SCIENTIFIC AMERICAN

WHY LEAVES FALL

FIFTY CENTS

November 1955

LETTERS

Sirs:

I submit the enclosed open letter to George Gamow, whose article, "Information Transfer in the Living Cell," published in your October issue, gave an erroneous value for pi: 3.14158 . . . instead of the correct 3.14159. . . .

Professor Gamow,
Fie!
You've undervalued π
(on page LXXV-
III, column 3)

A hundred thousandth. Why
Is π so oddly shy?
Was even 8 preferred
Since, 9éd, π's a surd?

Absurd! For π, with 8,
Still's incommensurate.
Oh, naught can justify
Redeucing valued π;

Buffon, that honest Count,
To reckon π's amount,
Cast needles down on lines,
But did not cast out 9s.

The eye is slower than
The hand; perhaps you can
Not only cheat your π
But halve it too, but I

(Imaginary *i*)

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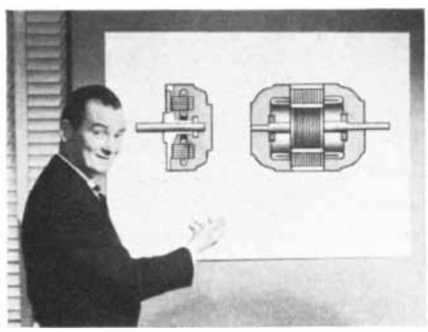
They wanted to add another machine on the line

Fairbanks-Morse Design Engineers wanted to see how *you* could get more production out of every square foot of premium production line space.

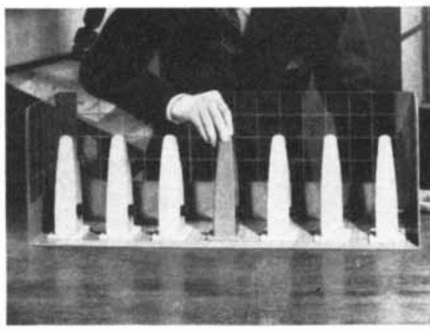
They designed the now-famous Fairbanks-Morse Axial Air Gap Motor that is much shorter than conventional type motors. That saved "motor space" can become "production space" by the addition of one or more machines to every production line.

It is this kind of design approach that typifies the product bearing the Fairbanks-Morse Seal of Quality. When next you look for an electric motor . . . a scale . . . a pump . . . a diesel engine, look for the F-M Seal and see the difference that quality makes.

Fairbanks, Morse & Co., Chicago 5, Ill.



The Secret . . . is that the air gap in this motor is perpendicular to the shaft, rather than parallel as in a conventional motor . . . without sacrifice in performance.



The Result . . . is that by replacing conventional motors with F-M Axial Air Gap Motors, enough space has been saved to add one or more machines to the line.

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ELECTRIC MOTORS AND GENERATORS • DIESEL LOCOMOTIVES AND ENGINES • PUMPS • SCALES • RAIL CARS • HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS

Will not stand idly by
While any constant *k*
Is idly chipped away.

Where'd logarithms be
If you diminished *e*?
Or relativity,
If one could vary *c*?

If π were any less
Than what we now profess,
The universe would then
Expand some more again.

(The red shift—is it due
To tamperers like you?)
Go pick on $\aleph_0$
There's plenty there to cull!

But please, Professor G.,
Leave π alone, for me.
(It's bad enough my T
→O.) Be

As generous with "stet"
As with ideas; let
π be, while life endures,
Itself, as I am,
Yours,

THEODORE MELNECHUK

Linde Air Products Company
New York, N. Y.

P. S. "Redeucing" in verse three is *sic*; "$\aleph_0$" in verse nine is Cantor's "aleph null."

T. M.

Sirs:

Two weeks ago I received the results of 3,000 RNA "poker games" played with a random selection of card suits on MANIAC, the digital computer at the Los Alamos Scientific Laboratory. These results slightly change some conclusions in the article I wrote for your October issue. I refer to the chart on page 76 and to the third paragraph from the end of the article. I should now like to add the following correction (or rather extension) to the article.

At the beginning of the paragraph it was stated: "When the 'weighted' triplet rule is applied to the four different types of nucleotides, assumed to be randomly distributed in the RNA chain, the curve of the nucleotide combinations occurring agrees perfectly with the observed abundances of amino acids in proteins [*see chart*]." This statement, as well as the gray line in the chart, pertains to the random distribution of the four nucleotides, the relative amounts of

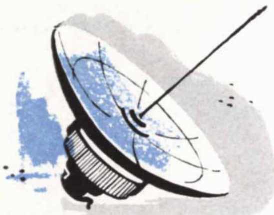
Farnsworth

In Defense and Industry

RESEARCH

Applied Physics, Circuit Research, Solid State Physics, Low Temperature Physics.

RADAR



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FARNSWORTH ELECTRONICS COMPANY • *FORT WAYNE, INDIANA*

a division of International Telephone and Telegraph Corporation which were chosen in accordance with the chemical analysis of RNA. It seems, however, that the relative amounts of the four nucleotides in RNA molecules are not random. In fact, the results obtained by Giulio Fermi and N. Metropolis, who drew their 3,000 MANIAC hands on the assumption of random abundances of the four nucleotides, do not fit at all with the observed curve of the amino acid abundances. Thus one must conclude that, while the *placement* of nucleotides in the RNA molecule is at random, the *selection* of nucleotides to be used is subject to some restrictions. The details will be soon published by the author and Martinas Yčas in *Proceedings of the National Academy of Sciences.*

GEORGE GAMOW

George Washington University
Washington, D. C.

Sirs:

As a geologist I am fascinated by the two-page oblique aerial photograph reproduced on pages 110-111 of your September issue. One of the most remarkable features shown, not mentioned in the description, is the clearly expressed, straight trace of the San Andreas Fault, which passes between the two southernmost of the snow-clad peaks, and on the northwest just this side of the most distant snow-covered peak.

R. F. YERKES

Brea, Calif.

Sirs:

I have just finished reading Jotham Johnson's article "The Changing American Language" [SCIENTIFIC AMERICAN, August] and thought he would like a tidbit to add to his collection.

I have heard an excellent example of vowel inversion ("turmoil—toimerl") in this country. The North Country folk (Lancashire, notably) have a very different pronunciation of the "u" and "o" from the southerners. A friend of mine is named Cutbush, which I normally pronounce with the short "u" for "cut" and an "oo" sound for "bush." In Lancashire he is called "Cootbush," with an exact inversion of the vowel sounds!

G. PARR

Chapman & Hall, Ltd.
London, England

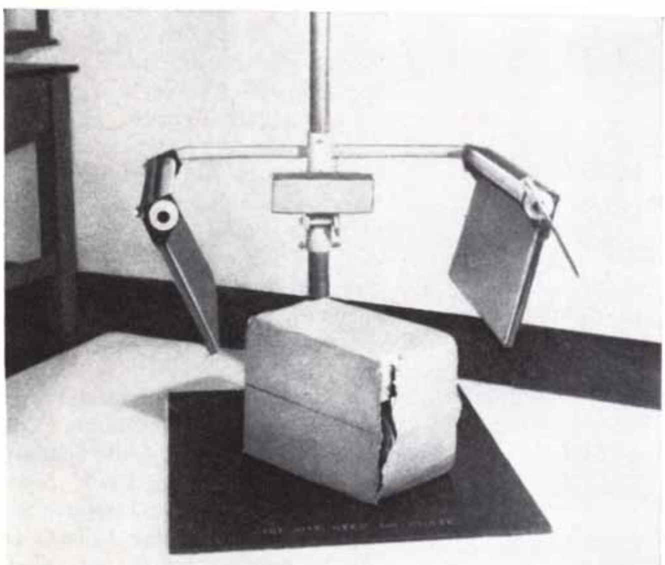
Life on the Chemical Newsfront

CYANAMID HAS RECENTLY RESEARCHED two new color-stable types of Phthalocyanine blue pigments to solve the problem of color drift in automotive finishes. The new red shade Cyan Blue Toner BNF 55-3750 and the green shade Cyan Blue Toner GT—NF 55-3450 have the unique physical properties of being both flocculation-resistant and crystal-stable in automotive finishes. So now, regardless of application techniques, uniform color and depth are easily obtained on both original and refinishing coatings. **(Pigments Division)**

UNDERWEIGHT INFANTS now may have their appetites stimulated and rate of growth increased by a new preparation known as INCREMIN® Lysine-Vitamin Drops. Developed by the Lederle Laboratories Division of Cyanamid, INCREMIN is a combination of a vital growth-stimulating amino acid and the necessary vitamins. Based on extensive research in human nutrition, INCREMIN is prepared as a cherry-flavored liquid and packaged in an unbreakable "squeeze" bottle for easy dispensing. Effective for infants, INCREMIN also may be used for elderly persons who do not have sufficient zest for their food. **(Lederle Laboratories Division)**

PACKAGED MEAT, FISH AND FROZEN FOODS keep fresher longer when the cellophane wrap is coated with ACCOBOND* 3900 Resin before waterproofing treatment. The cationic nature of ACCOBOND 3900 helps to produce strong adsorption to cellophane and exceptionally high bond strength between cellophane and the nitrocellulose waterproofing coating. A new and simple test method, developed by Cyanamid research, gives rapid evaluation of bond strength and better control of the cellophane coating process. For details of the new test write on your letterhead. **(Industrial Chemicals Division, Department A)**

A NEW LOOK now can be given thermosetting plastic products with colored decorations molded into the top surfaces. The dinnerware pictured above is molded of Cyanamid's Melamine Molding Compound No. 1077. The decorative paper overlay is impregnated with Cyanamid's Melamine Resin No. 405. Known as a "foil," the overlay can be printed with special inks in any number of colors. It is inserted in the mold during the breathing or de-gassing phase of the molding cycle. Heat and pressure fuse the impregnated foil and the molding compound into a homogeneous mass. Many other possible applications can be envisioned: decorative door knobs, gift boxes, closures, wall tiles and cosmetic containers. **(Plastics and Resins Division)**



NEW PERFORMANCE RECORDS for paper packaging materials such as the carton shown in the "drop-test" above, may be established by fortification with Polyacrylamide of the conventional adhesives used in carton construction. The addition of small amounts of Polyacrylamide increases the strength and durability of the adhesive bond. It also provides high initial tack and unusual spreadability. As a result, packages are stronger and more resistant to the wear and tear they encounter in transit. Polyacrylamide is a white, odorless powder, readily soluble in cold water, and it does not decrease in solubility with increase in temperature. The remarkable properties of Polyacrylamide make it suitable for a wide range of industrial applications. **(New Product Development Department)**

News Briefs

IMPROVED PERFORMANCE IN COLORED PAPERS is made possible with CALCOTONE* Pigment Pastes. Full color value is developed with CALCOTONE Pigment Pastes because their fine particle size and compatibility with paper additives assure excellent dispersion of the color in the beater. The CALCOTONE Pigment Pastes also have outstanding lightfastness and chemical stability. Better color results are obtained on all grades of paper ranging from tissues to heavyweight board. **(Organic Chemicals Division)**

MORE EFFICIENT PURIFICATION OF MUNICIPAL WATER has been obtained by replacement of dry alum with special liquid alum. The use of liquid alum reduces labor costs in handling and storage. Also, liquid alum can be fed continuously to the raw water at an accurate rate by metering devices, thus eliminating operation and maintenance of the dry feed machine. With the new liquid alum, savings of almost 10% have been reported in large-scale municipal water purification operations. **(Industrial Chemicals Division, Department A)**

ACCONOX* FEED SUPPLEMENT, the first antioxidant premix offered to feed manufacturers, keeps feeds appetizing longer by deterring rancidity which develops in feeds during storage. It eliminates the unpleasant smell and taste in feed by retarding oxidation. Also, it conserves vitamins A and E, thus helping to prevent deficiency diseases. ACCONOX 25 is a special blend of butylated hydroxyl toluene. It does not dust, cake, or cling to mixing equipment, thereby assuring even distribution in the mixing operation. **(Fine Chemicals Division)**

*Trade-mark

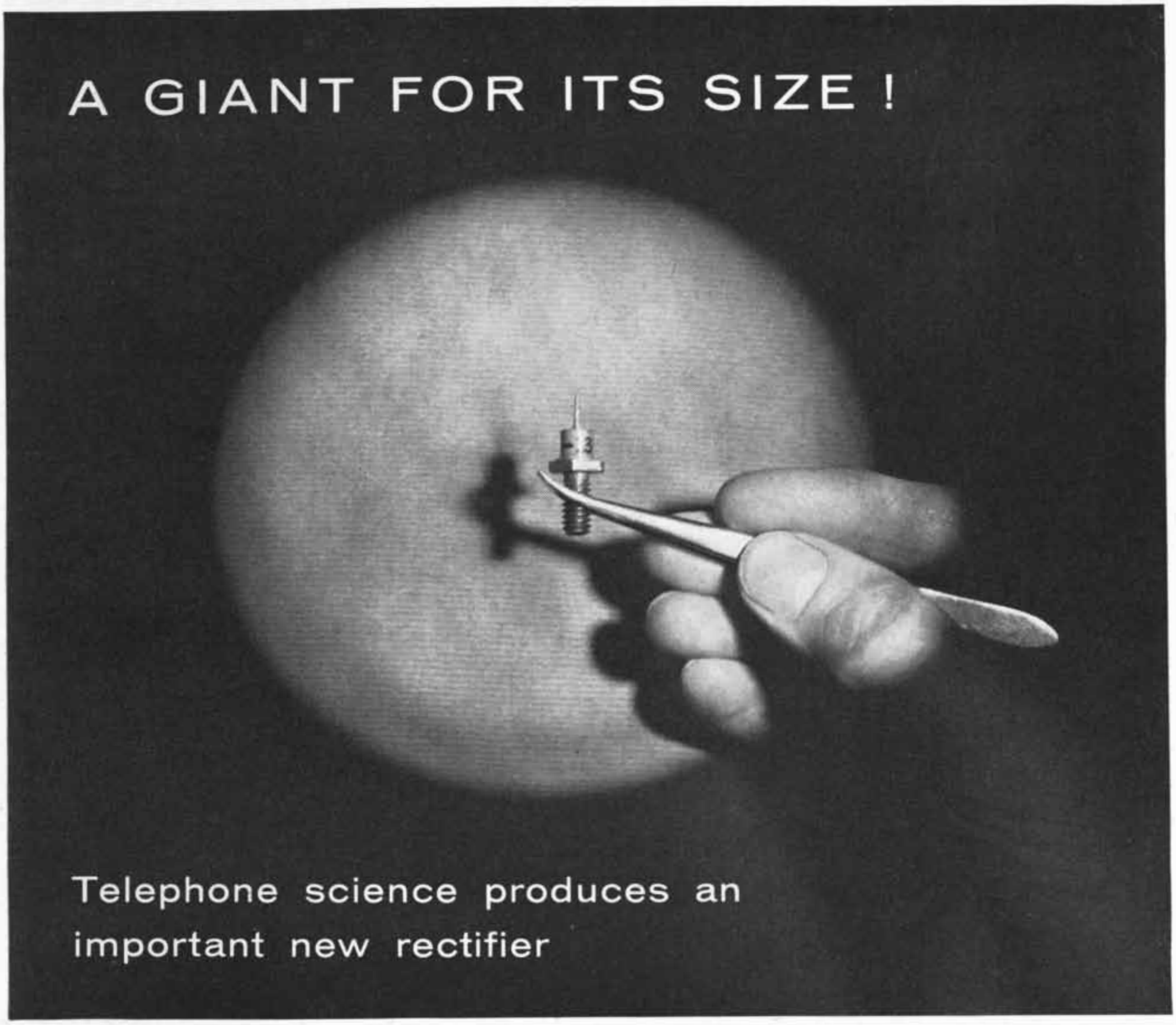
Additional information may be obtained regarding these products by writing on your business letterhead to the Division of American Cyanamid Company, 30 Rockefeller Plaza, New York 20, N. Y., indicated in the captions.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

