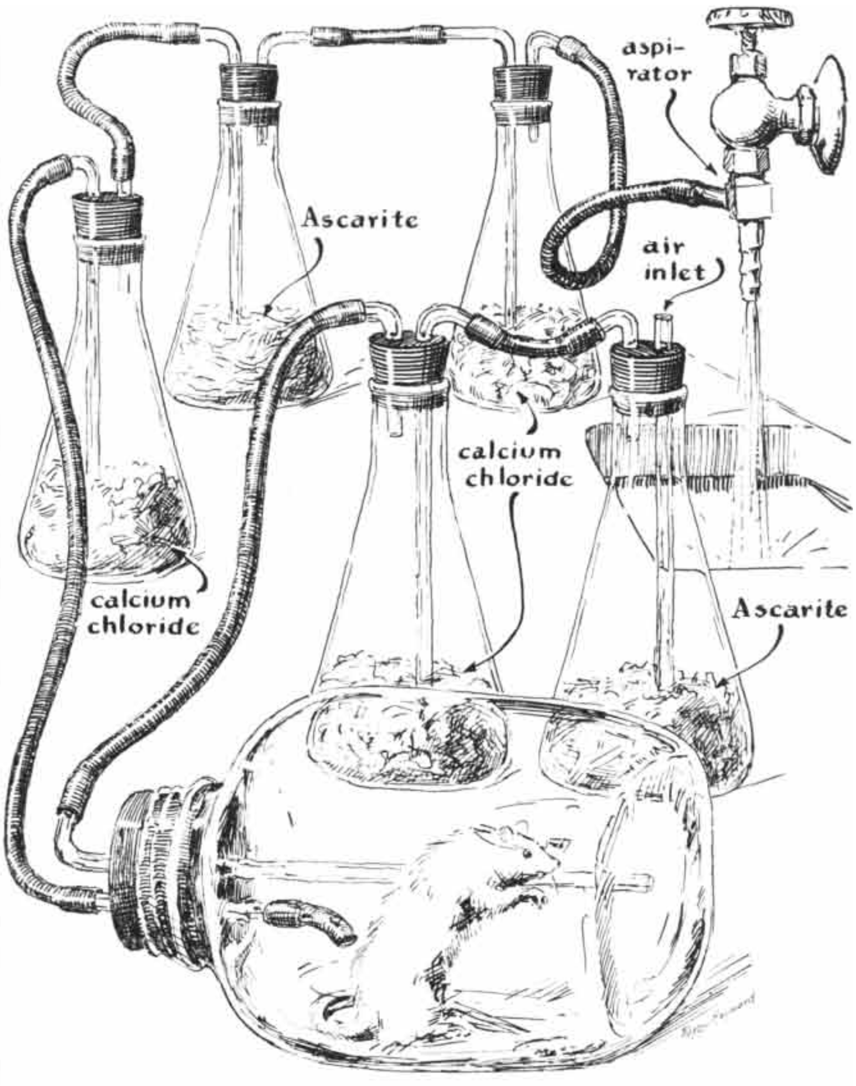


Respiratory quotient of treated and untreated rats was determined in this apparatus

follow the administration of chlorpromazine, according to reports in the professional journals. This reaction appeared in both groups of rats approximately two weeks after treatment was started. Their eyes became pale and their feces lost color. To check possible damage to the liver an autopsy was performed on one control and one treated rat 17 days after the beginning of the crossover phase. Sections of liver tissue were taken from both rats and preserved in xylol. Both specimens showed abnormality. The damage appeared more extensive in the animal that was undergoing treatment at the time the autopsy was performed. This part of the experiment was interesting, but because the observations were limited to two animals the result could not be considered conclusive.

"No diabetic effect was observed. The qualitative test for this reaction was made by a procedure which I learned at the Midland Hospital that requires the use of chemically treated test-strips that one must either purchase or borrow. The strip is dipped in the urine of the animal; if sugar is present, the tip of the stick turns blue within a minute.

"Metabolism was measured by a variation of the method devised in 1890 by the noted British physiologist J. S. Haldane [see "The Amateur Scientist"; August, 1957]. Essentially the test consists in supplying the animal for a known interval with air containing a minimum of water vapor and carbon dioxide and then subtracting the weight lost by the animal from the weight of the water vapor and carbon dioxide exhaled during the test interval. This gives the weight of oxygen absorbed by the animal, and when this figure is divided into the weight of exhaled carbon dioxide (adjusted for the molecular weights of oxy-

gen and carbon dioxide), the result is equal to the respiratory quotient of the animal. My apparatus consisted of an air pump (a water-powered aspirator) and five flasks of one liter each connected in series [*see illustration on page 258*]. The initial flask in the series contained approximately 600 cubic centimeters of 'Ascarite,' a commercial preparation that has the property of absorbing carbon dioxide. The second flask held a comparable amount of anhydrous calcium chloride, which absorbs water vapor. The intake of the second flask was coupled to the exhaust of the third, a wide-mouthed jar capped with a close-fitting stopper, which served as the animal chamber. The intake of the animal chamber led respectively to flasks of calcium chloride, Ascarite and calcium chloride. All containers and the animal were weighed individually before and after a test interval of one hour. The weight (in grams) lost by the rat was then divided into the product of the weight gained by the fourth and sixth flasks multiplied by .7282 (the ratio of the molecular weights of oxygen and carbon dioxide).

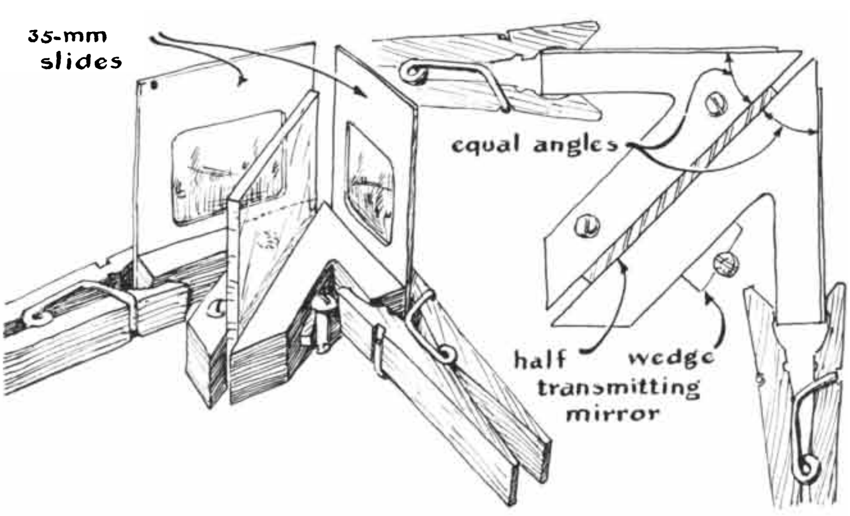
"Only two animals remained in each group at the time the respiratory quotient was measured, the other pair having been used for the autopsy. The respiratory quotients of the rats then under treatment were .56 and .58, whereas those of the control rats were .82 and .65. Here again the sample was too small to yield reliable figures. Differences in the individual determinations show a spread, however, which suggests that the lower activity of the tranquilized rats is accompanied by a correspondingly low respiratory rate.

"From this experiment it would seem that a rat is tranquilized by the steady administration of chlorpromazine, but with at least temporary cost to its health. The drug depresses the animal's memory and intelligence, alters the composition of its blood, invites infection, increases its pulse and body temperature, lowers its metabolism, induces abnormal sexual stimulation and damages its skin, hair and liver."

Many readers of this magazine have undertaken to repeat some of the experiments in color vision recently described by Edwin H. Land [see "Experiments in Color Vision"; Scientific American, May]. In one of these experiments Land made two black-and-white photographs of a colored scene, one photograph through a red filter and the other through a green filter. Positive transparencies were then made of both photographs. When the "red" transparency was projected on a screen through a red filter, and the "green" transparency projected without a filter, the superimposed images reproduced the original scene in full color.

Most amateurs who have repeated this experiment have used two 35-millimeter slide projectors—one borrowed from a friend. The experiment was then prematurely terminated by the necessity of returning the borrowed projector. Jeremy M. Palmer of North Hollywood, Calif., solved this problem by means of a gadget that can be built in 15 minutes.

On the face of a block of wood half an inch thick and 2½ inches square Palmer makes two saw cuts a quarter of an inch deep; one cut is parallel to one edge of the block and the other cut is parallel to an edge at a right angle to the first. A third cut is then made diagonally across the face of the block. This bisects the right angle made by the previous



Roger Hayward's device to observe slides made by the Land technique

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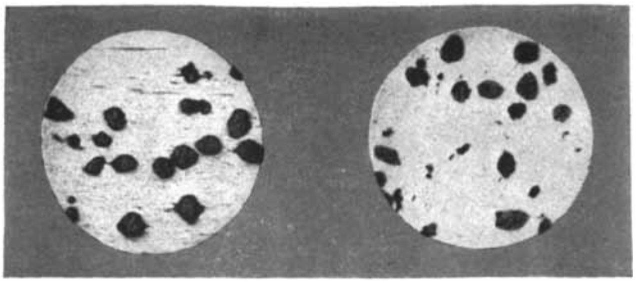
NARROWING THE "DEPARTURE FROM IDEALITY" IN DISPERSION FUEL DEVELOPMENT



† Longitudinal section of 200-μ UO_2 dispersed in Zircaloy matrix. 30X. BF. Reduced approximately 38% for reproduction.

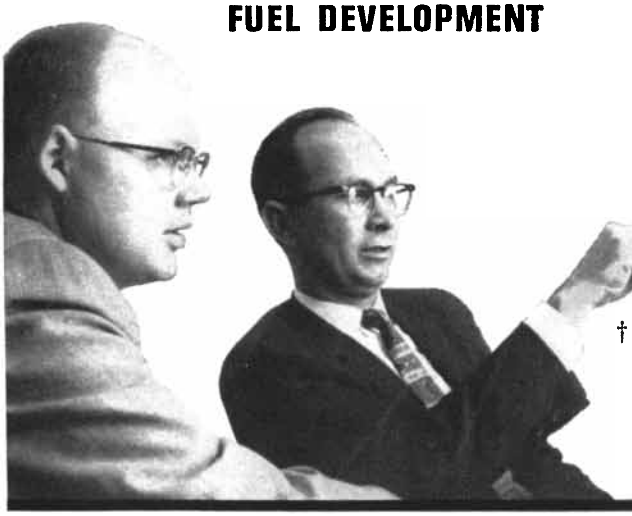
Transverse section of 200-μ UO_2 dispersed in Zircaloy matrix. 30X. BF. Reduced approximately 38% for reproduction.

Scientists have long been cognizant ot the theoretical advantages of applying the dispersion theory to reactor fuel elements. Ideally this concept could be utilized to extend substantially fuel rod life in high performance water cooled reactors.

But it remained for KAPL Metallurgists Dr. A. P. Beard and R. N. Honeyman to solve basic problems of process metallurgy involved and achieve *actual fabrication* of zirconium-alloy base dispersion elements which were a significant step closer to the theoretical ideal.

Encouraged by Dr. C. E. Weber, Manager of Basic Materials Development, and a leading figure in Dispersion Element research — and aided by consultation with specialists in several KAPL laboratories — Beard and Honeyman successfully completed evaluation of the irradiation behavior of their first samples in September 1958, only eighteen months (and 2 volumes of experimental data) after the study program was formally initiated.

A capsule description of their findings appears below. Reprints of a paper outlining the experimental method and techniques used to prepare laboratory samples will be furnished on request.



Summary of Findings: Dispersion Fuel Study

...showed that mechanical attritioning could be used to prepare zirconium powder with high corrosion resistance.

† ...that extrusion of dispersions of 200 micron dia. particles of spherical UO_2 & UC could be achieved at 750° C with little or no stringering and no reaction between particles and Zircaloy matrices.

...that irradiation behavior of zirconium base dispersion fuels confirmed theoretical concepts of such systems.

R. N. Honeyman (l.) and A. P. Beard (r.)

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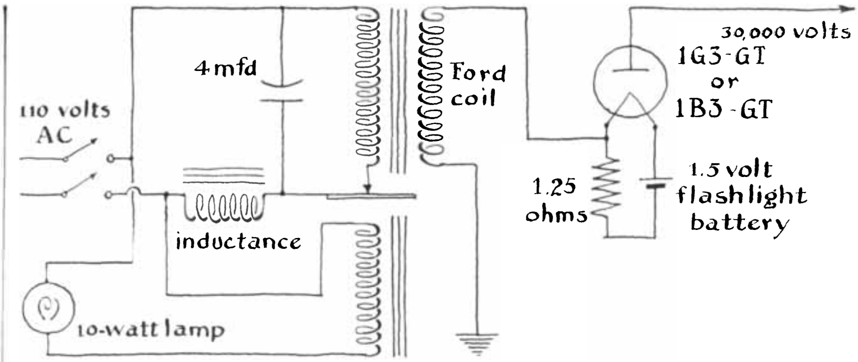


Circuit diagram of an amateur's high-voltage power supply

cuts. Two 35-millimeter slides made by Land's technique are placed in the right-angle cuts. A microscope cover-glass, mounted in a cardboard slide holder, is inserted in the diagonal cut. The cover glass functions as an optical beam-splitter. When one looks through it directly at one slide, the other is seen simultaneously by reflected light and in register if the two slides are properly positioned. One slide is lighted by reflection from a colored card and the other by reflection from a white card.

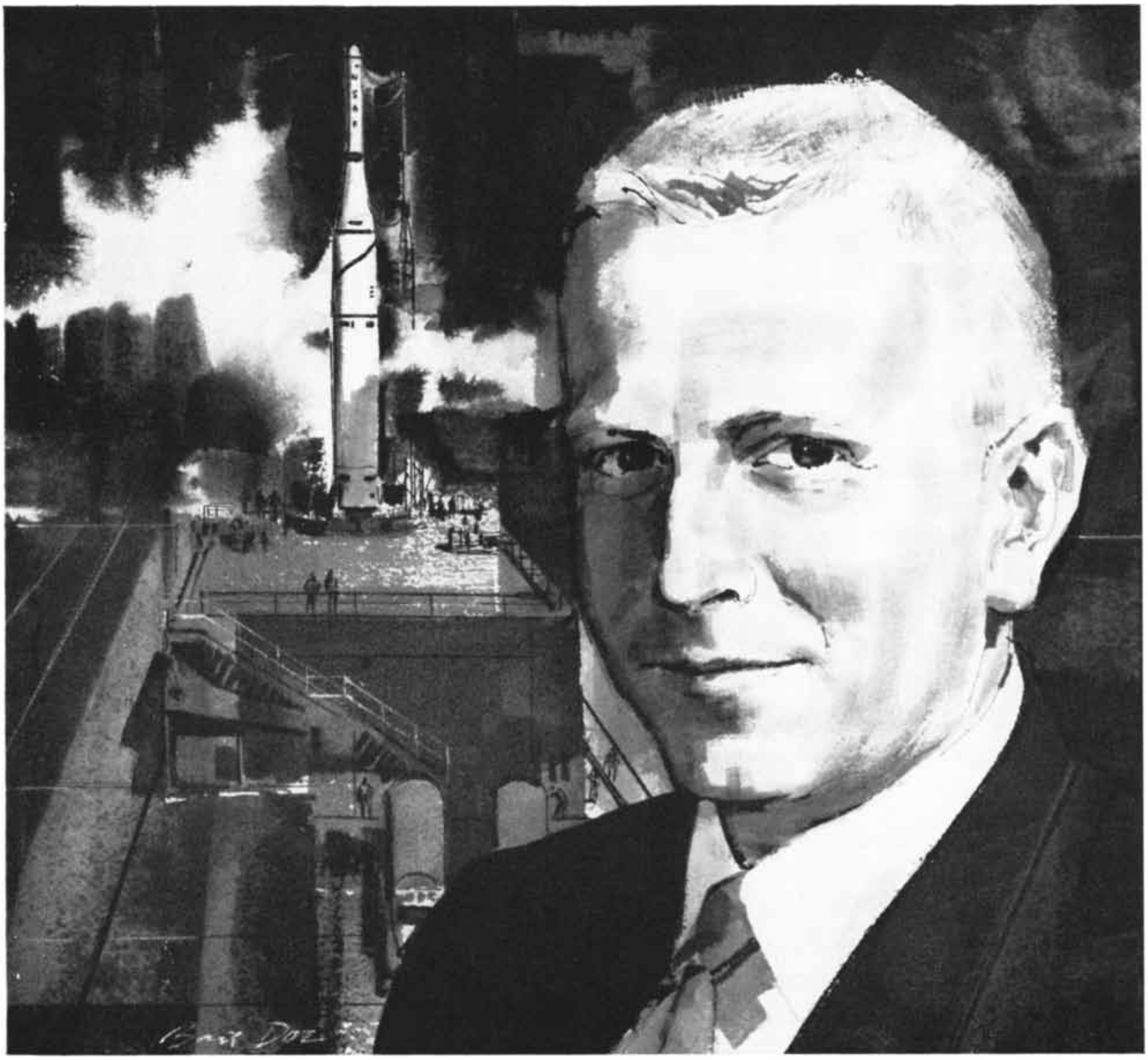
Roger Hayward, who illustrates this department, recommends a more elaborate version of Palmer's device. He makes a pair of wooden brackets with faces at an angle of 45 degrees and sandwiches a half-silvered mirror between them. The slides are clamped to the outer surfaces of the assembly (which meet at a right angle) by means of spring clothespins, as shown in the illustration on page 260. "Palmer's gadget works," writes Hayward, "but the slides tend to jiggle out of register in the saw kerfs. Clothespins, my favorite laboratory clamps, provide solid support. The substitution of a half-silvered mirror for the cover glass increases the brilliance of the image greatly because plain glass is a poor reflector."

William Tyrrel of Hempstead, N. Y., submits a solution for another problem that confronts many amateurs: the construction of a safe and inexpensive source of high voltage required for the operation of Crookes tubes and similar apparatus. "In the years before sources of alpha radiation became available," he writes, "I constructed a high-voltage, low-current supply for neutralizing the static charge that builds up on the paraffin ribbon from a microtome. It was based on a modified spark-coil from a Model-T Ford. The coil was driven by a 110-volt, alternating-current source, and the output was rectified by a vacuum-tube diode. The Model-T coil gave better results than any other.

"The coil was taken apart and the windings immersed for an hour in a mixture of melted paraffin containing about 3 per cent of beeswax at a temperature of 130 degrees Fahrenheit. The primary and secondary windings were next separated and fitted with leads of flexible lamp cord. The assembly was then re-potted in the wax, with the leads extending from the box.

"A vibrator of the type used in the power supply of automobile radios was substituted for the one with which the coil is fitted and was connected with the primary winding [*see illustration on this page*]. For maximum output the vibrator contact must close at the instant a four-microfarad line-capacitor reaches full charge. The time of closure is determined by the value of an iron-core inductance of the type used in 'B' battery eliminators, which is connected in series with the capacitor and is adjusted either by removing iron laminations from the core of the inductance or by adding capacitance. The proper adjustment must be determined experimentally. The coil that drives the armature of the vibrator is energized by the line voltage through a 10-watt lamp. Hence the device operates at 60 cycles per second, and a unidirectional voltage pulse appears at the output every half cycle. The quality of the output is improved by the addition of a rectifying tube of the high-voltage type used in power supply of television sets. The cathode of the tube operates at 30,000 volts above ground potential, so it must be energized by an insulated source. I used a flashlight battery. The current drain is low, however, so a cell will give many hours of service.

"Ford coils can still be procured from at least two of the large mail-order firms and from some of the suppliers who cater to those who make a hobby of restoring antique automobiles."



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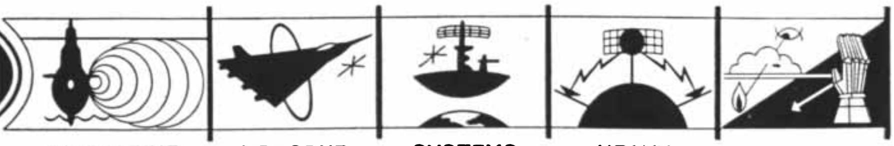

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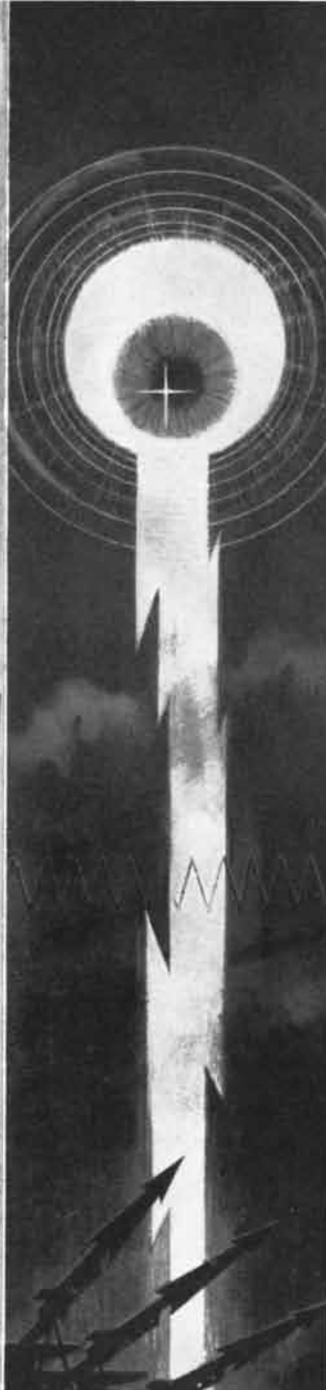

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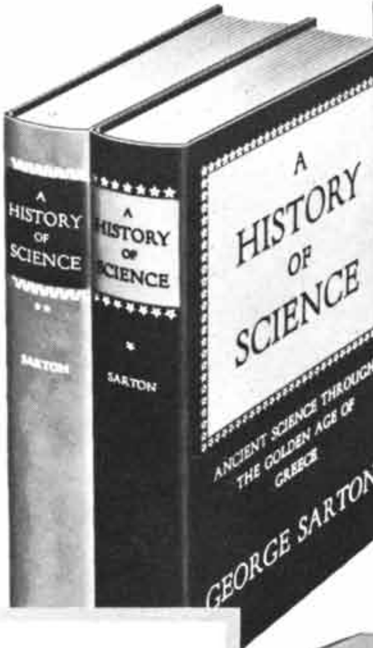