NOVEMBER, 1905: "The latest of the aeronautic experiments of Israel Ludlow, of New York City, occurred on Sunday, October 22, when the aeroplane carrying Charles K. Hamilton, a professional aeronaut, was successfully launched into the air from the east bank of the Hudson River, and after a flight of some minutes' duration, settled gradually into the water near midstream. The experiment was intended thoroughly to test the flying, or more properly the gliding, properties of the machine, and for this purpose the motive power at the end of the rope, or 'kite string,' was a powerful tugboat, an arrangement permitting the use as a course of the unbroken sweep above the river. After a number of unsuccessful starts—the slack not being completely taken up before the drag acted on the machine—the aeroplane was at length flung into the air in the teeth of a strong wind. Until a height of approximately 500 feet was attained the rise was rather erratic; Hamilton, however, with great coolness, managed to keep the giant white-winged kite on an even keel by shifting his weight from one point to another as the occasion required, and when more than 600 feet of rope had been let out from the tugboat, the machine settled down and followed steadily in the wake of the vessel."

"In an article in the last annual report of the Smithsonian Institution Col. W. C. Gorgas, U. S. A., Chief Sanitary Officer of the Isthmian Canal Zone, shows that yellow fever and malaria, the two great scourges of the Isthmus of Panama, can be successfully controlled. Briefly stated, the sanitary problem is to protect the fifteen thousand men that are likely to be employed on the canal. At present yellow fever is endemic nowhere in the Canal Zone except the city of Panama, and the immediate object is to get rid of the infected *Stegomyia* mosquitoes present in the city. An even more important problem is the control of malaria. Four times out of five, if the female *Anopheles* mosquito bites a na-



At Bell Laboratories one line of research is often fruitful in many fields. Latest example is the silicon power rectifier shown above.

Product of original work with semiconductors—which earlier created the transistor and the Bell Solar Battery—the new rectifier greatly reduces the size of equipment needed to produce large direct currents. It is much smaller than a tube rectifier of equal performance and it does not require the bulky cooling equipment of other metallic rectifiers.

In the Bell System the new rectifier will supply direct current more economically for telephone calls. It can also be adapted to important uses in television, computers, industrial machines, and military equipment. Thus, Bell Telephone Laboratories research continues to improve telephony—while it helps other fields vital to the nation.

Above, new rectifier (held in pliers) is contrasted with comparable tube rectifier and its filament transformer, rear. Mounted on a cooling plate, lower center, the new rectifier can easily supply 10 amperes of direct current at 100 volts, that is 1000 watts—enough to power 350 telephones.

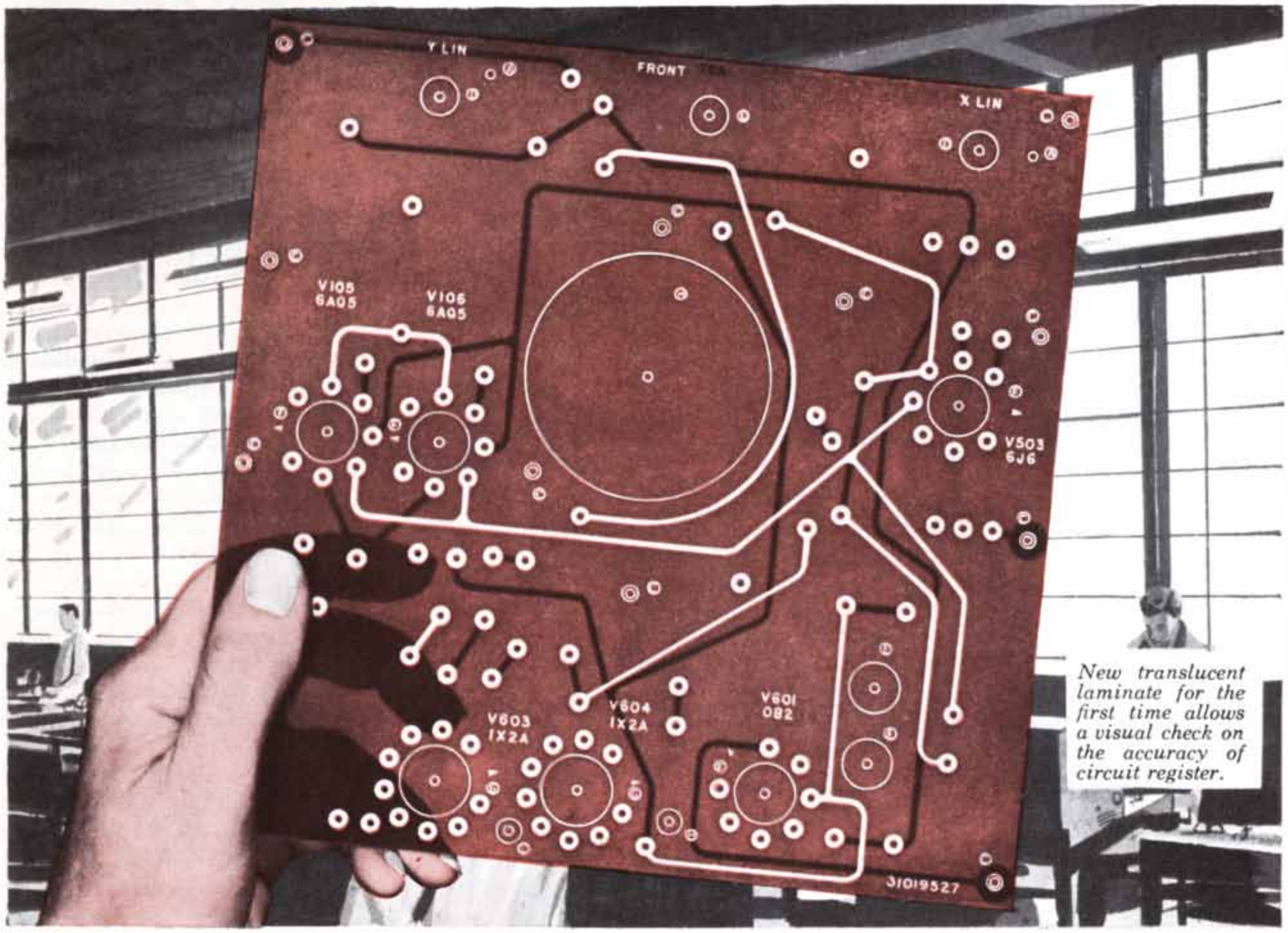
BELL TELEPHONE LABORATORIES

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS FOR CREATIVE MEN IN SCIENTIFIC AND TECHNICAL FIELDS tive it becomes infected, and when it bites one of our nearby laborers, he in turn becomes infected. Hence, if our laboring force is not to be completely used up, as was that of the French government, preventive sanitary measures must be taken. Most of the effective tropical sanitarians have achieved a great success by inducing as large a proportion of the population as possible to take regularly small quantities of quinine. The disease may also successfully be attacked from the mosquito's side, and the *Anopheles* may be exterminated by covering up water containers, preserving roads so there will be no puddles, instituting a regular system for the collection of garbage, and by the use of oil."

"In a lecture given in Paris July 8, 1904, and reprinted in the Smithsonian Institution's Annual Report, Elie Metchnikoff of the Pasteur Institute discusses the problem of old age. He notes that in the cells of certain senile organs the general and essential phenomena consist in the destruction of parts useful to the organism by wandering cells that present some traits in common with each other. They are voracious cells belonging to the category of elements designated under the generic name of macrophages. Certain macrophages remove the pigment of the hair, certain others destroy the osseous lamellae, others still devour the contractile substance of muscles. It is easy to prove that this activity or rather superactivity of the macrophages is observed in the most diverse organs of the aged. After having destroyed the noble elements of the aging organism, such as the nervous, renal and hepatic cells, the macrophages become fixed in place and are transformed into connective tissue without ever being able to supply the place of the precious elements that have disappeared. It is in this way that there is set up in the aged that main factor of our premature decay, sclerosis of the organs."

SCIENTIFIC AMERICAN

NOVEMBER, 1855: "At a recent meeting of the New York Academy of Medicine, Dr. Stowe, a distinguished surgeon of New Orleans, was introduced, who gave some valuable information respecting the yellow fever. In his opinion yellow fever is a specific disease, the same everywhere. Its epidemic character is almost undisputed. When the



Formica Research perfects sensational new cold punching laminate

Brings 1,000,000 megohms resistance value, precision and translucency to printed circuitry . . . . .

Research, an important part of the exclusive new Formica 4-point service, has just perfected a new cold punching paper base laminate offering 1,000,000 megohms insulation resistance and valuable new translucent properties.

Known as XXXP-36, the new grade brings greater accuracy to printed circuitry. Because of its cold punching qualities, XXXP-36 requires no heat cycle. Therefore, the base laminate is not subject to dimensional change as in grades which must be heated before punching. This means that with Formica XXXP-36, you can now produce printed circuits with new and higher standards of accuracy.

XXXP-36 translucency can be doubly useful. Make this simple test: hold it to the light. You can see (1) the smooth, homogenous structure, the total absence of resin pockets, voids and imperfections that dissipate the insulating properties of ordinary paper base laminates . . . and (2) how perfectly the circuit on one side registers with that on the other. New XXXP-36 is ideal for terminal boards and tv insulators requiring high I. R. Formica's engineering skill can help you find new materials for new products and processes. For complete information on the new XXXP-36, or on the new "Formica-4" service, use coupon below. The Formica Co., 4593 Spring Grove Ave., Cincinnati 32, Ohio.

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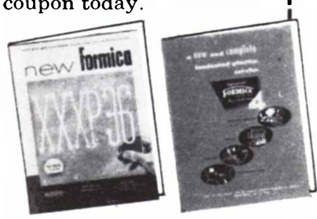
Laminated Plastic
Pays in Performance

FORMICA®—*the most famous name in laminated plastics—Engineered for industry, Beauty Bonded for the home.*

Make the Formica Translucency Test. Send for a sample XXXP-36 printed circuit. Fill out and mail coupon today.



Gentlemen:

☐ *I'd like a sample XXXP-36 printed circuit and complete information on this new grade.*

☐ *Send bulletin showing how I can take advantage of the new "Formica-4" laminated plastics service.*

Name________________________________

Company____________________Title__________

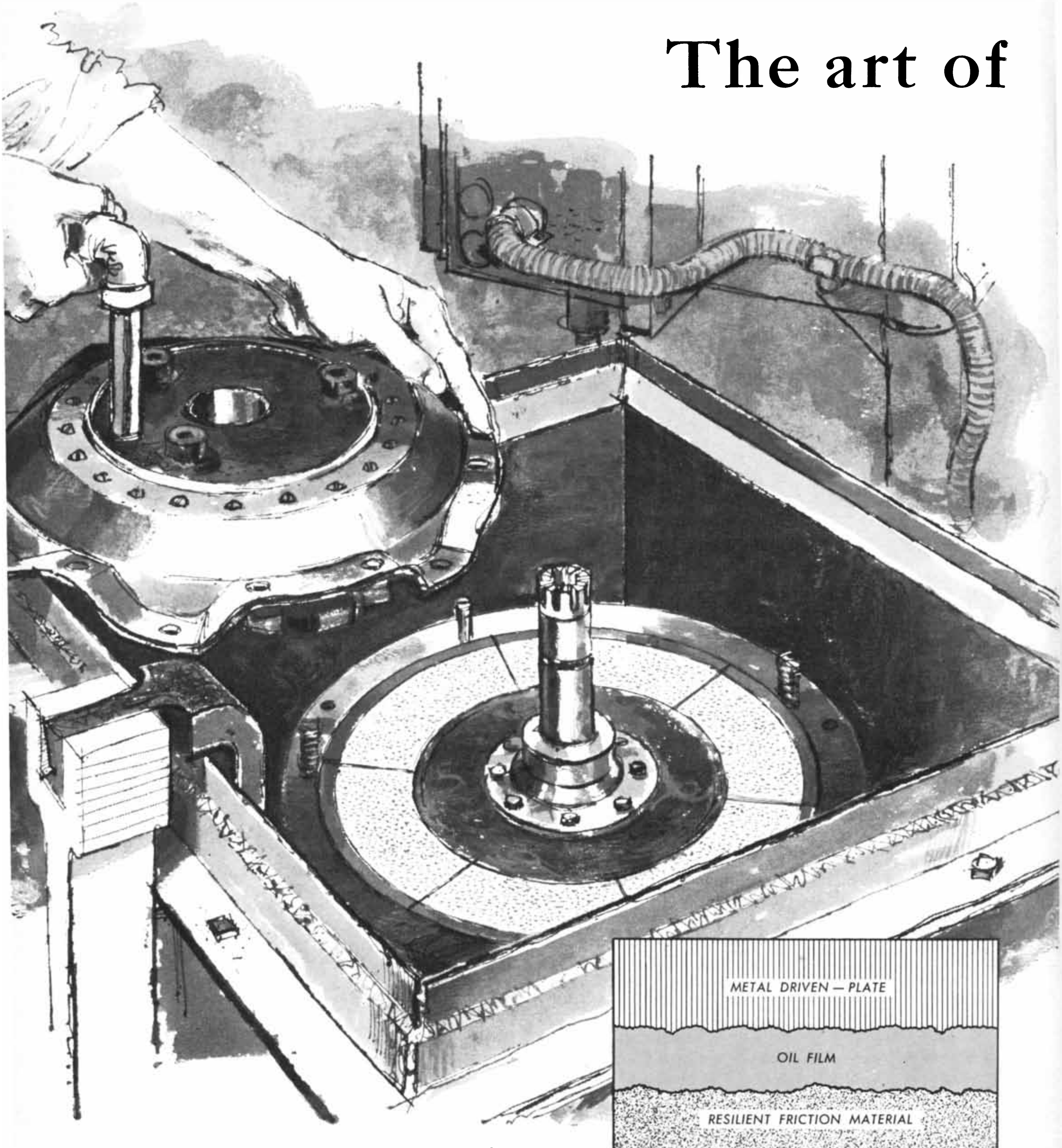
Address______________________________

City__________________Zone___State__________ fever is epidemic anything which disturbs the system develops it; at such seasons it is impossible to have any other disease. Any excitement at such times is sufficient to create or develop it. This disease has literally no anatomical character—it is a blood poison. It is a self-limited disease; it is not to be treated—it is to be managed. All that is to be done is to keep the patient alive for a certain time, and he will get well."