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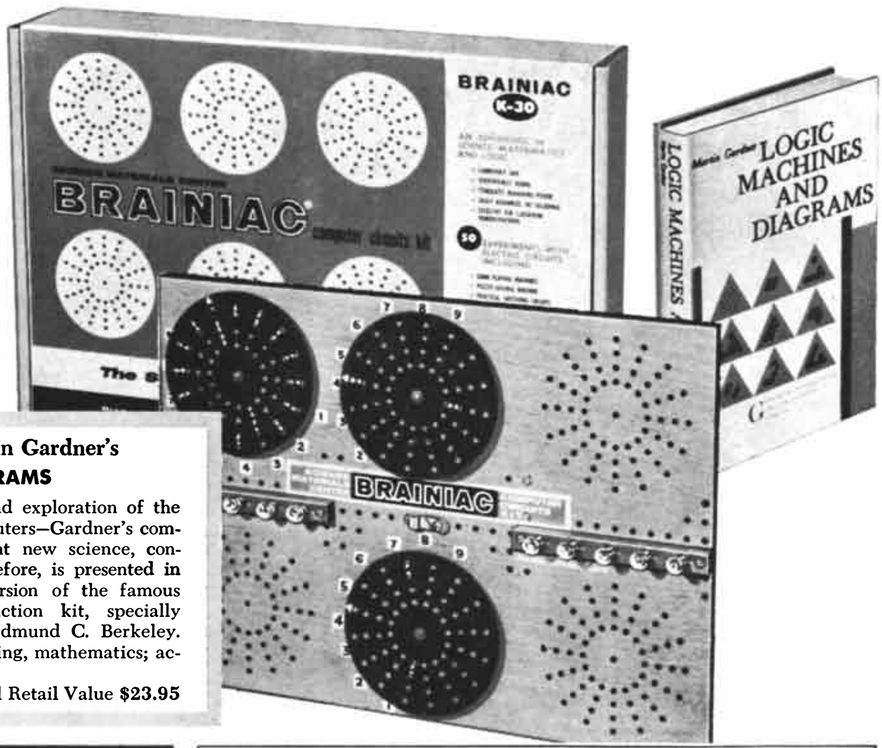

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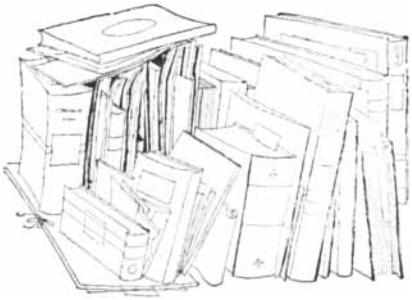

BOOKS

Discussions of the scientific validity of psychoanalysis, and of Freud the moralist

by Robert W. White

PSYCHOANALYSIS, SCIENTIFIC METHOD AND PHILOSOPHY, edited by Sidney Hook. New York University Press ($5).

FREUD: THE MIND OF THE MORALIST, by Philip Rieff. Viking Press ($6).

The first half of the 20th century has seen mankind scale astounding heights of rationality and fall to incredible depths of irrationality. If we fix our eyes on scientific achievement, we discover a world transformed for human use and happiness, but if we think of political history, we peer into mires of passion, hate and murder. Many thoughtful people, living in an age of such promise and such betrayal, have found a needed symbol and hero in Sigmund Freud, the man who dared look steadily at the dark forces within us and who held out hope, however cautiously, that they might be better governed. Freud can be seen as the scientist of the irrational, who used our best instrument—scientific method—to investigate our worst selves, and who told us, in the cool disillusioned spirit of the scientist, what chances we might have of happiness. It may be that Freud is climbing to the status of a modern Copernicus or Darwin; at all events it is a task of our period to come to terms with what he said.

Freud's contribution amounted to a revolutionary picture of human nature. It was worked out in the course of treating neurotic patients, and its strongest factual root still lies in those very intimate thoughts and feelings which only a sick person seeking help would be willing to disclose. Freud hunted relentlessly for meaning—motivational meaning—in the dreams, errors, resistances and symptoms of his patients, and he satisfied himself that these were all manifestations of instinctual energies struggling for discharge through the many barriers imposed upon them by civilization. He saw the young child as a creature of love and hate, of sex and aggression, whose strivings had to be much sacrificed to the demands of constraining parents. These contests more or less permanently shaped the child's personality. If the instincts were too badly defeated, neurosis might follow in later life, and the early inhibitions could be undone only by a protracted process of recollection which brought the ancient issues back into adult consciousness. The grave irrationalities in human behavior could thus be traced to repressed and distorted instincts, driven to unconscious cover by the constraints of the family circle.

The two books reviewed here aim in different ways to come to terms with this revelation. One of them, a symposium of philosophers and psychoanalysts, invites us to consider whether or not Freud really demonstrated his contentions about human nature. Do the theories of psychoanalysis deserve to be considered scientific? The other book, a detailed analysis of Freud's writings by a sociologist, hunts out the moral values that lie hidden in Freud's vision of personality and of psychotherapy. To anyone who is trying to reach a judgment on the significance of Freud's work, these two questions—how true is it all, and what are its moral implications?—are bound to be highly pertinent.

We begin with the scientific problem. The symposium, organized by Sidney Hook at New York University, brought together a distinguished group of psychoanalysts and philosophers who were told to be concerned "solely with psychoanalysis as a scientific theory." U. S. philosophy is currently much interested in the methodology and philosophy of science, so there was no doubt that the philosophers would come with well-sharpened knives. In retrospect Hook, who describes himself as "a seat-calloused veteran of innumerable conferences and institutes," calls this meeting unique in his experience for its "sense of absorption and intellectual excitement among the participants." Could this be because the philosophers, long smarting from Freudian interpretations of their concerns, were at last joined to attack psychoanalysis on its weakest flank?

At all events the psychoanalysts seem to have been much on the defensive. In the book, at least, they are badly outnumbered, being represented in only three of the original nine papers and one of the 19 contributions submitted afterward by other participants. And they must have been aware that the cards were stacked against them, affording no chance to overwhelm with clinical evidence or to dazzle with penetrating intuitions. Forced to stand on the bedrock of cold logic, they pointed to the unfinished, tentative character which Freud himself attributed to his theories, and they made much of the difficulty of precise observation in their realm. But they still claimed scientific status, resting their case mainly on two points. They maintained, in the first place, that the situation in which observations are made—the therapeutic situation wherein the analyst makes himself more or less a blank screen and the patient talks about whatever comes into his head—is sufficiently standardized to permit comparable observations on different days and with different patients. As the psychoanalyst Lawrence S. Kubie expressed it, free association is "our only approximation to a technique by which to secure relatively unweighted representative samples of *all* that is going on in the mind," with a minimum of interference and distortion by the observer. In the second place, observations made in this way, set in the context of much previous observation, make predictions possible—"predictions of various degrees of precision or reliability," in Heinz Hartmann's words, "but as a rule superior to any others that have been attempted in the psychology of personality." Indeed, the whole technique is full of predictions. Quite early the analyst can foretell what problems will next appear, what childhood situations will presently come to light, what points will offer the most stubborn resistance; and there are ways of judging from the patient's subsequent behavior the correctness of the interpretations whereby the analyst attempts to advance his patient's insight. In all this discussion there was scarcely a hint that a psychoanalyst might ever mention the unconscious determinants of philosophy. It remained for a philosopher, Morris Lazerowitz, to declare that "psychoanalysis can alone discover for us what philosophers really say, as against what they delusively appear to say." Many pages of the book, marked by something sharper than intellectual excitement, are used up in refuting this bit of extravagance.

The heaviest artillery directed at the psychoanalysts came from Ernest Nagel, who aimed his fire both at the logic of Freudian theory and at its method of gathering facts. "A credible theory," he said, "must not only be *confirmed* by observational evidence, but it must also be capable of being *negated* by such evidence," and he pointed out several Freudian propositions, such as those concerning instincts, energy levels, and the interrelations of id, ego and superego, which could not possibly be proved false by any conceivable empirical state of affairs. He was also impressed that Freud stuck to the Chevalier de Lamarck's view of inheritance and did not think its rejection by all competent biologists refuted any of his own premises; "it is therefore pertinent to ask what could refute those premises and whether they are at all refutable." These are severe strictures, but they were directed against those aspects of Freud's theorizing that are most metaphorical and that might well prove superfluous if one undertook to build a tighter theory on the basis of his facts. But what about those facts? Are they unequivocal, or does the method of observation poison them from the start with questionable theory?

Here Nagel attacked the very points on which the psychoanalysts tried to rest their case. However neutral the observer may try to be in the psychoanalytic situation, the technique requires that at suitable points in the patient's free associations he offer interpretations as to what he thinks is going on. To an unknown degree—and there are no outside observers to judge in what degree—he "directs the course of the narrative"; the free associations are never left to speak for themselves. Strictly speaking, the patient's response to an interpretation, whether it be agreement, denial, new insight, anxiety or a sense of relief, can never be considered competent evidence for the truth of the interpretation. And when connections with childhood experience are pointed out, they cannot, even if they are correct in the given case, become the basis for causal generalizations unless there is a control group in which the postulated cause and effect never occur singly. What do these criticisms mean for psychoanalytic theory? Nagel concluded: "I can only echo the Scottish verdict: Not proven."

In a way there could hardly be a more crashing anticlimax. Who has supposed that psychoanalytic doctrine was proven, in the strictly logical sense? To see force in Nagel's closing remark we have to know that he is speaking as a logical positivist, and that the members of this school of philosophy hold extremely rigorous standards for admission to the charmed circle of scientific knowledge. Only propositions that can be proved under controlled conditions can be considered scientifically confirmed. The point is dramatized in a contribution by Michael Scriven, who proposes an elaborate and rather impractical experiment to test the proposition that psychoanalytic therapy produces significant improvement in patients. Scriven declares that in the absence of such a crucial test "we are wholly ignorant, I repeat, *wholly* ignorant" concerning the proposition. Obviously we are not wholly ignorant about what has happened in thousands of treated cases, some of which, at least, have been much improved when they left the doctor. What Scriven means by "wholly ignorant," therefore, is not what we mean in ordinary speech. He means that no test has ever been made which fully excludes the possibility that improvement was due to factors other than the treatment, however remote such a possibility may seem to both analyst and patient. And when Nagel denies Freudian theory the status of science, he means that it has not brought its propositions to the level of indisputable proof.

Very much in the spirit of Nagel's cannonade, Hook pressed a question he claimed to have been asking in vain for 40 years. What kind of evidence, he demanded, would psychoanalysts accept "which could lead them to declare in any specific case that a child did not have an Oedipus complex?" The intent of this question is, of course, to determine whether or not one of Freud's most central proposals about the child's emotional development is cast in such a form that some kind of empirical evidence would show it to be false. If it is cast in such a form, then one can look for the evidence, and if this can never be found the theory stands confirmed. But if, on the other hand, there is no conceivable way to prove the theory false, there is also no way to prove that it is true. That psychoanalysts had been unwilling for 40 years to entertain this query seems rather to their discredit, even though the ques-

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tion might need recasting in order to be really fair. But now at last, in unreported discussion and in a subsequent contribution by Jacob A. Arlow, they endeavored to give Hook satisfaction. The attempt shows how difficult it is to satisfy a philosophic expert on scientific method. The acceptable evidence seemed to indicate a wholesale arrest of development, suggesting that only idiots would lack the Oedipus complex. Hook still wanted to know "in what circumstances the behavior of a nonidiotic child would be necessary and sufficient evidence that he had not achieved the oedipal phase of development." Let us hope that a further reply and clarification will come in less than 40 years.

Some of the philosophers were impressed by Nagel's stringent demands, but many of them, especially in the subsequent contributions, hastened to defend psychoanalysis. Was it really sensible, they asked, to deny a promising branch of inquiry the title of science, especially in a time when this term carries so many overtones of goodness and righteousness? Was it helpful to ask for crucial experiments in a realm where crucial experiments are just about impossible? There appeared to be considerable feeling that Nagel had drawn too tight a leash, that Freud's creation should be accorded the privileges of scientific youthfulness and inherent imprecision. Some contributors implied that logical positivism would disqualify all naturalistic, descriptive science, thus discouraging the valuable efforts of thousands of workers who by careful observation and dispassionate judgment stood as exemplars of the scientific spirit. There was even a suggestion that Nagel's requirements would prove too much for physical science. Philipp Frank put in a reminder that the law of conservation of energy cannot be demonstrated generally, but only under certain restricted conditions; that some thinkers consider it tautological; and that others have used this argument "to prove that the general laws of traditional science are not better confirmed than the principles of theology." Surely we should not require that psychoanalysis surpass the rigor of physics.

In such fashion logical positivism won the battle and lost the war. Under the pitiless glare of logic Freud's theories looked loose and leaky, but many participants continued to regard them as embodying highly probable insights into human nature. In taking such a stand they were, of course, making a judgment about uncertainties. But this is no different from what we all do when we make decisions about human affairs, private or public. We run our lives on estimates, not proofs; we send for the doctor when we are ill, even though we know he can only guess what might make us better. Most people who have heard free associations, given them or done experiments involving them, are much impressed by the things that come to light, and they judge it improbable that all these things were in some way suggested from outside, even though, under the circumstances, there is always a chance that they might have been so suggested. We constantly live by such judgments, making our bets as to what is probably the true state of affairs; we offer no apologies for balancing weights of evidence in our minds when they cannot be measured in objective scales. Logical positivism does not want to dignify this universal but fallible operation by the name of science. Yet Freud conceived himself to be a scientist, made his momentous observations with patient care, and left a body of doctrine that most of us perceive as scientific in intent, however faulty may be the fulfillment.

We must account for the fact, however, that the gist of Freud's contribution is accepted today by thousands of thoughtful people who have had no direct experience with free association in the technical sense. What is the appeal of his doctrines to these mere readers of his work? For an opinion of this point we turn to the book by Philip Rieff, who says: "It is precisely its combination of strict medical judgments with a sweeping criticism of the contemporary moral climate that has elevated Freudianism to its present position of intellectual affluence." Science conceives itself to be ethically neutral except on issues of truth and untruth. A system of psychotherapy, however, can never be ethically neutral: There is always an implication of good and bad, desirable and undesirable, even if it is expressed (a little metaphorically) as health and illness, in any procedure that undertakes to bring about changes of personality. But Rieff's remark clearly implies more than this minimum commitment to good against evil. Viewing Freud as "the presiding figure in our culture," he extracts from his writings an impressive—though not strictly measurable—body of evidence that Freud was a significant modern moralist, a man who "derived lessons on the right conduct of life from the misery of living it."

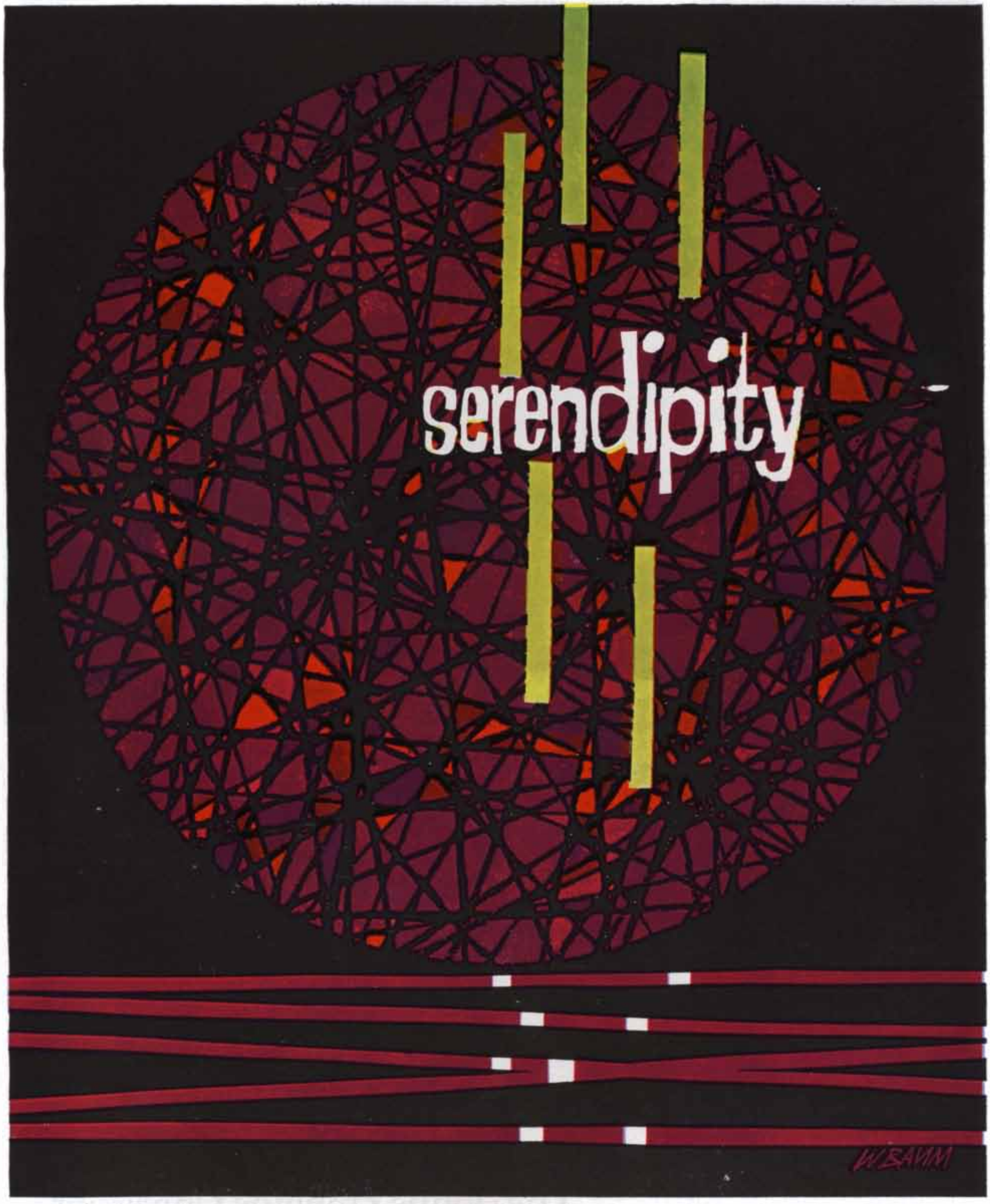
The reader of this book should not be in a holiday mood. Rieff's tremendous scholarship and rich reflections fill his pages with memorable treasures but preclude both a brisk pace and an orderly unfolding of the argument. Those who believe that one man alone in his study can contribute more than 50 men chattering at a symposium will very likely feel that our present pair of volumes constitutes a case in point. If we reduce Rieff's argument to a simple summary, it cannot be on the analogy of boiling down maple syrup, where what goes up in steam is merely superfluous water. All of the book is nourishing, even when it seems to stray from its theme.

Freud's implicit morality can best be approached by considering what is supposed to happen to the neurotic patient during treatment. The patient is told to tell everything and conceal nothing that passes through his mind, an instruction that soon proves to set a taxing ethical ideal of honesty. In particular he is warned to suppress nothing in the interests of conventional decency, for this will only distort the revelation of his real motives. In technical terms, the job to be done is to unmask and neutralize the superego, the irrational force established in the child's mind by parental punishments and prohibitions. If the crippling anxieties and guilt feelings engendered by the superego can be lifted, if repression can be abolished, the instinctual urges need no longer express themselves in the indirect, distorted forms that constitute neurotic symptoms. Instead, they are governed by the realistic ego and are guided by adult, conscious judgment. The goal of treatment is thus to free the patient from the irrational anxieties that have come to beset him as a consequence of his childhood training to be a member of civilized society.

If we looked no deeper, this account of the patient's progress could easily pass for a movement in the direction of health. But neither Rieff nor Freud allows us to look no deeper. Freud's writing did not stop at patients and therapy. If one overlooked a polemical intent in his clinical papers, in spite of the constant dramatic opposition between the unhappy instincts and an overbearing culture, one could certainly not miss it in *Civilization and Its Discontents*, where the toll taken by civilization from man's instincts was explicitly mourned, or in *The Future of an Illusion*, where for once with obvious passion he unmasked what he conceived to be the stupidity and cruel repressiveness of religion. It is worth noting that Freud's anger against religion was not a personal rebellion against early teachings, of which he had none; his image of religion was usually that of Viennese Roman Catholicism, with its hierarchy of authority, its pressure toward conformity and its anti-Semitism. This was the culture toward which he felt such a powerful antipathy. Producing neurosis was but one of the evils he laid at its door. Civilized pretensions in general annoyed him: "There are many more hypocrites than truly civilized persons." The world needed a whole new standard of righteousness.

With convincing detail Rieff shows us the intrusion of Freud's moral values into his scientific theories. The superego, as he described it, seemed to be roughly equivalent to conscience, which is generally assigned a constructive part in behavior, but he made it infantile, irrational and in cases of neurosis harshly punitive. Feelings of guilt he considered to be symptoms of neurosis. Freud thus circumscribed and made evil the traditional forces for good, but correspondingly he greatly enlarged the meaning of sexuality and greatly improved its ethical position. Rieff points out that he "concentrated in the attributes of sexuality every variety of emotion: sympathy and attachment, respect and contempt, parental love and filial piety, friendship and enmity." Thus many a virtue hitherto claimed by the moral hypocrites turned out to be a manifestation of the very urge they most strenuously denied. Freud's *Three Contributions to the Theory of Sex* is seen by Rieff to be at once "an oblique 'scientific' plea for great sexual latitude" and "a way of scoring points against the repressive order." Freud's formulation also involved the contention that sexuality, being a fundamental instinct, can never be fully tamed. "In sexuality," says Rieff, "and in the products of fantasy (dreams, wit and art) a refuge from society is created. At the same time these activities defy society and triumph over it; they are a mode of blasphemy."