"The London *Athenaeum* contains an account of the rumored recent discovery of a large sea in Africa, which occupies the vast space between the Equator and lat. 10 south, and between lon. 23 and 30 east—or about 7,000 miles long and 450 broad, and therefore twice as large as the Black Sea. It is not stated whether it is a fresh or salt sea."

"Our London correspondent sends us the following particulars in regard to the mammoth steamship *Great Eastern:* 'On my visit to the mammoth steamer now building at Blackwall on the Thames, I was fortunate enough to procure from the engineers and others the following information. Much has been said, although little is known respecting her, especially in the United States. The vessel is not yet named, though it is rumored she is to be called the *Great Eastern*. She is being built by J. K. Brunel, Esq., the well-known engineer for the Eastern Steam Navigation Company, who have a capital of six million of dollars; their vessels are all designed for the India and Australia trade, and will be four in number, the first being the *Great Eastern*. She will be the largest and most powerful steamship in the world, as will be seen by the following statement of her dimensions: length, 680 feet; breadth 83 feet; number of decks, 4; length of saloons, 400 feet; capacity, 27,000 tuns. She is to have both screw and paddle engines, whose total nominal horse power will be 2,600. The paddle wheels have been fixed at sixty feet diameter. She is to carry six hundred first-class passengers and eighteen hundred second-class. If used as a transport, she will carry an army of 10,000 men, with all their field equipments. The masts are five in number—ship rigged. The vessel will have ten boilers and five smoke pipes. In her external appearance—drawing inference from the working model—I should think the *Great Eastern* would be a splendid ship. Her speed should average fourteen miles an hour. At the present time over five hundred men are at work upon the ship in all departments."

The art of



Experimental friction materials get a workout in this test clutch at the Armstrong Research and Development Center. All conditions—temperature, pressure, and speed—are precisely controlled. Automatic recorders chart the operating characteristics of facings during each engagement cycle.

In wet clutches, the driving and driven surfaces are separated by an oil film when disengaged. The film thins as engagement pressure forces the surfaces into contact. After a brief period of slip, the surfaces grip and the clutch becomes fully engaged as relative movement ends.

making friction behave

How research men control the grip of friction materials to help cars, appliances run smoother

Shifting gears automatically in an automobile . . . changing from "rinse" to "spin-dry" in a washer . . . rapid-fire starting and stopping of an industrial sewing machine — all depend on how well a thin sheet of friction material in a clutch does its work.

Although the job of the clutch — to engage and disengage the driving force — is nearly always the same, the way it engages may vary considerably.

With an industrial sewing machine, for example, the operator runs a seam at high speed, stops on a stroke of the needle, turns the fabric, and races down another seam. Here, research men found that a cork clutch facing material, operated "dry," will take hold fast enough to take the machine from a dead stop to full speed in a fraction of a second.

But the same kind of fast-acting dry clutch in an automobile would produce too much shock for both car and rider. And if to avoid this shock the clutch plates were allowed to slip during engagement, the heat generated might burn up the facing material.

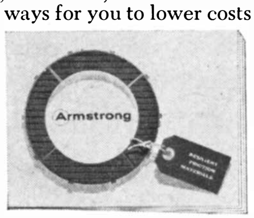
Smooth, gradual engagements are commonplace, however, in the clutches of automatic transmissions. Here cork facings are operated "wet," that is, immersed in oil. Surprisingly, cork keeps much of its high friction even when flooded with the same oil that lubricates the transmission. In fact, oil makes gradual engagements practical by carrying off much of the heat that's generated.

Changing the shape of the plates in a wet clutch produces different kinds of engagement, too. A flat plate with radial slots, for example, engages faster than a plain flat plate. On the other hand, a "waved" plate engages more slowly.

Although there are many such mechanical techniques, the art of making friction behave also depends a great deal on the compounding of the friction material itself. The research worker faces almost limitless possible combinations of cork, rubber, resins, and fibers. Even small changes in these ingredients or their proportions may make significant differences in clutch performance.

As a result, developing a new material with specific frictional properties is a job that takes a large measure of resourcefulness and imagination. The only criterion for success, however, is found in the very practical question, "Does it work?"

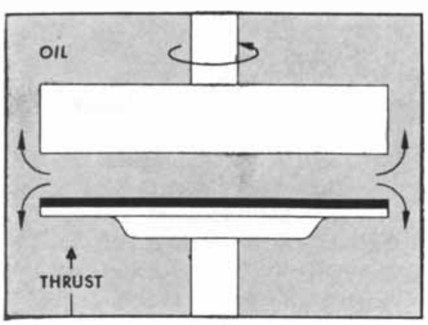
If you make or design clutches for automobiles, appliances, machine tools, business machines, or the like, send us the details. We may be able to suggest ways for you to lower costs or improve performance with Armstrong resilient friction materials. And for data on designing with cork facings, write for the booklet, "Armstrong Resilient Friction Materials." Armstrong Cork Company, Industrial Division, 8211 Inland Road, Lancaster, Pa.



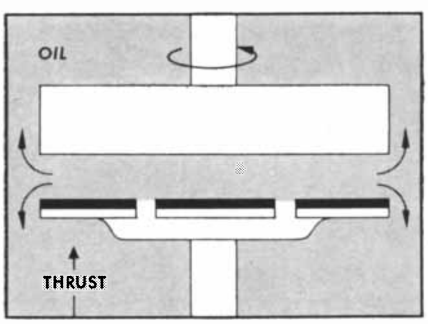
Armstrong INDUSTRIAL PRODUCTS

. . . USED WHEREVER PERFORMANCE COUNTS

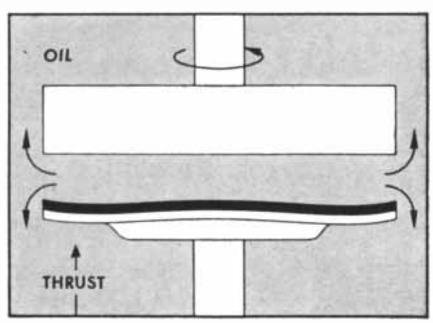
adhesives . . . cork compositions . . . cork-and-rubber . . . felt papers . . . friction materials



Changes in clutch plate design permit designers to manipulate the oil film and control the engagement period. It takes a flat plate, for example, a relatively long time to squeeze away the oil film and become fully engaged.



Radial slots in a flat clutch plate tend to create short engagement periods, even with low engagement pressures. The slots apparently set up a "squeegee" action that wipes away the film of oil, hastening full contact.



A "waved" plate maintains the oil film much longer during engaging period when the pressure is being applied. When full pressure is finally developed, the plate flattens to make full contact, and engagement is completed.

THE AUTHORS

SOLOMON E. ASCH ("Opinions and Social Pressure") is professor of psychology at Swarthmore College. He was born in Warsaw in 1907, came to the U. S. in his youth and graduated from the College of the City of New York in 1928. After taking his M.A. and Ph.D. at Columbia University, he taught at Brooklyn College and the New School for Social Research before joining the Swarthmore faculty in 1947. This year he is giving a course on the psychological foundations of social behavior at Harvard University and participating in the Laboratory of Social Relations.

ROBERT L. FISHER and ROGER REVELLE ("The Trenches of the Pacific") are members of the University of California's Scripps Institution of Oceanography. Revelle, who has been at Scripps since 1931, is now its director. After graduating from Pomona College in 1929, he went to Scripps as a research assistant, taking his Ph.D. there in 1936. He was a Navy oceanographer during World War II, and was head of the oceanographic section of the task force which conducted the atomic bomb test at Bikini in 1946. He addressed the recent Geneva Atoms for Peace Conference on disposal of radioactive wastes in the ocean. Fisher is a marine geologist. He did his undergraduate work at the California Institute of Technology and his graduate work at Northwestern University and at Scripps. "My interest in oceanography," he writes, "dates from a not-particularly-distinguished naval career in the western Pacific in World War II, augmenting early reading of Melville, Maugham and Pierre Loti." For the past four years he has been engaged in field studies of several Pacific trenches. He acted as scientific leader of the 1953 and 1954 Scripps expeditions to the west coasts of Mexico and Central America.

P. W. BRIDGMAN ("Synthetic Diamonds"), after a long career devoted to the physics of high pressure and the philosophy of science, retired last year as University Professor at Harvard University. He was born in Cambridge in 1882 and did his graduate and undergraduate work at Harvard, taking a Ph.D. in physics in 1908. He has taught at Harvard ever since, from 1926 to 1950 as Hollis Professor of mathematics and natural philosophy. He was named University Professor in 1951. From an early

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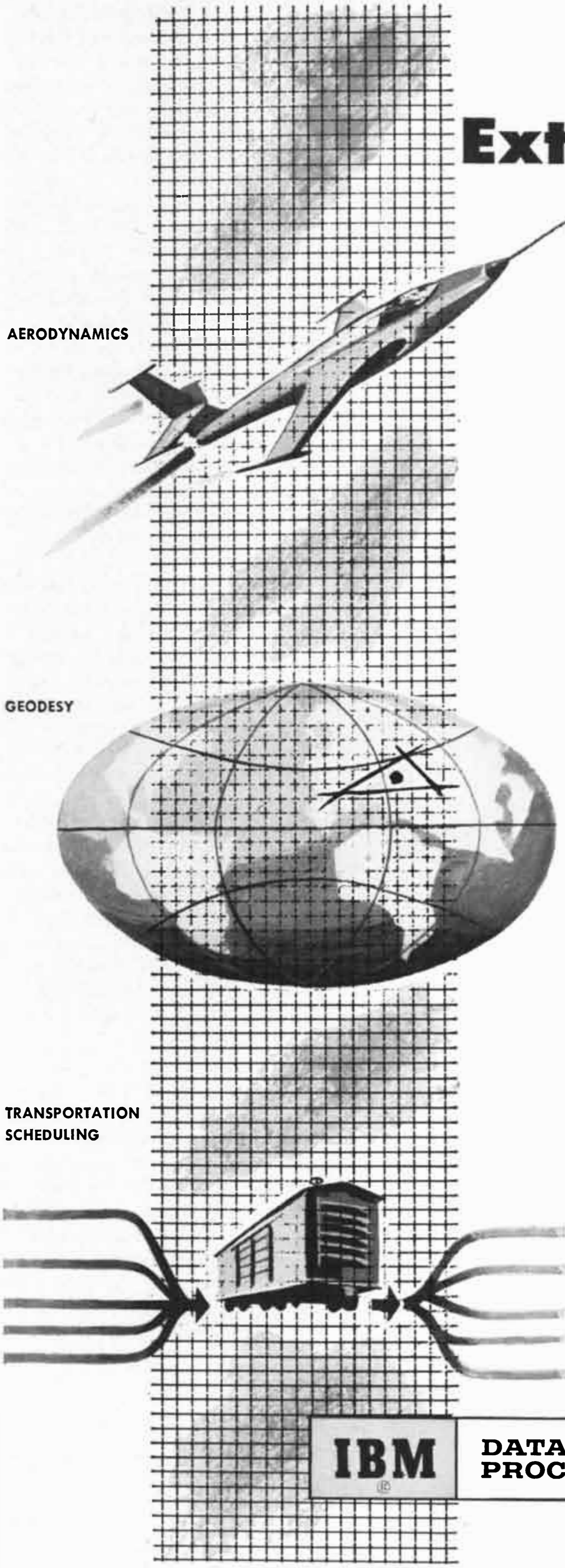

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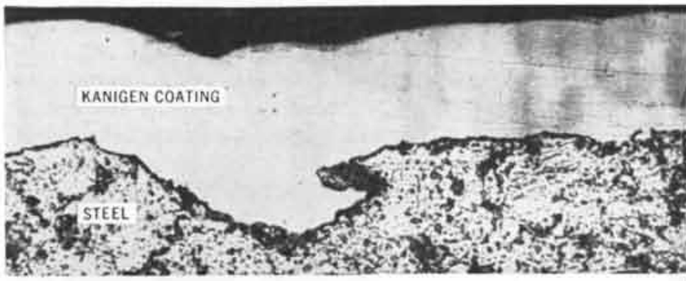
date he devoted himself to the physics of high pressure, ultimately finding ways to increase available laboratory pressures almost 100 times. Bridgman has managed to produce pressures of six million pounds per square inch, and most of his recent work has been in the range of 500,000 to 1,500,000 pounds per square inch. He has also been active outside the laboratory—in the more general and social concerns of science. In 1927, with *The Logic of Modern Physics*, he launched a new interpretation of the values of science, which he called "operationalism." He proposed that physical entities have no significance except in terms of the human operations through which they can be observed, and that ideas which cannot be tested by such operations are without meaning. For the high-pressure apparatus he invented and for the states of matter he discovered with it, Bridgman was awarded the Nobel prize in physics for 1946.