This revelation of Freud's ethical mission should not, however, be carried to the point of seeing in him a Romantic champion of sexual liberation. There is no hint of the noble savage in his view of the child's "polymorphous perverse" sexual life. There is nothing lyrical about his drily scientific account of sexual impulse. Indeed, Reiff considers that his whole idea about sex has an element of harshness, an air that it was a little nasty after all, and a sad feeling about the fleeting character of satisfaction. "The erotic life, like the economic, becomes under Freudian guidance an area for methodical self-examination and systematic improvement. . . . In this sense, although Freud is critical of middle-class moralism, he himself may be charged



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8641 Georgia Avenue, Silver Spring, Maryland with being very middle-class in his moral attitudes." No libertine in his personal life, Freud assumed that the entry of sexual impulses into consciousness would not lead to an "unrealistic" disregard for social convention. Perhaps it is legitimate to say that Freud loved sex less than he hated the hypocrisy that denies sex while claiming for itself the supposedly civilized virtues.

We arrive, then, at the heart of Freud's ethical imperative. The good is somehow identified with honesty—with the opposite of "civilized" self-deception—and thus with the untrammeled functioning of the ego, which is responsible for knowing about reality, both external and internal. Just as the cure of the patient means a strengthening of the ego, so the good life for all men means being free from illusions about oneself and the world. Freud once asked how people would behave "if their flight into illness is barred by the indiscreet revelations of psychoanalysis." His answer, says Rieff, "hints another kind of civilization, one that is not built on reticence or hypocrisy: they will have to 'confess to the instincts that are at work in them, face the conflict, fight for what they want, or go without it.' " This is Freud's definition of normality, but normality for him was a rare thing, difficult to achieve—an exacting ethical ideal. The deep strain of pessimism that many people have felt in his doctrines lies partly here: The rational, realistic ego is our only hope, but the ego is weak amidst the forces surrounding it, and there is only an outside chance that it will really prevail.

Freud's contribution as a moralist thus consists of what Rieff calls "the ethic of honesty." "This honesty Freud would have us achieve by working through the layers of falsehood and fantasy within us to a superior accommodation to reality." The new conscience demands a special candor and disenchantment, "a more accurate and yet more scrupulous self-centeredness." The ideal image created by the ethic is that of "psychological man," seen by Reiff as the natural successor of economic man, who has been our most recent dominant moral type. "Once again," says Rieff with something of a flourish, "history has produced a type specially adapted to endure his own period: the trained egoist, the private man, who turns away from the arenas of public failure to re-examine himself and his own emotions." And he points out an astounding irony, that psychological man "has espoused the Oriental ideal of salvation through self-contemplative manipulation just at the historic moment when the Orient, whose westernmost outpost is Russia, has adopted the Occidental ideal of saving activity in the world." But perhaps our author has gone too far when he finds something Oriental about an ethic that actually arose as a protest against upper-middle-class Viennese society in the late 19th century. As he points out elsewhere, Freud's ego is a brisk managerial agency: rational, prudent, with a gift for compromise, by no means disposed to turn its back on everyday realities or to court unnecessary friction with existing conventions. Psychological man may look within, but he is very much of this world.

The current appeal of Freud's ethical message is a powerful one in intellectual circles. He speaks to those who have become disillusioned about consoling beliefs and public enthusiasms, telling them that life should be led without such beliefs and enthusiasms. But Rieff does not allow potential converts to overlook the disturbing consequences of being a psychological man, consequences that may have arisen from Freud's own complete isolation from public affairs and from the fact that, thinking of himself as a neutral scientist, he never brought to his own consciousness the moral implications of his ideas. There is, according to Rieff, a "fatal lack of commitment about Freud's ideal type." The ego-directed, uninhibited person will be "busy, spirited, and self-confident," but this goal "will inspire only those who have resigned the ghosts of older and nobler inspirations." Rieff further points out that Freud "never understood the ethic of self-sacrifice," and that on this account his doctrine offers no real opposition to quite sinister possibilities. "Being honest, admitting one's nature, does not resolve specific issues of choice. . . . Freud gives no reason why unblinking honesty with oneself should inhibit unblinking evil." Psychological man thus proves in the end to be not a whole man. If he finds ways to affirm his membership in society, if he becomes a participant in cooperative endeavors to improve the conditions of life, he will be acting on some moral behest that was foreign to the founder of psychoanalysis.

Much as we owe to Rieff for his extraordinary analysis of the moral implications of Freud's doctrines, it is perhaps necessary to keep reminding ourselves that Freud did not strictly intend to be a moralist. And those who find him a hero perhaps similarly do not intend to take him as a complete moral guide. But this whole question has been shrouded in an obscurity which Rieff has now gone far to dispel.

Short Reviews

THE ART OF NAVIGATION IN ENGLAND IN ELIZABETHAN AND EARLY STUART TIMES, by D. W. Waters. Yale University Press ($12.50). This massive, attractively illustrated book is a thorough and scholarly history of the development of navigation during a period of dramatic advance, from 1550 to 1630. A new age of exploration, colonization and merchant enterprise demanded improvements in the mariner's art, which in the mid-16th century consisted mainly of the individual pilot's skill aided by handwritten records of traditional knowledge. Pilotage, or coasting, as described by a 16th-century French writer, meant "knowing perfectly by sight all the capes, ports and rivers met with, how they rise up and how they appear from the sea, and what distance lies between them, and what route or course, or rather bearing, they have one from another; also in knowing on what rhumb (bearing) of the moon high and low tides occur and the ebb and flow of the waters; and in knowing the depth and nature of the bottoms." Oceanic navigation—*la navigation grande*—was a more formidable profession: the navigator had not only to be a well-tried pilot, but had to know how to direct the ship's course in the absence of landmarks, to fix the ship's position by instrumental observation of heavenly bodies and mathematical calculation. The 80 years covered by Commander Waters's monograph saw much progress in chart-making, position-finding, the preparation of reliable tables, the construction of globes, compasses, astrolabes and other instruments, ship design and the training of navigators. Until the latter half of the 16th century an English shipmaster was still typified by Chaucer's "shipman" who had:

. . . to rekene wel his tydes,
His stremes and his daungers him bisydes,
His herberwe and his mone, his lodemenage . . .
Hardy he was, and wys to undertake;
With many a tempest hadde his berd been shake.

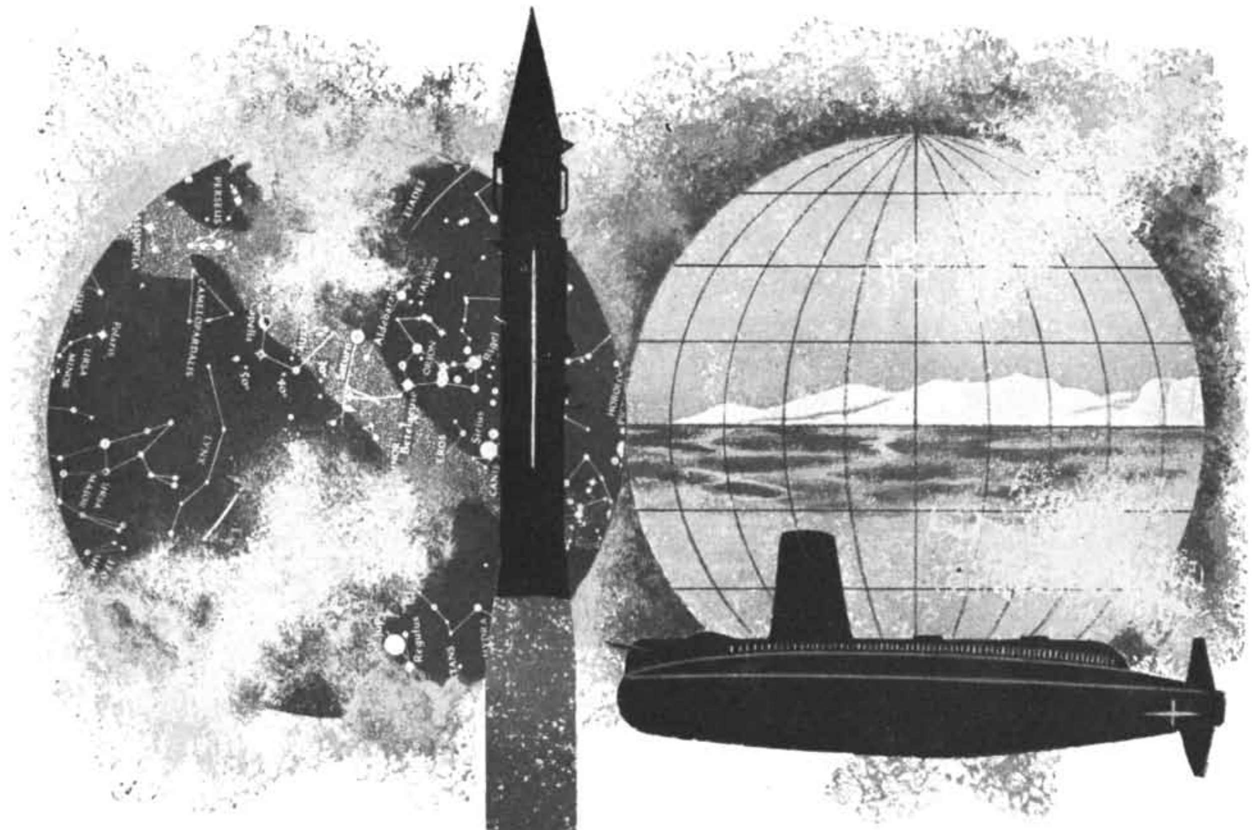
But little more than half a century later the master's beard had not only to withstand the tempest, but the rigors of trigonometry, of arithmetical and logarithmical navigation, of new learning—and its application—in astronomy, mathematics and hydrography. Waters's fact-filled, graphic story, which will give pleasure to readers of many different interests, has an extensive bibliography, a superb index (which merits special mention), 87 plates and 43 figures.

TRIGONOMETRIC SERIES, by A. Zygmund. Cambridge University Press ($27.50). The first edition of this work, published in Warsaw in 1935 and later translated into English, was at once accepted as the best study of its kind. In the last quarter-century the theory of trigonometric series, as the author points out, has undergone considerable change. Its notions and methods now appear in abstract form, in distant fields such as the theory of groups, algebra and the theory of numbers. Zygmund has taken account of progress in this much-enlarged and revised edition. The first volume of this two-volume work contains the rewritten material of the original book; the second volume covers much material that has not been previously published in book form, including trigonometric interpolation, differentiation of series, complex methods, Fourier integrals, convergence and summability.