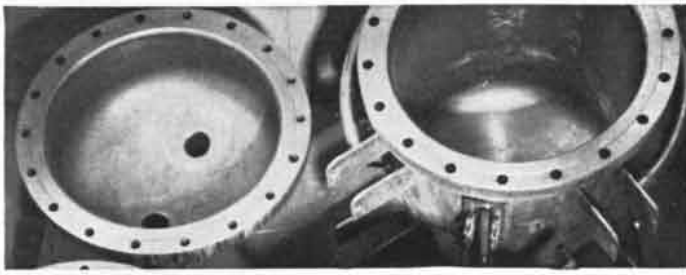
H. J. MULLER ("Radiation and Human Mutation"), professor of genetics at Indiana University, is the man who found that mutations could be accelerated by X-rays. This discovery, which he made in 1927, won him the Nobel prize in physiology and medicine for 1946. Muller was born in New York City in 1890 and was educated at Columbia University, where he took a Ph.D. in zoology in 1916. From 1915 to 1936 he taught zoology, first at the Rice Institute, then at the University of Texas. In 1933 to 1937 he worked at the Institute of Genetics in Moscow as senior geneticist, but he later became a fierce foe of the Soviet system. After spending some years at the University of Edinburgh and at Amherst College, he joined Indiana University in 1945.

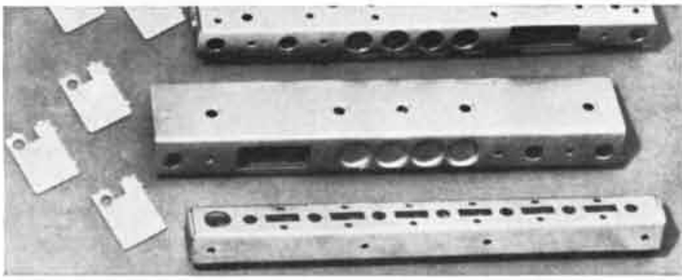
H. C. VAN DE HULST ("Empty Space") is an astrophysicist at the Observatory in Leiden, the Netherlands. He took up theoretical astronomy during World War II, when the University, at which he was a student, was closed. Van de Hulst was the first to suggest, in 1944, that the hydrogen in interstellar space probably emitted radio vibrations at the 21-centimeter wavelength. He has recently been following up the clues these signals give to the content of interstellar space.

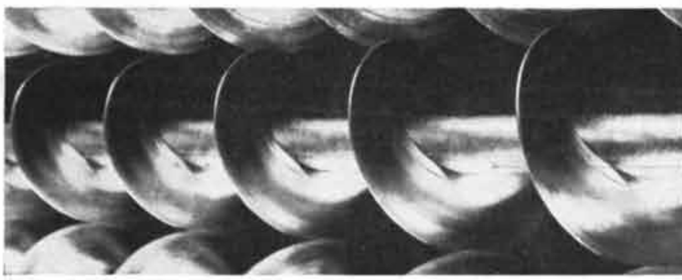
WILLIAM P. JACOBS ("What Makes Leaves Fall?") is an associate professor of biology at Princeton University. Born in Boston, he graduated from Harvard College in 1942, then studied at the California Institute of Tech-



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


Kanigen-coated pressure vessels


Kanigen-coated aluminum electronic assembly ready for soldering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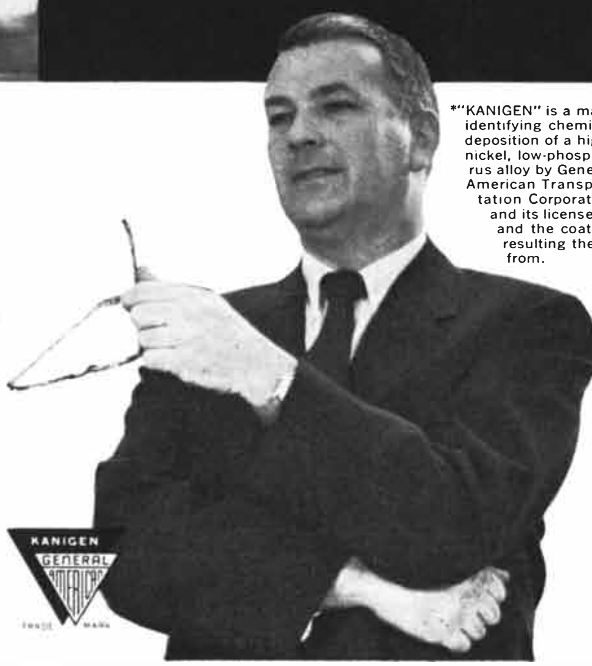

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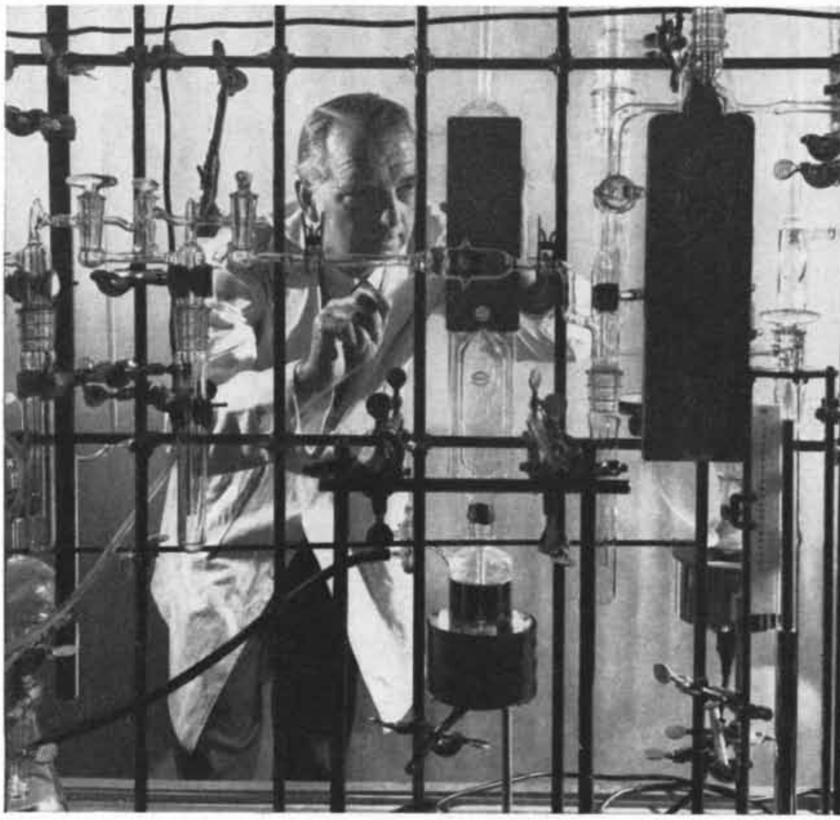
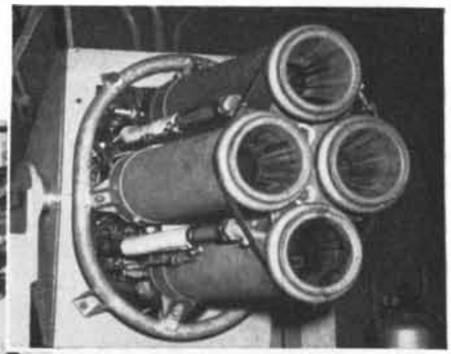
nology on a Sheldon traveling fellowship from Harvard, returned to Harvard as a Fellow and took a Ph.D. in biology in 1946. He has been at Princeton since 1948. About the choice of his line of work he writes: "Under the influence of Professor Ralph H. Wetmore of Harvard and Professor Frits Went of California Institute of Technology, I decided to concentrate on trying to discover what internal factors *normally* control the growth and differentiation of plants. The control of leaf fall was picked as a 'warm-up' problem, preparatory to applying similar quantitative methods to the more difficult problems of what is going on inside the plant in terms of cell differentiation."

ALDO NEPPI MODONA ("Etruscan Metallurgy") is professor of ancient Greek and Roman civilization at the University of Florence. He was born in Florence, which lies near the northern limit of the ancient Etruscan territory, and has specialized in Etruscan studies, doing his doctoral thesis on the Etruscan findings at Cortona. In 1928 a scholarship took him to the island of Rhodes; while on that trip he did much research on the neighboring island of Cos and there met his wife. Neppi Modona is secretary of the Florence Institute for Etruscan Studies and director of the Permanent Committee for Etruscan Research.

A. STARKER LEOPOLD ("Too Many Deer") is associate professor of zoology at the University of California, where he teaches wildlife conservation and management. He graduated from the University of Wisconsin in 1936 with a major in soils and agronomy, then trained in forestry at Yale University. From 1939 to 1944 he was a field biologist for the Missouri Conservation Commission, working on problems of managing deer and wild turkeys in the Ozarks. He took a Ph.D. in zoology at the University of California in 1944. After conducting a survey of wildlife resources in Mexico for two years, he returned to the University of California. He is currently on sabbatical leave, writing a book on Mexican wildlife, of which he has kept track intermittently in recent years. Leopold's part in the California deer surveys started in 1947, when the California Fish and Game Commission contracted with the University of California for an extensive study of deer in the state. The project lasted three years. One of the five members of Leopold's field crew, Thane Riney, later became chief of Big Game Research in New Zealand.

new team impetus...





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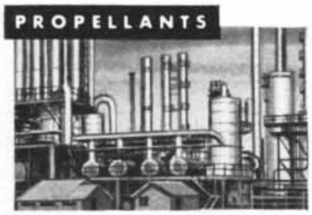

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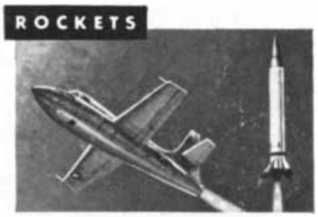

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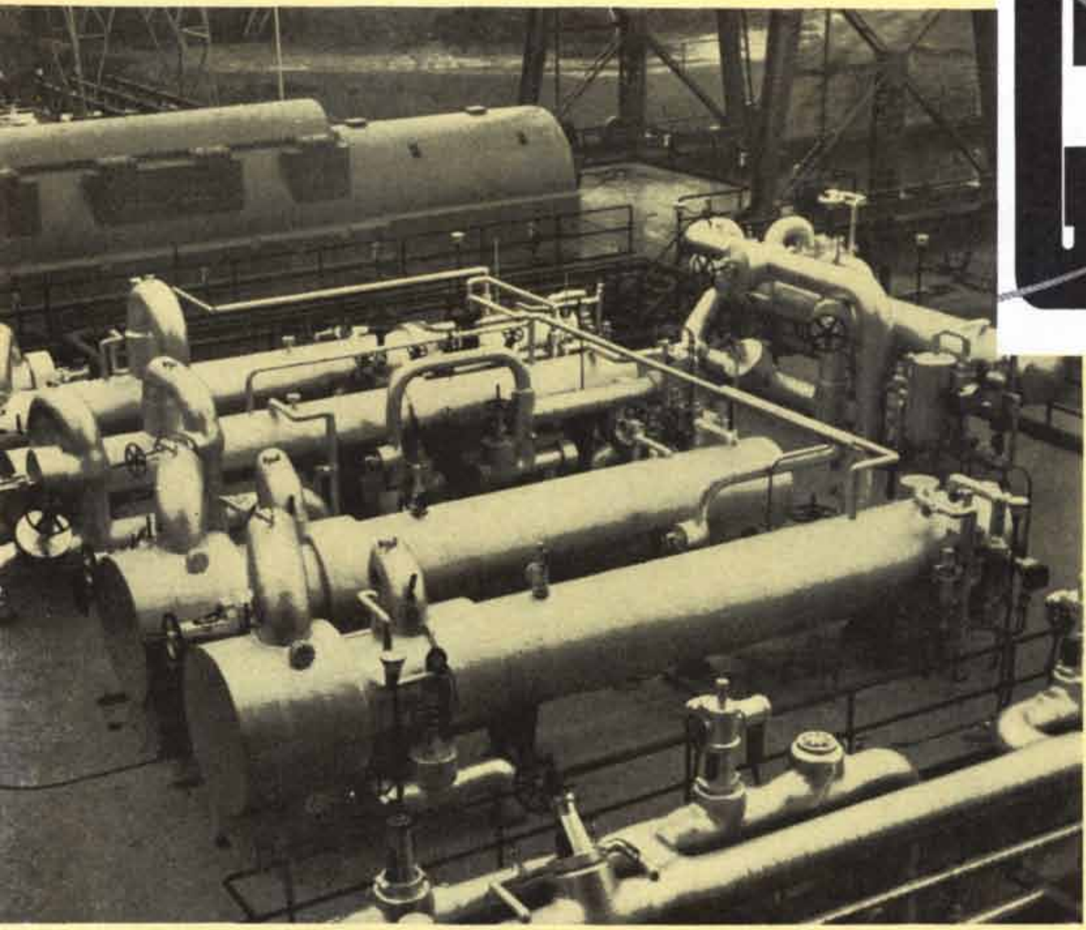

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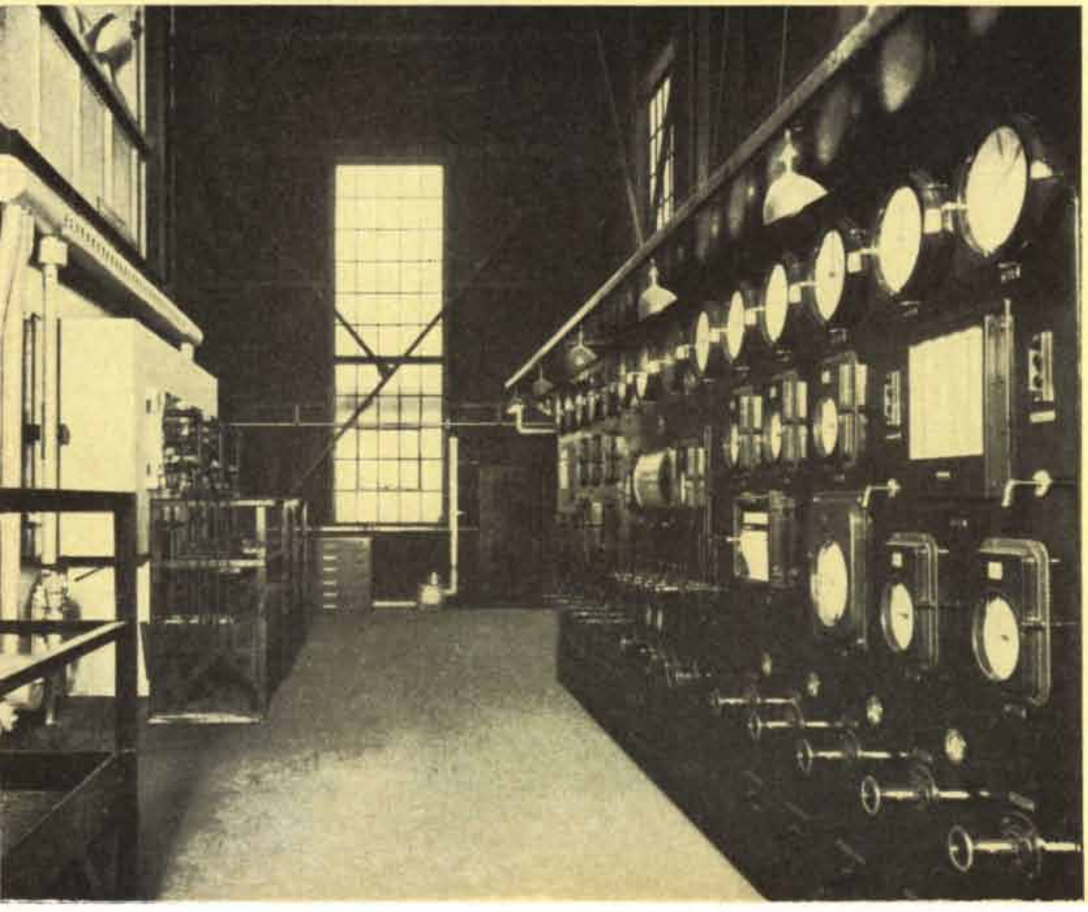

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THE COVER

The painting on the cover shows a leaf falling from the branch of an oak tree. The fundamental process that causes leaves to fall is discussed in the article beginning on page 82. Until recently it was thought that leaves fell when their production of the plant hormone auxin tapered off. New experiments with the plant *Coleus* indicate, however, that auxin produced by young leaves plays an important role in the process.

THE ILLUSTRATIONS

Cover painting by Bernard Perlin

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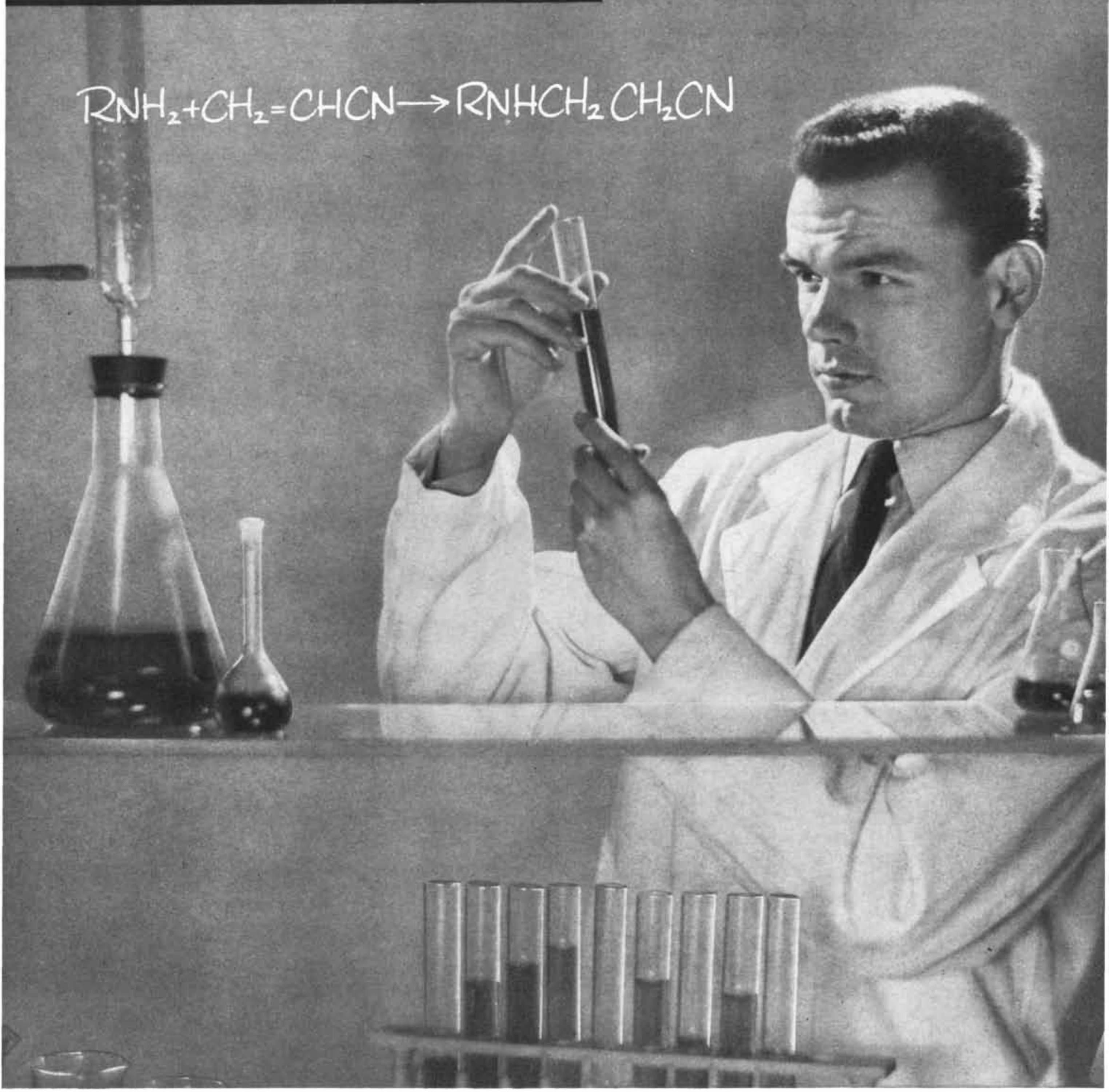

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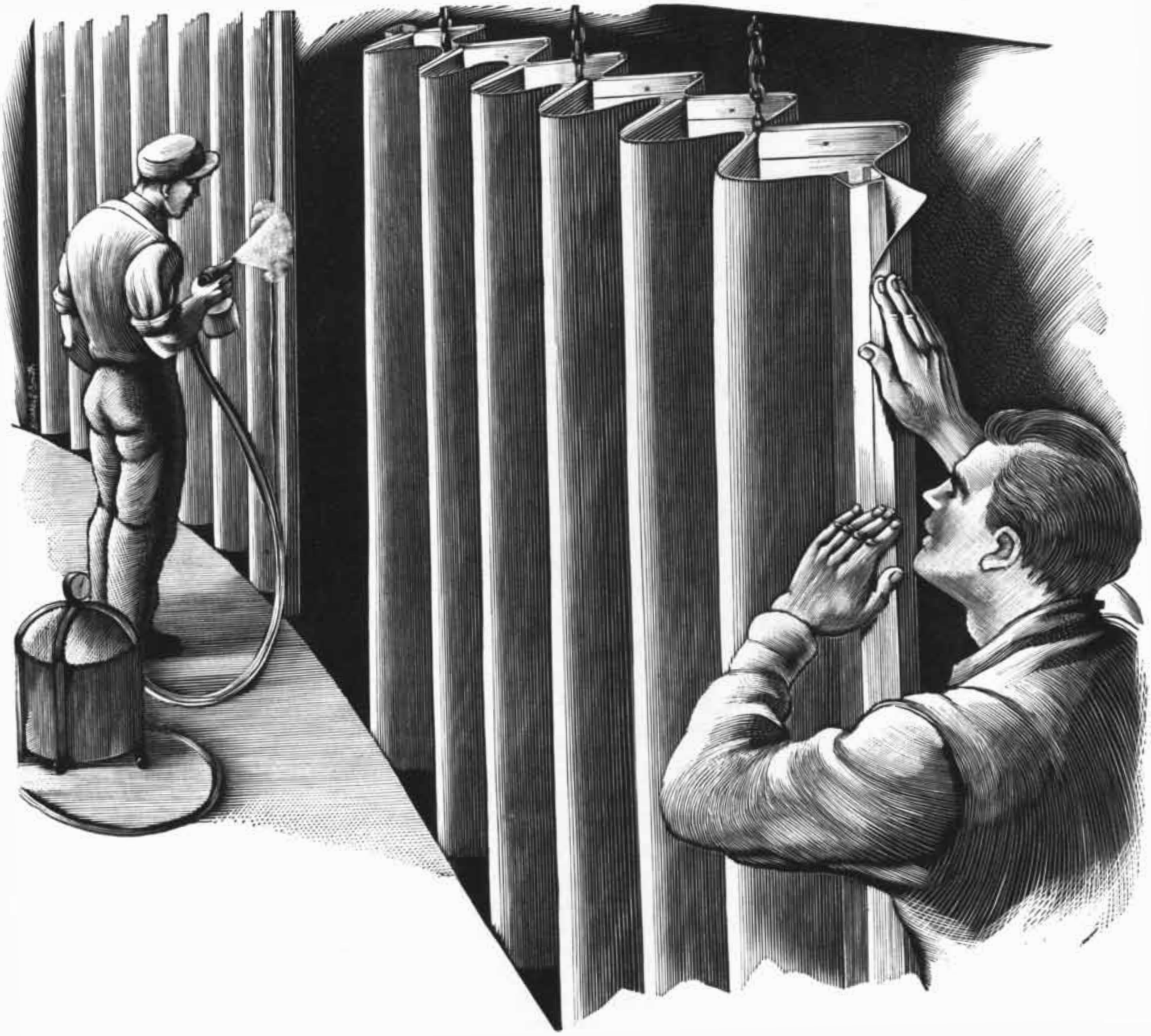


SCIENTIFIC AMERICAN
NOVEMBER, 1955 VOL. 193, NO. 5

Opinions and Social Pressure

Exactly what is the effect of the opinions of others on our own? In other words, how strong is the urge toward social conformity? The question is approached by means of some unusual experiments

by Solomon E. Asch

That social influences shape every person's practices, judgments and beliefs is a truism to which anyone will readily assent. A child masters his "native" dialect down to the finest nuances; a member of a tribe of cannibals accepts cannibalism as altogether fitting and proper. All the social sciences take their departure from the observation of the profound effects that groups exert on their members. For psychologists, group pressure upon the minds of individuals raises a host of questions they would like to investigate in detail.

How, and to what extent, do social forces constrain people's opinions and attitudes? This question is especially pertinent in our day. The same epoch that has witnessed the unprecedented technical extension of communication has also brought into existence the deliberate manipulation of opinion and the "engineering of consent." There are many good reasons why, as citizens and as scientists, we should be concerned with studying the ways in which human beings form their opinions and the role that social conditions play.

Studies of these questions began with the interest in hypnosis aroused by the French physician Jean Martin Charcot (a teacher of Sigmund Freud) toward the end of the 19th century. Charcot believed that only hysterical patients could be fully hypnotized, but this view was soon challenged by two other physicians, Hyppolyte Bernheim and A. A. Liébault, who demonstrated that they could put most people under the hypnotic spell. Bernheim proposed that hypnosis was but an extreme form of a normal psychological process which became known as "suggestibility." It was shown that monotonous reiteration of instructions could induce in normal persons in the waking state involuntary bodily changes such as swaying or rigidity of the arms, and sensations such as warmth and odor.

It was not long before social thinkers seized upon these discoveries as a basis for explaining numerous social phenomena, from the spread of opinion to the formation of crowds and the following of leaders. The sociologist Gabriel Tarde summed it all up in the aphorism: "Social man is a somnambulist."

When the new discipline of social psychology was born at the beginning of this century, its first experiments were

EXPERIMENT IS REPEATED in the Laboratory of Social Relations at Harvard University. Seven student subjects are asked by the experimenter (*right*) to compare the length of lines (*see diagram on the next page*). Six of the subjects have been coached beforehand to give unanimously wrong answers. The seventh (*sixth from the left*) has merely been told that it is an experiment in perception.

essentially adaptations of the suggestion demonstration. The technique generally followed a simple plan. The subjects, usually college students, were asked to give their opinions or preferences concerning various matters; some time later they were again asked to state their choices, but now they were also informed of the opinions held by authorities or large groups of their peers on the same matters. (Often the alleged consensus was fictitious.) Most of these studies had substantially the same result: confronted with opinions contrary to their own, many subjects apparently shifted their judgments in the direction of the views of the majorities or the experts. The late psychologist Edward L. Thorndike reported that he had succeeded in modifying the esthetic preferences of adults by this procedure. Other psychologists reported that people's evaluations of the merit of a literary passage could be raised or lowered by ascribing the passage to different authors. Apparently the sheer weight of numbers or authority sufficed to change opinions, even when no arguments for the opinions themselves were provided.

Now the very ease of success in these experiments arouses suspicion. Did the subjects actually change their opinions, or were the experimental victories scored only on paper? On grounds of common sense, one must question whether opinions are generally as watery as these studies indicate. There is some reason to wonder whether it was not the investigators who, in their enthusiasm for a theory, were suggestible, and whether the ostensibly gullible subjects were not providing answers which they thought good subjects were expected to give.

The investigations were guided by certain underlying assumptions, which today are common currency and account for much that is thought and said about the operations of propaganda and public opinion. The assumptions are that people submit uncritically and painlessly to external manipulation by suggestion or prestige, and that any given idea or value can be "sold" or "unsold" without reference to its merits. We should be skeptical, however, of the supposition that the power of social pressure necessarily implies uncritical submission to it: independence and the capacity to rise above group passion are also open to human beings. Further, one may question on psychological grounds whether it is possible as a rule to change a person's judgment of a situation or an object without first changing his knowledge or assumptions about it.