THE GOLD OF TROY, by Robert Payne. Funk & Wagnalls Company ($3.95). A biography of the legendary Heinrich Schliemann, trader, plunger, banker, antiquarian, historian, philologist, archaeologist, who uncovered the buried cities of ancient Greece. Schliemann was born in 1822 in the parsonage of an obscure village in Mecklenburg-Schwerin, not far from the Polish frontier. His formal schooling ended when he was 13, and thereafter he had to fend for himself. His first job was as a grocer's assistant, but before he was 30 he had made a fortune as an indigo merchant in St. Petersburg and as a buyer of gold dust in Sacramento. He was an extraordinarily complex and gifted man who did not know what he wanted, could not fail at what he undertook and was unable to enjoy what he achieved. Self-taught, he mastered some 12 or 13 languages within a few years, learned the *Iliad* and the *Odyssey* by heart, studied philology at the Sorbonne, was cultivated and well mannered, and lived like a prince. But the image he showed to the world bore little resemblance to the inward man. The years of privation, wretchedness and frustration had scarred him. He was restless, driven, suspicious, contemptuous, deceitful and vainglorious. No matter how his wealth multiplied—on top of what he already had he made millions profiteering in the Crimean War—he was constantly in hysterical fear of ruin. "Fires blazed in him and sexual passion drove him almost insane. Above all he wanted a wife and children and with all the women in Russia to choose from, he had to choose a cold virago who married him only for his money, refused to share his bed, taunted him continuously, and lived out her life as though she were waiting for him to die so that she could inherit his fortune." By this woman he had three children, having "stolen" two of them from her, as he wrote brutally. Finally he divorced her in Indianapolis (he had become an U. S. citizen for the purpose), and soon afterward in Athens married a lovely 17-year-old Greek girl, a third his age, picked out for him by a friend pursuant to specifications and approved by Schliemann from a photograph. The marriage marked a turning point. With adventures, travels and successes behind him enough to fill a dozen lives, Schliemann at last found the clue to himself and began the career for which he is remembered. His grand and passionate aim was to unearth the buried city of Troy, and to that end he began a series of extensive excavations. He was surely the most erratic, impulsive and unscientific of archaeologists; he was also self-seeking, dishonest, greedy for the treasure he hoped to find, more interested in gold than in knowledge. Yet there was a genuine urge to uncover the past, a last desperate hope for self-fulfillment in making contact with the remains of the Greek heroes whose deeds had haunted and fascinated him since childhood. He dug like a madman, recklessly destroying whatever blocked his path to treasure; he uncovered walls and palaces and cities and enough antiquities (most of which he stole for himself) to fill a museum. His grandiose notions of the places he located—Hissarlik, for example, his greatest excavation, he believed to be the ancient citadel of Homer's Troy—were completely wrong; he had touched Troy but failed to recognize it "because he worked with such astonishing speed and because he was tempted to remove everything that was not Homeric from his path." The world he thought he had found probably never even existed; in his mania he created it because it was so much more beautiful than the world he knew. Still, through a blend of flaming imagination, high skill and incredible perseverance, he did a giant's work and, as Payne says, in the roll call of those who have brought the Homeric age to life Schliemann was the boldest and saw the farthest. An absorbing, fast-moving story, written in Payne's practiced, lightning-quick style. It is inexcusable, however, that the book has no index.

The Crossing of Antarctica, by Sir Vivian Fuchs and Sir Edmund Hillary. Little, Brown and Company ($7.50). The story of the Commonwealth Trans-Antarctic Expedition 1955-1958, told by its leaders. In November, 1957, after two years of intensive preparations and reconnaissance, Fuchs and 11 of his men set out on a tractor-and-sledge journey across the Antarctic continent, from Shackleton Base, which they had established on the Weddell Sea, over the Pole to Scott Base on the Ross Sea. The 2,500-mile journey took 99 days. Earlier Hillary had traveled from Scott Base to the Pole, marking a trail and setting up supply depots that facilitated Fuchs's traverse. The achievement itself is not as dramatic as the polar expeditions of a hardier day: the mechanized equipment, radio communications and aircraft support inevitably dull the edge of the adventure. Still it was an exciting feat, here very ably reported and holding one's attention throughout. The weather was mostly frightful, as Antarctic weather usually is; the repeated white-outs were formidably dangerous; the Sno-Cats and Weasels kept falling into treacherous crevasses (though miraculously no one was injured and no tractor was lost). There were innumerable mechanical difficulties, and although extensive repairs—some requiring complete rebuilding of engines and tracks—had to be made in portable tent-workshops at 10,000 feet altitude in 35-below-zero weather, with a 30- or 40-knot "breeze" blowing, the engineer crew managed to keep every vehicle rolling as long as it was needed. Scientific observations were made along the way, including geological surveys, seismic soundings of ice depth, mapping, collection of meteorological data, glacier studies, physiological research. But for most of the participants it was the journey itself, rather than its scientific fruits, that justified the undertaking. G. L. Mallory's oft-quoted epigram that men climb mountains "because they are there" does not really hit the mark; they climb them, as they explore deserts and polar wastes, because of the danger, the satisfactions of shared privation, the beauty of silence and lovely places. Excellent illustrations.

The World of Insects, by Paul Pesson. McGraw-Hill Book Company, Inc. ($15). A translation from the French, by R. B. Freeman, of a lavishly illustrated popular survey of insects: their history and evolution, respiration,



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BRANCH OFFICES: BOSTON, NEW YORK, CHICAGO, SAN FRANCISCO, PASADENA, AND LONDON, ENGLAND conservation of water, reproduction, embryology and development, sense organs and behavior, relation to climate and man. Insects, as the author clearly shows, are the most effective of living forms, and if man should succeed in exterminating himself, they will very properly inherit the earth. There are 225 photographs (some are marvelous), 52 in color. The color pictures are not of exceptional quality.

The Gulf Stream: A Physical and Dynamical Description, by Henry Stommel. University of California Press ($6). A technical monograph by a physical oceanographer who has spent some years in specialized study of the subject. The book discusses the history of ideas about the Gulf Stream, the instruments used to observe and measure its behavior, the balance of forces in the Stream, its hydrography, the wind system over the North Atlantic, linear and nonlinear theories of the Gulf Stream, meanders in the Stream, fluctuations in the current, the role of the thermohaline circulation. The author's general conclusions run along these lines: The central North Atlantic is covered to a depth of about 700 meters with a layer of warm water, slowly drifting toward the southwest under the combined influence of the wind and the earth's rotation. This is the fabled Sargasso Sea. It does not reach the eastern coast of North America but is bounded some distance offshore by the Gulf Stream, which "acts as a kind of dynamic barrier" or dam, which by virtue of the Coriolis force restrains the Sargasso Sea from overflowing the colder northern water of the North Atlantic. The water in the Stream is not much different in temperature from that in the Sargasso; the Gulf Stream, in short, "is not an ocean river of hot water," as is commonly supposed. Thus the popular and long-established belief that the Gulf Stream keeps the European climate warm is open to question. It is unlikely that the Stream itself has a direct climatological influence; more probably its effects are indirect, in determining the northern boundaries and average-temperature structure of the large mass of warm water on its eastern flank. Because of the many complex factors that must be taken into account, including the transport of the Stream, the physical relations between the Stream and the density and thermal structure of the water on either side, the thermocline of the Sargasso, the radial shrinking of the current system, the rates of the formation of water masses, the effects of wind on ocean currents and vice versa, oceanographers have not thus far succeeded in framing a comprehensive, testable theory of the Gulf Stream. A great deal of work must still be done before we can hope to understand the physical processes involved.

The Fossil Book, by Carroll Lane Fenton and Mildred Adams Fenton. Doubleday and Company, Inc. ($12.50). Fossils are remains or traces of organisms that lived during ancient geologic times and were buried in rocks. Ancient geologic times is a loose expression covering an enormous span from 1.5 billion years ago to the beginning of the present ice age; and the word rocks is not confined to its common usage but may mean gravel, clay, permafrost, paraffin beds, asphalt, amber or any other substance that registers and preserves traces of organic matter. In these traces the long story of life on our planet has been written, the story of our antediluvian ancestors and relatives, of the unceasing change that led "from jelly-like blobs to oaks and redwoods, from very simple wormlike creatures to snails, elephants and dinosaurs." The Fentons present an excellent account in text and pictures of the evolutionary parade. Their book explains how fossils have been preserved by freezing, drying, simple burial, fixing in wax and asphalt, carbonization, petrification, the formation of casts and molds, the solidification of tracks, trails and burrows. In some cases the complete organism has been almost perfectly preserved, but in most instances mere fragments are the basis of reconstruction of past life. From footprints men have learned where dinosaurs walked, ran and rested; from furrows, the trail of trilobites and snails; from bones, the nature of the soft anatomy and mental and sensory equipment of many fossil vertebrates; from fossil spores, the chromosome structure of plants; from bone lesions and scars, the diseases (*e.g.*, rheumatism, arthritis, tumors, abcesses) of ancient vertebrates; from the shapes and positions of shells, the habits of invertebrates. In 1950 Harold C. Urey analyzed a Jurassic belemnite roughly 150 million years old, and from the isotopes of oxygen present in the fossil he was able to show that the animal hatched in the summer, lived almost four years and died in the spring; that during its life summer temperatures ranged from 68 to 70 degrees Fahrenheit and winter temperatures from 59 to 64 degrees. The Fentons' book has hundreds of drawings and photographs, eight color-plates that show both actual fossils and restorations of

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plants and animals, a glossary, a bibliography, and directions on how to collect fossils.

HISTORY OF AMERICAN STEAM NAVIGATION, by John H. Morrison. Stephen Daye Press ($10). Reissue of a noted history first published in 1903. Morrison's book is a mine of important as well as marvelously trivial information about steamships and steamboats of the century following Fulton's *Clermont*. It covers the experimental period, the vessels of the Hudson and Delaware rivers, western-river navigation, coastal traffic, the lines plying Long Island Sound, Lake Erie and Lake Ontario, Maine and Boston shipping, ocean lines and liners, steam ferries and tugs, lighthouses, the deepening of New York City's Hell Gate. There is even a section on the steam calliope. Fifty quaint pen-and-ink drawings by Samuel Ward Stanton and a few photographs illustrate this volume, which will delight the antiquarian and inform the student of technology.