In what follows I shall describe some experiments in an investigation of the effects of group pressure which was carried out recently with the help of a number of my associates. The tests not only demonstrate the operations of group pressure upon individuals but also illustrate a new kind of attack on the problem and some of the more subtle questions that it raises.

A group of seven to nine young men, all college students, are assembled in a classroom for a "psychological experiment" in visual judgment. The experimenter informs them that they will be comparing the lengths of lines. He shows two large white cards. On one is a single vertical black line—the standard whose length is to be matched. On the other card are three vertical lines of various lengths. The subjects are to choose the one that is of the same length as the line on the other card. One of the three actually is of the same length; the other two are substantially different, the difference ranging from three quarters of an inch to an inch and three quarters.

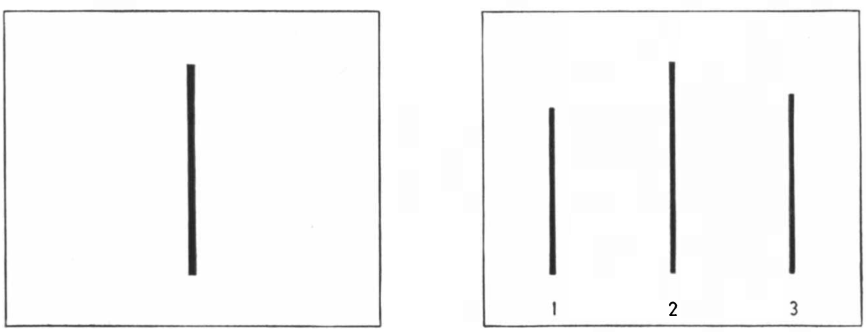
The experiment opens uneventfully. The subjects announce their answers in the order in which they have been seated in the room, and on the first round every person chooses the same matching line. Then a second set of cards is exposed; again the group is unanimous. The members appear ready to endure politely another boring experiment. On the third trial there is an unexpected disturbance. One person near the end of the group disagrees with all the others in his selection of the matching line. He looks surprised, indeed incredulous, about the disagreement. On the following trial he disagrees again, while the others remain unanimous in their choice. The dissenter becomes more and more worried and hesitant as the disagreement continues in succeeding trials; he may pause before announcing his answer and speak in a low voice, or he may smile in an embarrassed way.

What the dissenter does not know is that all the other members of the group were instructed by the experimenter beforehand to give incorrect answers in unanimity at certain points. The single individual who is not a party to this prearrangement is the focal subject of our experiment. He is placed in a position in which, while he is actually giving the correct answers, he finds himself unexpectedly in a minority of one, opposed by a unanimous and arbitrary majority with respect to a clear and simple fact. Upon him we have brought to bear two opposed forces: the evidence of his senses and the unanimous opinion of a group of his peers. Also, he must declare his judgments in public, before a majority which has also stated its position publicly.

The instructed majority occasionally reports correctly in order to reduce the possibility that the naive subject will suspect collusion against him. (In only a few cases did the subject actually show suspicion; when this happened, the experiment was stopped and the results were not counted.) There are 18 trials in each series, and on 12 of these the majority responds erroneously.

How do people respond to group pressure in this situation? I shall report first the statistical results of a series in which a total of 123 subjects from three institutions of higher learning (not including my own, Swarthmore College) were placed in the minority situation described above.

Two alternatives were open to the subject: he could act independently, repudiating the majority, or he could go along with the majority, repudiating the evidence of his senses. Of the 123 put to the test, a considerable percentage yielded to the majority. Whereas in ordinary circumstances individuals matching the lines will make mistakes less than 1



SUBJECTS WERE SHOWN **two cards. One bore a standard line. The other bore three lines, one of which was the same length as the standard. The subjects were asked to choose this line.**

per cent of the time, under group pressure the minority subjects swung to acceptance of the misleading majority's wrong judgments in 36.8 per cent of the selections.

Of course individuals differed in response. At one extreme, about one quarter of the subjects were completely independent and never agreed with the erroneous judgments of the majority. At the other extreme, some individuals went with the majority nearly all the time. The performances of individuals in this experiment tend to be highly consistent. Those who strike out on the path of independence do not, as a rule, succumb to the majority even over an extended series of trials, while those who choose the path of compliance are unable to free themselves as the ordeal is prolonged.

The reasons for the startling individual differences have not yet been investigated in detail. At this point we can only report some tentative generalizations from talks with the subjects, each of whom was interviewed at the end of the experiment. Among the independent individuals were many who held fast because of staunch confidence in their own judgment. The most significant fact about them was not absence of responsiveness to the majority but a capacity to recover from doubt and to reestablish their equilibrium. Others who acted independently came to believe that the majority was correct in its answers, but they continued their dissent on the simple ground that it was their obligation to call the play as they saw it.

Among the extremely yielding persons we found a group who quickly reached the conclusion: "I am wrong, they are right." Others yielded in order "not to spoil your results." Many of the individuals who went along suspected that the majority were "sheep" following the first responder, or that the majority were victims of an optical illusion; nevertheless, these suspicions failed to free them at the moment of decision. More disquieting were the reactions of subjects who construed their difference from the majority as a sign of some general deficiency in themselves, which at all costs they must hide. On this basis they desperately tried to merge with the majority, not realizing the longer-range consequences to themselves. All the yielding subjects underestimated the frequency with which they conformed.

Which aspect of the influence of a majority is more important—the size of the majority or its unanimity? The experiment was modified to examine this

EXPERIMENT PROCEEDS as follows. In the top picture the subject (*center*) hears rules of experiment for the first time. In the second picture he makes his first judgment of a pair of cards, disagreeing with the unanimous judgment of the others. In the third he leans forward to look at another pair of cards. In the fourth he shows the strain of repeatedly disagreeing with the majority. In the fifth, after 12 pairs of cards have been shown, he explains that "he has to call them as he sees them." This subject disagreed with the majority on all 12 trials. Seventy-five per cent of experimental subjects agree with the majority in varying degrees.

question. In one series the size of the opposition was varied from one to 15 persons. The results showed a clear trend. When a subject was confronted with only a single individual who contradicted his answers, he was swayed little: he continued to answer independently and correctly in nearly all trials. When the opposition was increased to two, the pressure became substantial: minority subjects now accepted the wrong answer 13.6 per cent of the time. Under the pressure of a majority of three, the subjects' errors jumped to 31.8 per cent. But further increases in the size of the majority apparently did not increase the weight of the pressure substantially. Clearly the size of the opposition is important only up to a point.

Disturbance of the majority's unanimity had a striking effect. In this experiment the subject was given the support of a truthful partner—either another individual who did not know of the prearranged agreement among the rest of the group, or a person who was instructed to give correct answers throughout.

The presence of a supporting partner depleted the majority of much of its power. Its pressure on the dissenting individual was reduced to one fourth: that is, subjects answered incorrectly only one fourth as often as under the pressure of a unanimous majority [*see chart at lower left on the opposite page*]. The weakest persons did not yield as readily. Most interesting were the reactions to the partner. Generally the feeling toward him was one of warmth and closeness; he was credited with inspiring confidence. However, the subjects repudiated the suggestion that the partner decided them to be independent.

Was the partner's effect a consequence of his dissent, or was it related to his accuracy? We now introduced into the experimental group a person who was instructed to dissent from the majority but also to disagree with the subject. In some experiments the majority was always to choose the worst of the comparison lines and the instructed dissenter to pick the line that was closer to the length of the standard one; in others the majority was consistently intermediate and the dissenter most in error. In this manner we were able to study the relative influence of "compromising" and "extremist" dissenters.

Again the results are clear. When a moderate dissenter is present, the effect of the majority on the subject decreases by approximately one third, and extremes of yielding disappear. Moreover, most of the errors the subjects do make are moderate, rather than flagrant. In short, the dissenter largely controls the choice of errors. To this extent the subjects broke away from the majority even while bending to it.

On the other hand, when the dissenter always chose the line that was more flagrantly different from the standard, the results were of quite a different kind. The extremist dissenter produced a remarkable freeing of the subjects; their errors dropped to only 9 per cent. Furthermore, all the errors were of the moderate variety. We were able to conclude that dissent *per se* increased independence and moderated the errors that occurred, and that the direction of dissent exerted consistent effects.

In all the foregoing experiments each subject was observed only in a single setting. We now turned to studying the effects upon a given individual of a change in the situation to which he was exposed. The first experiment examined the consequences of losing or gaining a partner. The instructed partner began by answering correctly on the first six trials. With his support the subject usually resisted pressure from the majority: 18 of 27 subjects were completely independent. But after six trials the partner joined the majority. As soon as he did so, there was an abrupt rise in the subjects' errors. Their submission to the majority was just about as frequent as when the minority subject was opposed by a unanimous majority throughout.

It was surprising to find that the experience of having had a partner and of having braved the majority opposition with him had failed to strengthen the individuals' independence. Questioning at the conclusion of the experiment suggested that we had overlooked an important circumstance; namely, the strong specific effect of "desertion" by the partner to the other side. We therefore changed the conditions so that the partner would simply leave the group at the proper point. (To allay suspicion it was announced in advance that he had an appointment with the dean.) In this form of the experiment, the partner's effect outlasted his presence. The errors increased after his departure, but less markedly than after a partner switched to the majority.

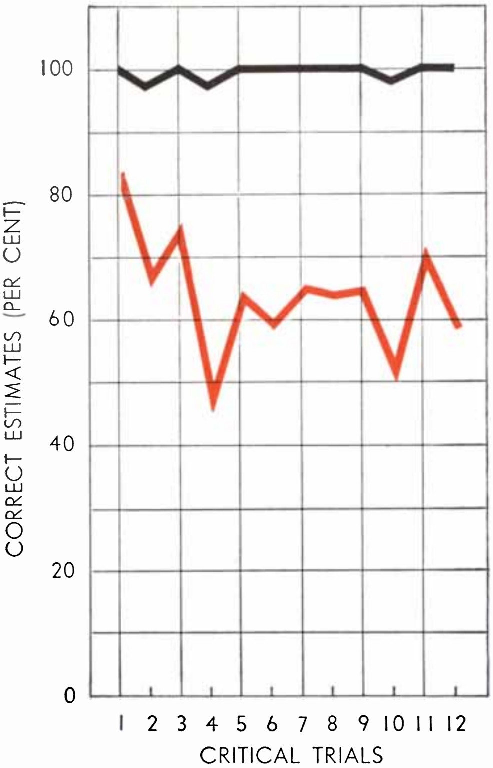
In a variant of this procedure the trials began with the majority unanimously giving correct answers. Then they gradually broke away until on the sixth trial the naive subject was alone and the group unanimously against him. As long as the subject had anyone on his side, he was almost invariably independent, but as soon as he found himself alone, the tendency to conform to the majority rose abruptly.

As might be expected, an individual's resistance to group pressure in these experiments depends to a considerable degree on how wrong the majority is. We varied the discrepancy between the standard line and the other lines systematically, with the hope of reaching a point where the error of the majority would be so glaring that every subject would repudiate it and choose independently. In this we regretfully did not succeed. Even when the difference between the lines was seven inches, there were still some who yielded to the error of the majority.

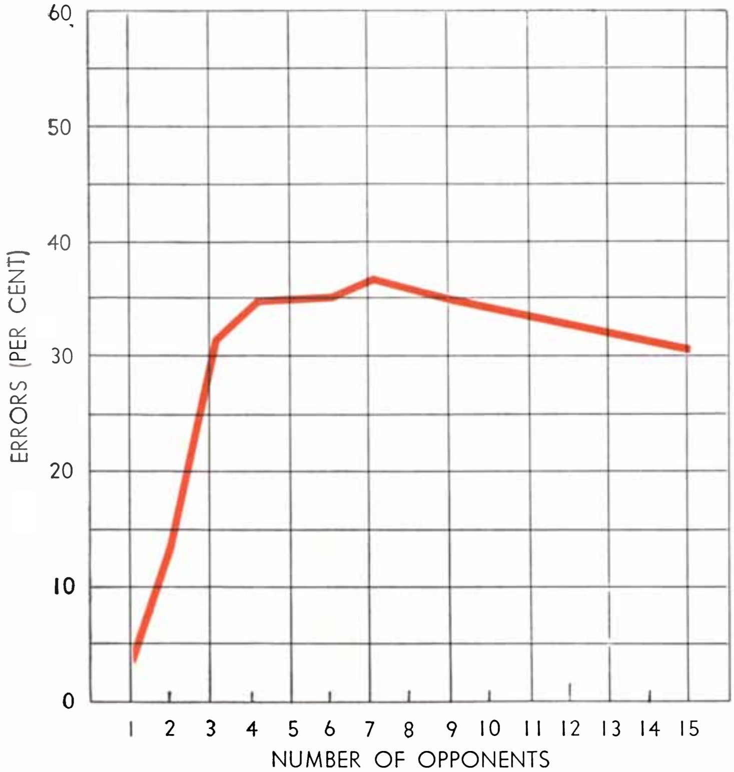
The study provides clear answers to a few relatively simple questions, and it raises many others that await investigation. We would like to know the degree of consistency of persons in situations which differ in content and structure. If consistency of independence or conformity in behavior is shown to be a fact, how is it functionally related to qualities of character and personality? In what ways is independence related to sociological or cultural conditions? Are leaders more independent than other people, or are they adept at following their followers? These and many other questions may perhaps be answerable by investigations of the type described here.

Life in society requires consensus as an indispensable condition. But consensus, to be productive, requires that each individual contribute independently out of his experience and insight. When consensus comes under the dominance of conformity, the social process is polluted and the individual at the same time surrenders the powers on which his functioning as a feeling and thinking being depends. That we have found the tendency to conformity in our society so strong that reasonably intelligent and well-meaning young people are willing to call white black is a matter of concern. It raises questions about our ways of education and about the values that guide our conduct.

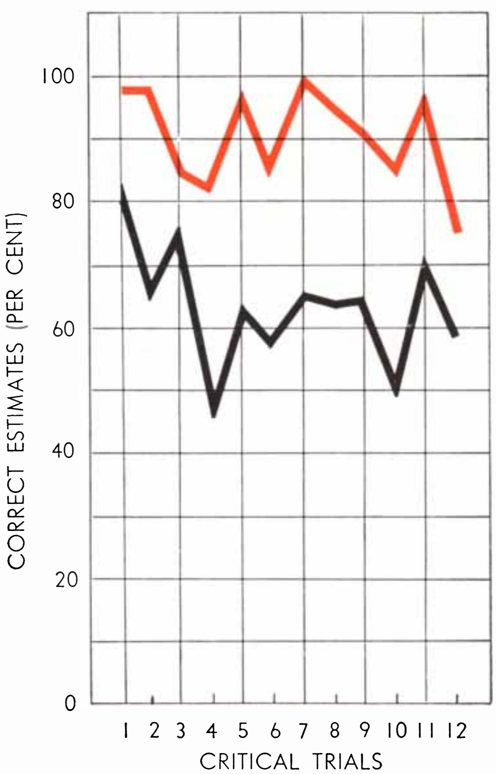
Yet anyone inclined to draw too pessimistic conclusions from this report would do well to remind himself that the capacities for independence are not to be underestimated. He may also draw some consolation from a further observation: those who participated in this challenging experiment agreed nearly without exception that independence was preferable to conformity.



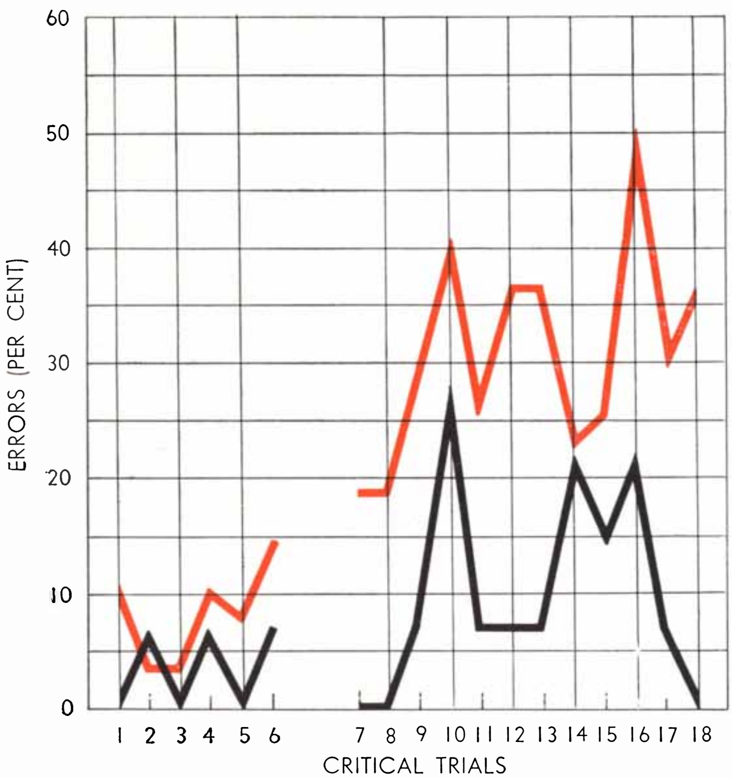
ERROR of 123 subjects, each of whom compared lines in the presence of six to eight opponents, is plotted in the colored curve. The accuracy of judgments not under pressure is indicated in black.



SIZE OF MAJORITY which opposed them had an effect on the subjects. With a single opponent the subject erred only 3.6 per cent of the time; with two opponents he erred 13.6 per cent; three, 31.8 per cent; four, 35.1 per cent; six, 35.2 per cent; seven, 37.1 per cent; nine, 35.1 per cent; 15, 31.2 per cent.



TWO SUBJECTS supporting each other against a majority made fewer errors (*colored curve*) than one subject did against a majority (*black curve*).



PARTNER LEFT SUBJECT after six trials in a single experiment. The colored curve shows the error of the subject when the partner "deserted" to the majority. Black curve shows error when partner merely left the room.

THE TRENCHES OF THE PACIFIC

The floor of the great ocean is incised with tremendous furrows. The bottoms of several are farther below sea level than Everest is above it. They are clues to the history of the earth's crust

by Robert L. Fisher and Roger Revelle

On April 28, 1789, Lieutenant William Bligh, commanding H.M.S. *Bounty*, had a memorable quarrel in the Pacific Ocean with his senior warrant officer, one Fletcher Christian, as a result of which they parted company and sailed off in opposite directions—Christian in the *Bounty* and Bligh in the ship's longboat. This historic mutiny took place near the great volcano of Tofua in the Friendly Islands, better known today as the Tonga Islands. Bligh and Christian were well acquainted with the fact that the oceanic topography around these islands was somewhat unusual—full of treacherous shoals and narrow interisland passages. But they could not know, for methods of deep-sea sounding had not yet been invented, how unusual it really was, nor that this place would one day yield one of the most remarkable discoveries in the history of ocean-going exploration.

Beneath the placid sea east of the Tonga Islands yawns a monstrous chasm nearly seven miles deep. A hundred years after the *Bounty* episode another British vessel first plumbed its depths. Surveying the ocean bottom around the islands, Pelham Aldrich, commanding H.M.S. *Egeria*, was surprised to find that on two occasions his sounding lead did not touch bottom until 24,000 feet of wire had been paid out. Aldrich's discovery prompted other nations to send out expeditions to explore the Tonga undersea abyss. Eventually they traced out a great trench running from the Tonga Islands south to the Kermadec Islands [*see map on page 40*]. The deepest sounding made recently by the research vessel *Horizon* of the Scripps Institution of Oceanography, is some 35,000 feet. The immense chasm plunges about 6,000 feet farther below sea level than Mount Everest rises above it!

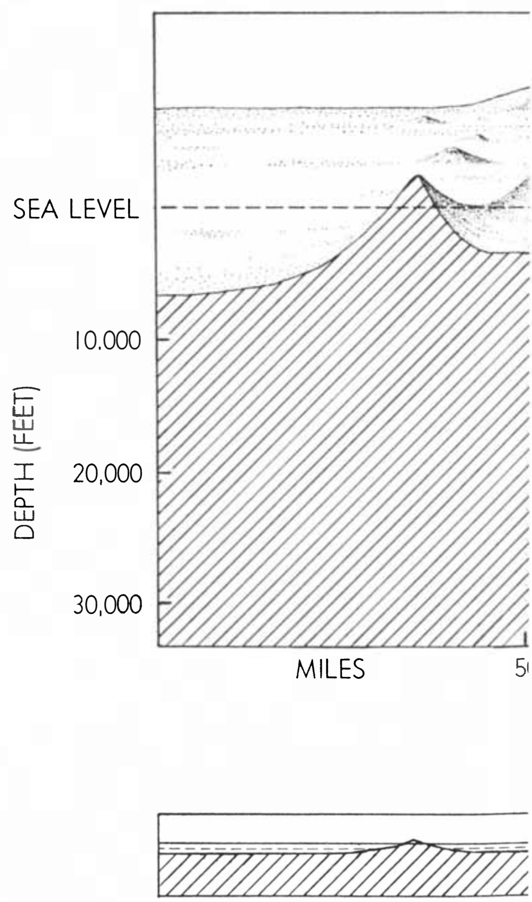
The Tonga-Kermadec Trench is now known to be but one member in a vast chain of deep, narrow trenches which lie like moats around the central basin of the Pacific [*see map*]. All of them parallel island archipelagoes or mountain ranges on the coasts of continents. Along the coast of South America, the drop from the top of the Andes to the bottom of the offshore trench is more than 40,000 feet. And the length of the undersea troughs is no less remarkable than their depth: some are 2,000 miles long.

These great gashes in the sea floor are so unlike anything on land that they are difficult for us as land animals to visualize. It is hard to grasp the reality of a chasm so deep that seven Grand Canyons could be piled on one another in it, and so long that it would extend from New York to Kansas City. Yet these are the dimensions of the Tonga-Kermadec Trench.

The size and peculiar shape of the Pacific trenches stir our sense of wonder. What implacable forces could have caused such large-scale distortions of the sea floor? Why are they so narrow, so long and so deep? What has become of the displaced material? Are they young or old, and what is the significance of the fact that they lie along the Pacific "ring of fire"—the zone of active volcanoes and violent earthquakes that encircles the vast ocean?

Although the trenches are still only sketchily explored, some tentative answers to these questions can be gleaned from the information already obtained. We can take the Tonga-Kermadec Trench as a typical example.

The Trench lies on a long, nearly straight, north-south line east of the Tonga and Kermadec archipelagoes. At its northern end it has a slight hook. It begins there as a gentle, spoon-shaped depression, runs southeasterly between Tonga and Samoa, then turns and deepens, strikes south for 1,200 miles and finally shoals and disappears at a point

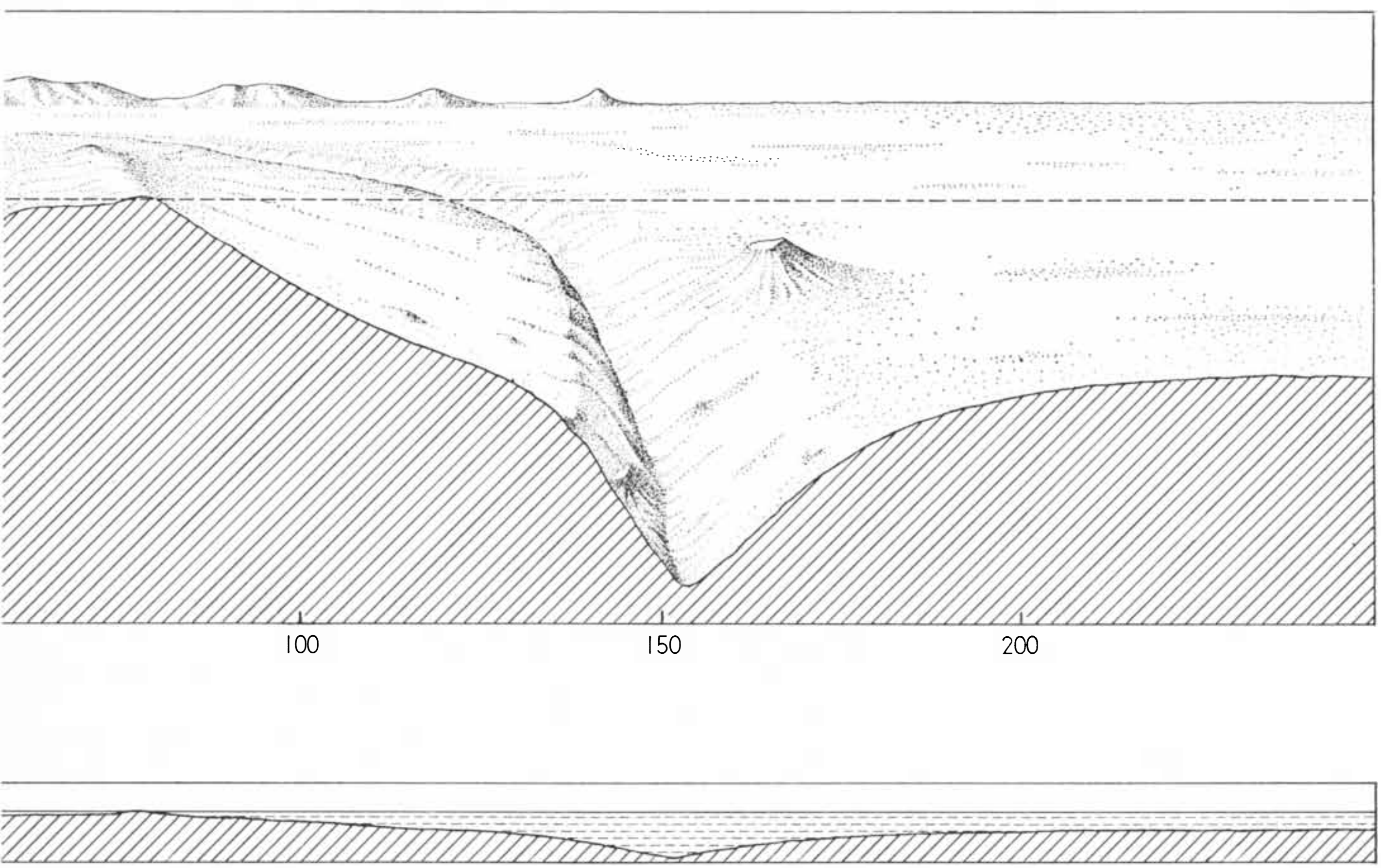


TONGA TRENCH would appear as in the upper drawing if viewed northward from a point in the central Tonga Islands, and if vertical distances were exaggerated by a north of New Zealand. In its deepest central portion the Trench is very narrow—no more than five miles wide. The chasm is V-shaped, but the arm of the V on the island side is considerably steeper than on the seaward side: on the landward western wall the slopes average from 16 to 30 per cent—*i.e.*, in places they are steeper than the 24-per-cent-average slope of the sides of the Grand Canyon at Bright Angel. In longitudinal section the Trench consists of deep depressions separated by saddles; it looks like beads on a string, or peaks and saddles on an upside-down mountain range.

The islands on the western lip of the Trench appear to be part of the same crustal structure. They lie in two lines on a thousand-mile-long ridge atop the Trench's western slope. The islands of the Polynesian kingdom of Tonga are capped with limestones, laid down in shallow water during the last era of geologic time. These islands rest on broad shelves of drowned coral, 180 to 360 feet deep, and they rise in a series of terraces to a few hundred feet above sea level. West of the limestone islands, separated from them by a shallow trough, is a chain of submarine volcanoes and high volcanic islands. The volcanoes are explosive, rather than of the quiet Hawaiian variety. They have contributed great quantities of ash and cinders to the surrounding sea floor. Five of the island volcanoes have erupted during the last hundred years, and the danger of further explosions has forced the government of Tonga to evacuate the inhabitants. There are also active volcanoes below the sea surface. One of them, Falcon Bank, rises several hundred feet above the sea during an eruption; indeed, this bank is commonly called Falcon Island. After each eruption waves quickly erode the erupted lava, and within a few years the volcano is submerged again.