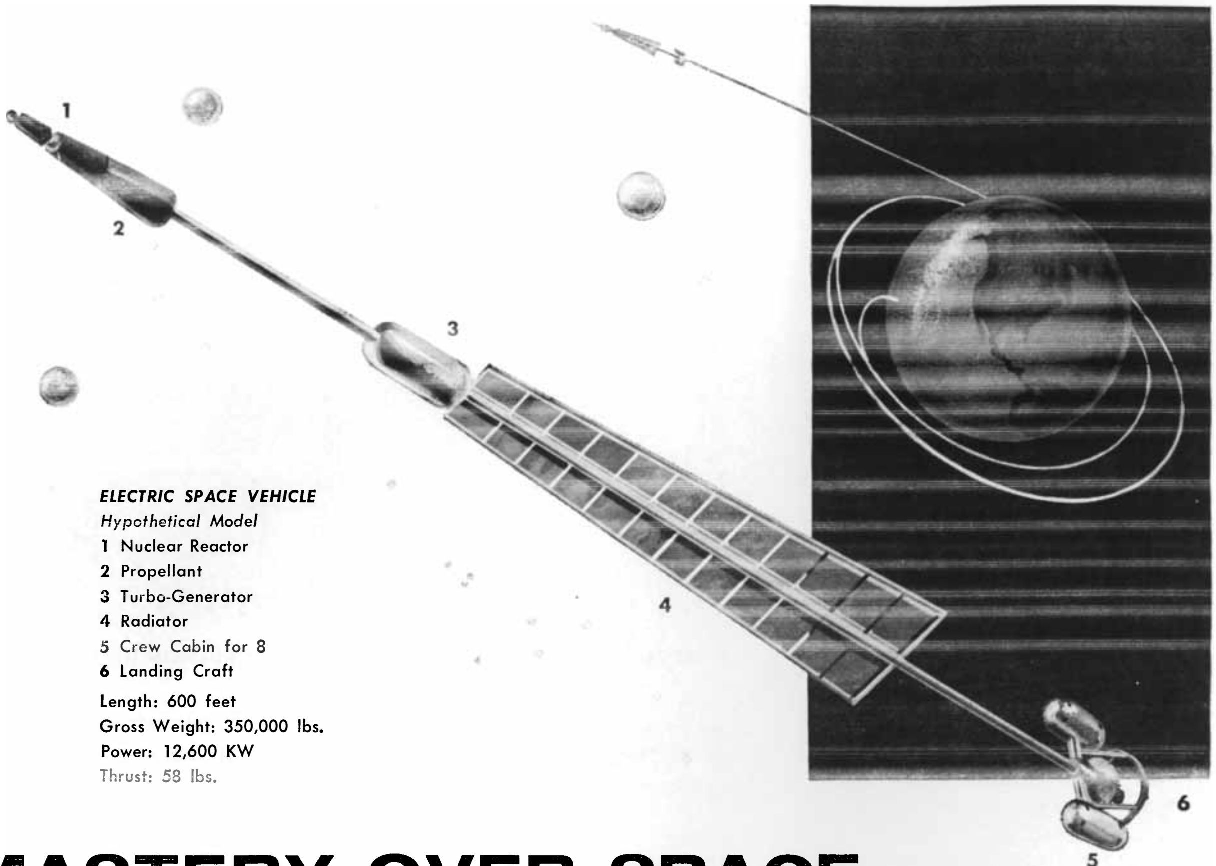
Notes

BIOLOGICAL AND BIOCHEMICAL BASIS OF BEHAVIOR, edited by Harry F. Harlow and Clinton N. Woolsey. The University of Wisconsin Press ($8). Papers presented at a symposium at the University of Wisconsin, attempting to correlate studies in progress in anatomy, physiology, biochemistry and behavior.

PSYCHOPHARMACOLOGY FRONTIERS, edited by Nathan S. Kline. Little, Brown and Company ($10). Proceedings of the Psychopharmacology Symposium of the Second International Congress of Psychiatry, with papers by many different specialists on the general problems of psychopharmacology, clinical observations and descriptions of the action of various drugs, and studies on the mode of action of psychotherapeutic drugs.

DICTIONARY OF PHYSICS AND ALLIED SCIENCES; VOL. I, GERMAN-ENGLISH, edited by Charles J. Hyman. Frederick Ungar Publishing Co., Inc. ($9). The first bilingual dictionary primarily devoted to physics, with some coverage of related sciences such as mathematics, astronomy, chemistry, mineralogy, geology, geophysics, meteorology and technology.

THE NEW SCIENCE, by Max Planck. Meridian Books, Inc. ($5). Three complete works of Planck are collected in this attractive volume: "Where is Science Going?", "The Universe in the



ELECTRIC SPACE VEHICLE
Hypothetical Model
1 Nuclear Reactor
2 Propellant
3 Turbo-Generator
4 Radiator
5 Crew Cabin for 8
6 Landing Craft

Length: 600 feet
Gross Weight: 350,000 lbs.
Power: 12,600 KW
Thrust: 58 lbs.

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Light of Modern Physics" and "The Philosophy of Physics." There is also a brief prefatory essay by Albert Einstein and a biographical introduction by James Franck. A fine package.

INTRODUCTION TO SYMBOLIC LOGIC AND ITS APPLICATIONS, by Rudolf Carnap. Dover Publications, Inc. ($1.85). First English translation of a text by an outstanding authority, covering the elementary and advanced portions of the theory of symbolic logic and treating its applications.

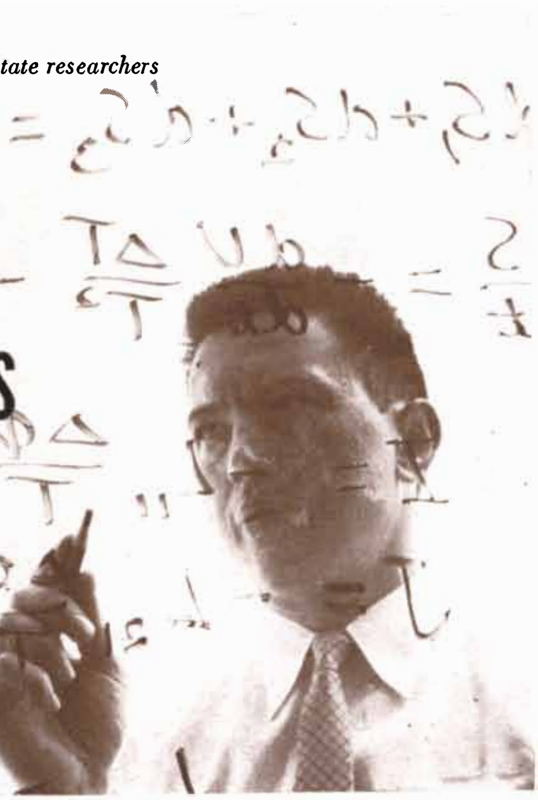
THINKING TO SOME PURPOSE, by L. Susan Stebbing. Penguin Books (95 cents). A reissue of Miss Stebbing's manual of first aid to clear thinking, which exposes the assorted stupidities, illogicalities, canned ideas, frauds and chicaneries by which politicians succeeded in bamboozling not only us but themselves. This book was pointed to the world problems of 1939 but was never more needed than today.

THE NEW CAMBRIDGE MODERN HISTORY: VOL. II, THE REFORMATION, 1520-59, edited by G. R. Elton. Cambridge University Press ($7.50). The second volume in this new series which succeeds, without necessarily supplanting, the first *Cambridge Modern History* of 50 years ago, describes the open conflicts of the Reformation "from Luther's first challenge to the uneasy peace of the early 1560's." The chapter on intellectual tendencies has a section on science written by A. R. Hall.

PHYSICAL LAWS AND EFFECTS, by C. Frank Hix, Jr., and Robert P. Alley. John Wiley & Sons, Inc. ($7.95). A compilation for engineers of major physical laws and effects from absorption and Ampère's law to Wien's displacement law and the Zeeman effect. Descriptions and examples are given in clear language, and references to the literature. A quite useful book but overpriced.

A SHORT ACCOUNT OF EARLY MUSLIM ARCHITECTURE, by K. A. C. Creswell. Penguin Books ($1.95). This book, based on the author's well-known larger work, explains how Muslim architecture was born and describes the cultural influences that helped to mold it. Seventy-two plates and numerous text figures.

THE THEORY OF ELEMENTARY PARTICLES, by J. Hamilton. Oxford University Press ($12). An account of the basic mathematical methods used in investigating elementary particles.



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BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful.

WHAT IS IONIZING RADIATION?

PRINCIPLES OF RADIOLOGICAL PHYSICS. Ugo Fano in *Radiation Biology*, Vol. I, Part 1, pages 1-44. McGraw-Hill Book Company, Inc., 1954.

THE CIRCULATION OF RADIOACTIVE ISOTOPES

RADIOACTIVITY IN GEOLOGY AND COSMOLOGY. T. P. Kohman and N. Saito in *Annual Review of Nuclear Science*, Vol. 4, pages 401-446; 1954.

THE RADIOACTIVITY OF THE ATMOSPHERE AND HYDROSPHERE. Hans E. Suess in *Annual Reviews of Nuclear Science*, Vol. 8, pages 243-256; 1958.

IONIZING RADIATION AND THE LIVING CELL

ACTIONS OF RADIATIONS ON LIVING CELLS. Douglas Edward Lea. Cambridge University Press, 1955.

ATOMIC RADIATIONS AND LIFE. Peter Alexander. Pelican Books, 1957.

IONIZING RADIATION AND THE CELL. Edited by Roy Waldo Miner. *Annals of the New York Academy of Sciences*, Vol. 59, Art. 4, pages 467-664; February 3, 1955.

RADIATION BIOLOGY. Edited by Alexander Hollaender, with the cooperation of Austin M. Brues, Berwind P. Kaufmann, Hermann J. Muller and Lauriston S. Taylor. McGraw-Hill Book Company, Inc., 1954.

IONIZING RADIATION AND THE WHOLE ANIMAL

EVIDENCE FOR A HUMORAL FACTOR (OR FACTORS) CONCERNED IN RECOVERY FROM RADIATION INJURY: A REVIEW. Leon O. Jacobson in *Cancer Research*, Vol. 12, pages 315-325; 1952.

THE RELATIONSHIP OF X-RAY DOSE TO THE TIME OF DEVELOPMENT OF RADIATION SICKNESS FOLLOWING EXPOSURE TO A SINGLE DOSE OF X-RAYS. W. M. Court Brown and John D. Abbatt in *British Journal of Radiology*, Vol. 28, pages 153-158; 1955.

REPORT OF THE UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION. General Assem-

bly Official Records: Thirteenth Session. Supplement No. 17, 1958.

IONIZING RADIATION AND EVOLUTION

THE CAUSES OF EVOLUTION. J. B. S. Haldane. Harper & Brothers, 1932.

THE DARWINIAN AND MODERN CONCEPTIONS OF NATURAL SELECTION. H. J. Muller in *Proceedings of the American Philosophical Society*, Vol. 93, No. 6, pages 459-479; December 29, 1949.

EVOLUTION, GENETICS AND MAN. Theodosius Dobzhansky. John Wiley & Sons, Inc., 1955.

GENETICS, PALEONTOLOGY AND EVOLUTION. Edited by Glenn L. Jepsen, Ernst Mayr and George Gaylord Simpson. Princeton University Press, 1949.

RADIATION AND THE ORIGIN OF THE GENE. Carl Sagan in *Evolution*, Vol. 11, No. 1, pages 40-55; March, 1957.

IONIZING RADIATION AND MEDICINE

DR. W. C. RÖNTGEN. Otto Glasser. Charles C. Thomas, 1945.

A MANUAL OF ARTIFICIAL RADIOISOTOPE THERAPY. Edited by Paul F. Hahn. Academic Press, 1951.

A PRACTICAL MANUAL ON THE MEDICAL AND DENTAL USE OF X-RAYS WITH CONTROL OF RADIATION HAZARDS. American College of Radiology, 1958.

RADIATION DOSIMETRY. Edited by Gerald J. Hine and Gordon L. Brownell. Academic Press, 1956.

RADIATION HAZARDS AND WHAT IS BEING DONE ABOUT THEM: A SYMPOSIUM. *The American Journal of Roentgenology, Radium Therapy and Nuclear Medicine*, Vol. 78, No. 6, pages 944-1,002; December, 1957.

RADIATION HYGIENE HANDBOOK. Edited by Hanson Blatz. McGraw-Hill Book Company, Inc., 1959.

IONIZING RADIATION AND ORGANIC CHEMISTRY

THE EFFECTS OF IONIZING RADIATION ON NATURAL AND SYNTHETIC HIGH POLYMERS. Frank Alden Bovey. Interscience Publishers, Inc., 1958.

THE EFFECTS OF RADIATION ON MATERIALS. Edited by J. J. Harwood, Henry H. Hausner, J. G. Morse and W. G. Rauch. Reinhold Publishing Corporation, 1958.

THE PHYSICS OF RUBBER ELASTICITY. L. R. G. Treloar. Oxford University Press, 1949.

PRINCIPLES OF POLYMER CHEMISTRY.

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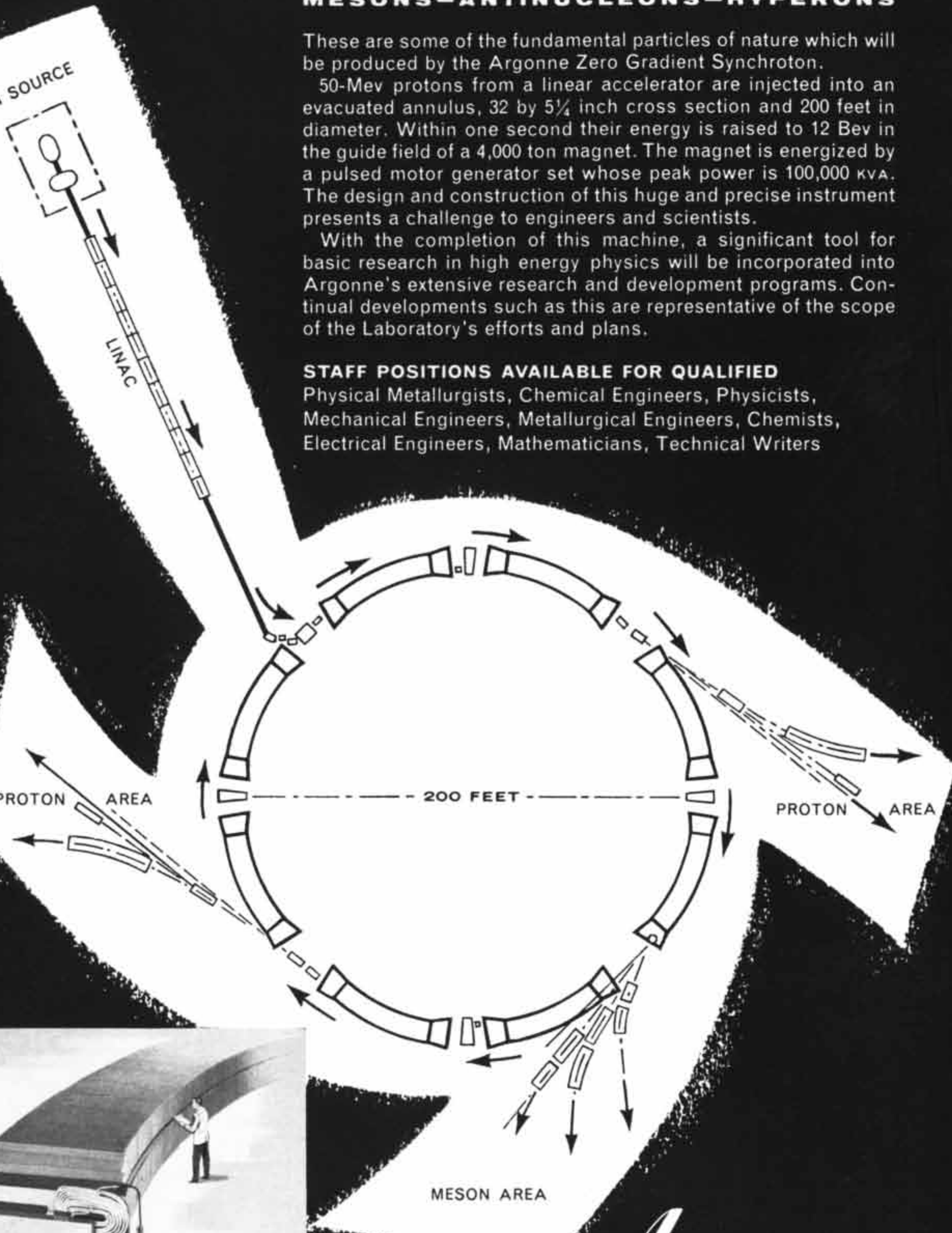

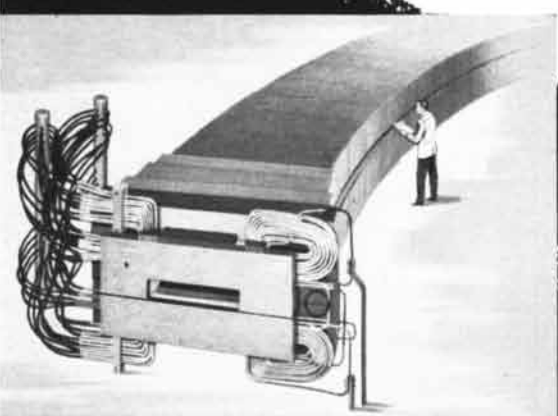

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Paul J. Flory. Cornell University Press, 1953.

IONIZING RADIATION AND METALS

CHEMISTRY OF THE SOLID STATE. Edited by William Edward Garner. Butterworths Scientific Publications, 1955.

DISPLACEMENT OF ATOMS DURING IRRADIATION. Frederick Seitz and J. S. Koehler in *Solid State Physics*, edited by Frederick Seitz and David Turnbull. Academic Press Inc., 1956.

RADIATION EFFECTS IN SOLIDS. G. J. Dienes and G. H. Vineyard. Interscience Publishers, Inc., 1957.

VACANCIES AND OTHER POINT DEFECTS IN METALS AND ALLOYS. The Institute of Metals, 1958.

IONIZING RADIATION AND THE CITIZEN

THE ABC OF NUCLEAR WEAPONS. H. W. B. Skinner in *The New Scientist*, Vol. 5, No. 119, pages 473-475; February 26, 1959.

THE BIOLOGICAL EFFECTS OF ATOMIC RADIATION. National Academy of Sciences, 1956.

GENETIC AND SOMATIC EFFECTS OF CARBON-14. Linus Pauling in *Science*, Vol. 128, pages 1,183-1,186; November 14, 1958.

GENETICS IN THE ATOMIC AGE. Charlotte Auerbach. Oliver and Boyd, 1956.

RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. *British Journal of Radiology*, Supplement No. 6; 1955.

WORLD-WIDE CAPABILITIES FOR PRODUCTION AND CONTROL OF NUCLEAR WEAPONS. Howard Simons in *Daedalus*, Vol. 88, No. 3, pages 385-409; Summer, 1959.

MATHEMATICAL GAMES

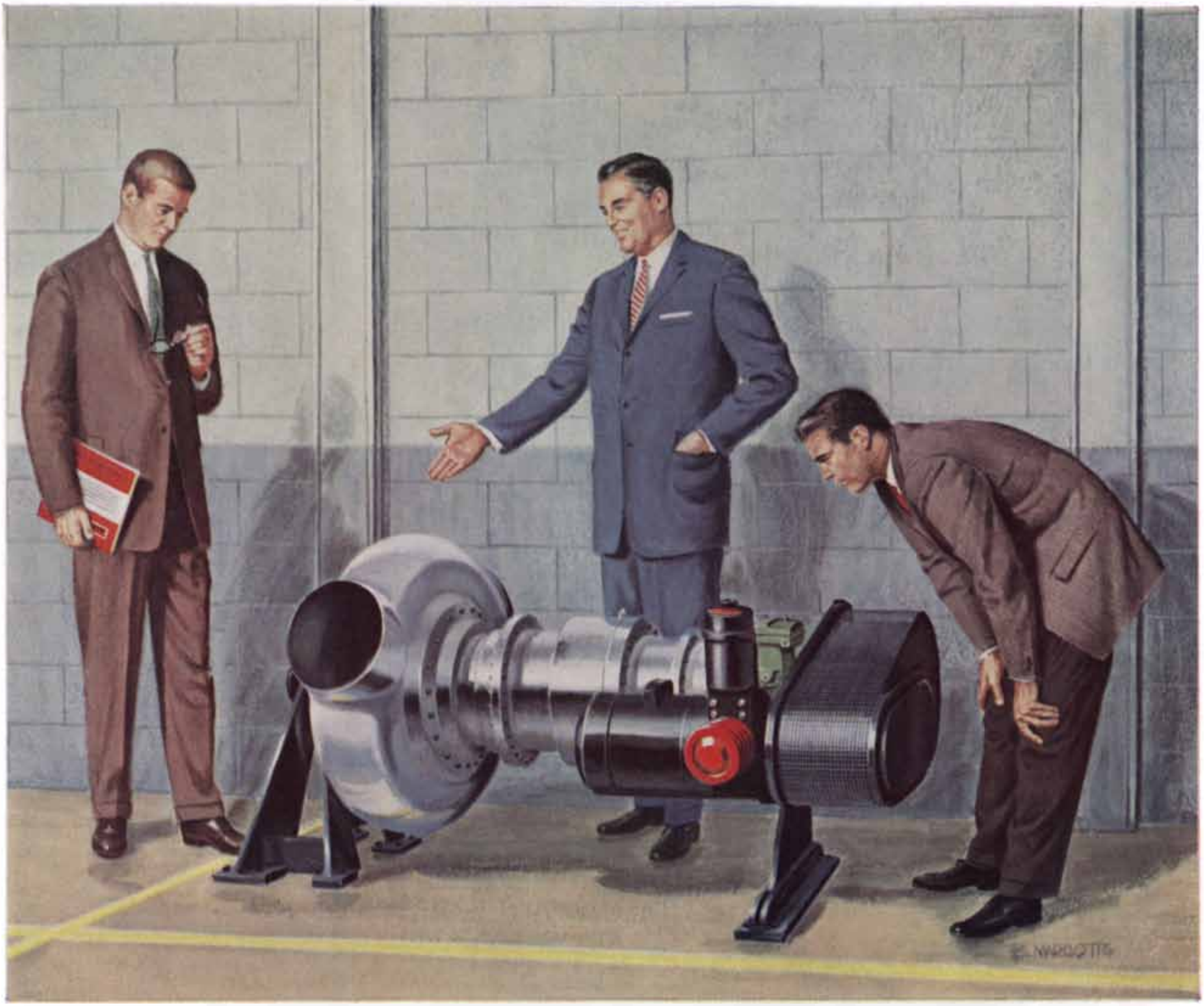
100 PUZZLES: HOW TO MAKE AND HOW TO SOLVE THEM. Anthony S. Filipiak. A. S. Barnes and Company, 1942.

PUZZLES OLD AND NEW. Professor Hoffmann (pseudonym of Angelo Lewis). Frederick Warne and Company, 1893.

A THEOREM ON THE TANGRAM. Fu Traing Wang and Chuan-Chih Hsiung in *The American Mathematical Monthly*, Vol. 49, No. 9, pages 596-599; November, 1942.

THE AMATEUR SCIENTIST

THE NEW PSYCHIATRIC DRUGS. Harold E. Himwich in *Scientific American*; October, 1955.



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