The floor of the Tonga-Kermadec Trench is rocky and seems to be nearly bare of sediments. During the Scripps Institution *Capricorn* expedition of 1952-1953, a core barrel with a heavy lead weight, which because of difficulties with the winch was dragged along the sea floor for several hours before it could be raised, came up badly battered by the bottom rocks. The heavy steel bail holding the instrument had been bent, and the lead weight looked as if it had been beaten with a hammer and chisel. Small fragments of black volcanic rock were embedded in the lead.

On the seaward slope of the Trench a single volcanic cone rises smoothly 27,000 feet, to within 1,200 feet of the sea surface. Just below its summit is a broad flat bench, tilted to the westward. Further study of this great cone, one of the highest mountains on earth, might tell us much about the history of the trench. Almost certainly the flat bench was cut by waves when the topmost part of the peak was above sea level. If



factor of 10 in comparison with horizontal. (In the lower drawing the cross section is shown without vertical exaggeration.) The exposed land mass in the left foreground is the island of Kao, a dormant volcano. In the distance are the Samoan Islands. The flat-topped seamount on the eastern slope of the trench is one of the highest mountains in the world. Its summit, which is tilted down toward the west about one degree, was probably worn flat by wave action when trench was shallower and mountain above water.

shallow-water fossils could be recovered from the summit, we could fix the time when submergence occurred, and perhaps when the bench began to be tilted. This in turn might give us information about the rate of downward bending of the trench floor.

The Tonga Trench, as we have said, is typical of the great trenches in the Pacific. Some of the other giant furrows are the Aleutian, Kurile, Japan, Marianas, Philippine and Java Trenches on the northern and western sides and the Acapulco and Peru-Chile Trenches on the eastern side of the ocean. It is a remarkable and probably significant fact that the deepest trenches all have about the same maximum depth. The record sounding so far was one estimated to be somewhere between 35,290 and 35,640 feet, made in the trench southeast of the Mariana Islands. Appropriately enough this depth was measured by H.M.S. *Challenger*, the modern namesake of the famous ship whose voyage around the world in the 1870s marks the beginning of modern oceanography [see "The Voyage of the *Challenger*," by Herbert S. Bailey, Jr.; Scientific American, May, 1953]. The original *Challenger* actually discovered the Marianas depression, and for many years it was known as the Challenger Deep.

All the deep trenches seem to be generally V-shaped in cross section, although some are slightly flattened at the very bottom; in the Japan and Philippine trenches this flat portion is two to 10 miles wide. Some shallower trenches and trenchlike depressions are U-shaped, with extremely flat bottoms over broad areas, as if they had been partly filled with sediments. If the V-shaped trenches contain any sediments, the layer cannot be more than a few hundred feet thick.

Direct exploration of the trenches is most difficult. Their great depth and extreme narrowness present formidable obstacles. To lower a dredge or other heavy sampling apparatus to the bottom of the deeper trenches, the ship needs a tapered wire rope of the strongest steel and a powerful, specially designed winch. Only three such winches exist today. One was built for the Swedish *Albatross* Expedition of 1948-49 and was later used on the Danish *Galathea* Expedition of 1950-52; another is installed on the Scripps Institution's research vessel *Spencer F. Baird*; the third is on the U.S.S.R. research ship *Vitiaz*. The winch drum on the *Baird* carries 40,000 feet of wire rope. When this wire was paid out in the Tonga Trench with a heavy core barrel on the end, the strain at deck level was 12 tons.

A single lowering of a dredge or core barrel takes many hours. It is complicated by the problem of keeping a small ship in position in a rolling sea, often under the influence of strong and unpredictable currents and shifting winds. The hazards of fouling the wire or of machinery breakdown under the heavy strain are always present, with the possible loss of the precious cable. Such a loss would be crippling, and much of the investment in time and effort required to send a scientific ship to a remote part of the world would also be lost.

If sounding and sampling of the bottom are difficult, drilling to find what lies beneath the bottom of the trenches is quite impossible, with present techniques. For such explorations we must depend on indirect methods—studies of earthquake waves, measurements of gravity anomalies, the flow of heat through the crust and the magnetic properties of the buried rocks.

The zone of trenches is the scene of our planet's most intense earthquake activity. Nearly all the major earthquakes, especially those originating at great depths, occur in this zone. The deepest-focus earthquakes are associated with the deepest and steepest trenches. This strongly suggests that the seat of the trench-producing forces lies far below the earth's surface.

The earthquakes may, indeed, be responsible for the fact that a line of explosive volcanoes parallels the trenches. Some investigators have proposed that the heat produced near the focus of an earthquake melts the surrounding rocks, and that the melted material rises and is eventually ejected by the volcanoes.

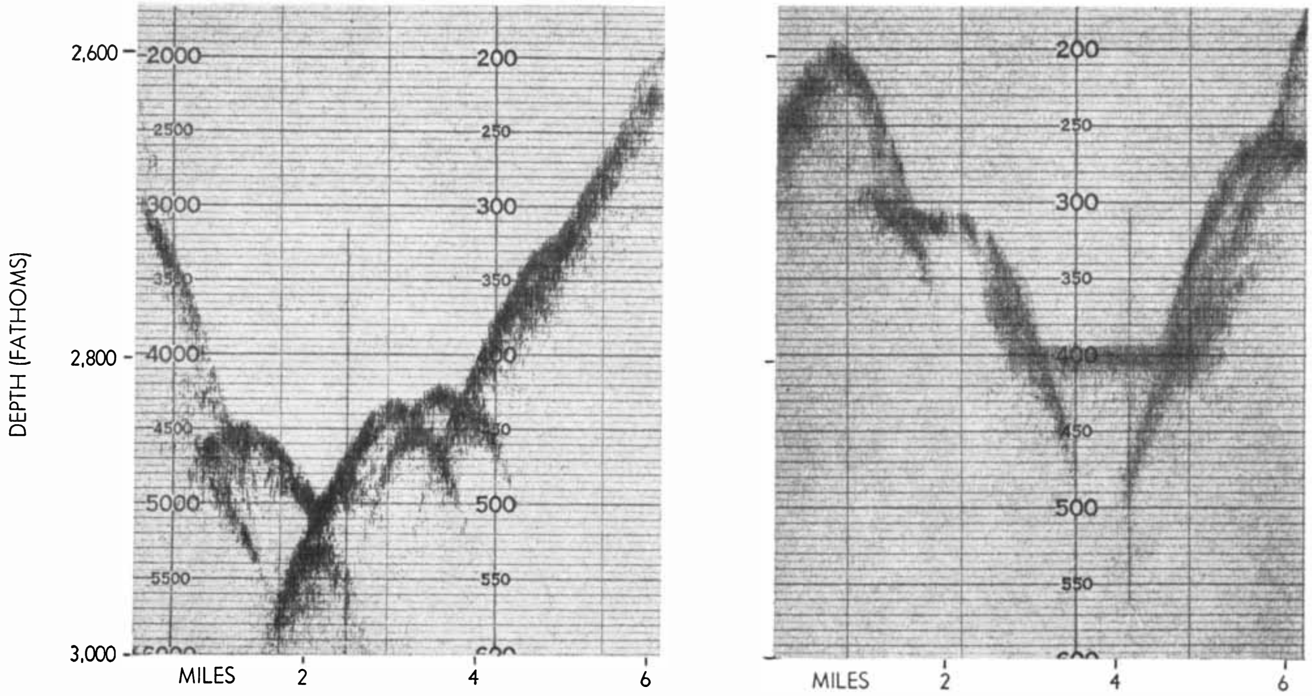
Seismic refraction studies give us another clue to the nature of the crust under the trenches. These investigations have shown that beneath the trenches (Tonga and others) the outer crust is less than one third as thick as under the continents. We therefore arrive at the important conclusion that the crustal structure under the trenches is oceanic and not continental.

The most striking phenomenon associated with the trenches is a deficiency in gravity. The force of gravity depends on the mass of matter between the surface and some great depth in the earth. In general this force at any given latitude is about the same in ocean basins as in the continents, despite the fact that the volume of rock under a continental area is greater than under an equal area of the ocean. Evidently the continents "float" high above the deep sea floor, like rafts of light material in a heavier medium. Within the continents themselves, there is usually little difference in gravity between high mountains and low plains, and it is commonly supposed that the mountains are underlain by a larger thickness of light material than the plains. This state of the earth's crust is called isostatic equilibrium.

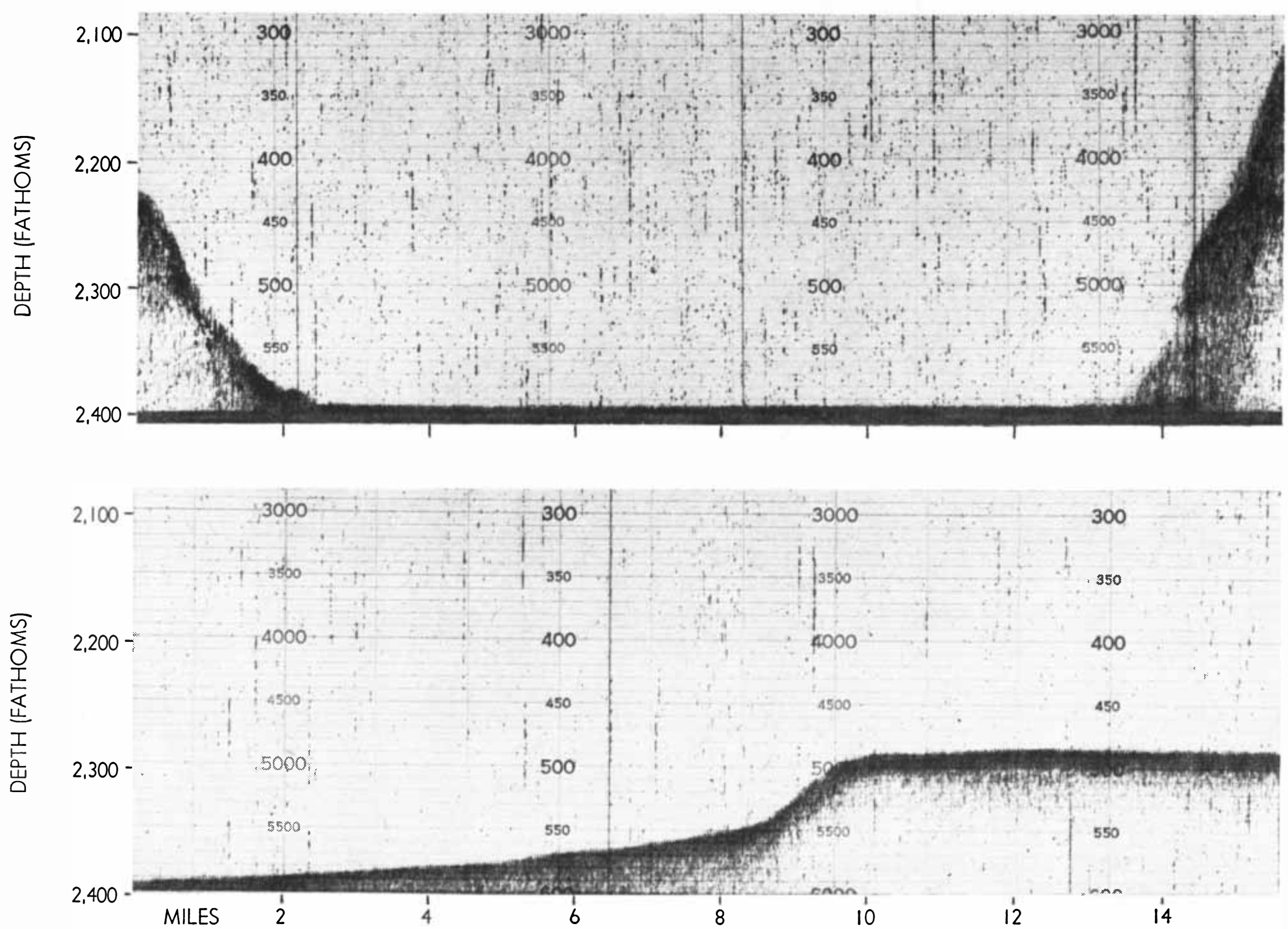
Measurements of gravity near trenches show pronounced departures from the expected values. These gravity anomalies are among the largest found on earth. It is clear that isostatic equilibrium does not exist near the trenches. The trench-producing forces must be acting against the force of gravity to pull the crust under the trenches downward!

What may these forces be? Here studies of heat flow in the crust suggest a possible answer. It has long been known that there is a small, steady flow of heat from the earth's depths outward toward the surface. Most of this heat is generated by the disintegration of radioactive elements in the crust and the mantle just beneath the crust. Near the surface of the earth the heat is transported outward principally by conduction, but at greater depths there may be a slow upward movement of the hot rock itself, carrying heat toward the surface. If rock at these depths moves upward in some regions of the earth, there must be other regions where cold rock moves downward. This movement would reduce the outward flow of heat. Now measurements near the floor of the Acapulco Trench show that the flow of heat there is less than half the average for the earth's surface (the average being about 250 calories per year per square inch of surface). So it may be that relatively cool rocks are slowly moving downward under the trench. Such a downward flow would tend to drag the crust down with it and may well account for the formation of the trench. If this process is occurring, the earth's mantle should be cooler under the trench than elsewhere. Magnetic measurements suggest that this is in fact the case, but they are too few so far to be conclusive.

Speculating from what we know, we may imagine that a trench has the following life history. Forces deep within the earth cause a foundering of the sea floor, forming a V-shaped trench. The depth stabilizes at about 35,000 feet, but crustal material, including sediments, may continue to be dragged downward into the earth. This is suggested by the



ACAPULCO TRENCH is revealed in cross section by echo soundings. Near Acapulco (*left*), the bottom is V-shaped, with little sediment, and 2,930 fathoms deep. Near Manzanillo (*right*), it is flat at 2,795 fathoms. Numbers on the records do not represent fathoms.



CEDROS TROUGH, a short trench off the coast of Lower California, is traced in cross section by the upper echo-sounding and longitudinally by the lower. The bottom is flat at 2,395 fathoms and measures 11 miles across at the point where measurement was made.

fact that the deepest trenches contain virtually no sediments, although they are natural sediment traps. During this stage in the trench's history there is violent volcanic and earthquake activity.

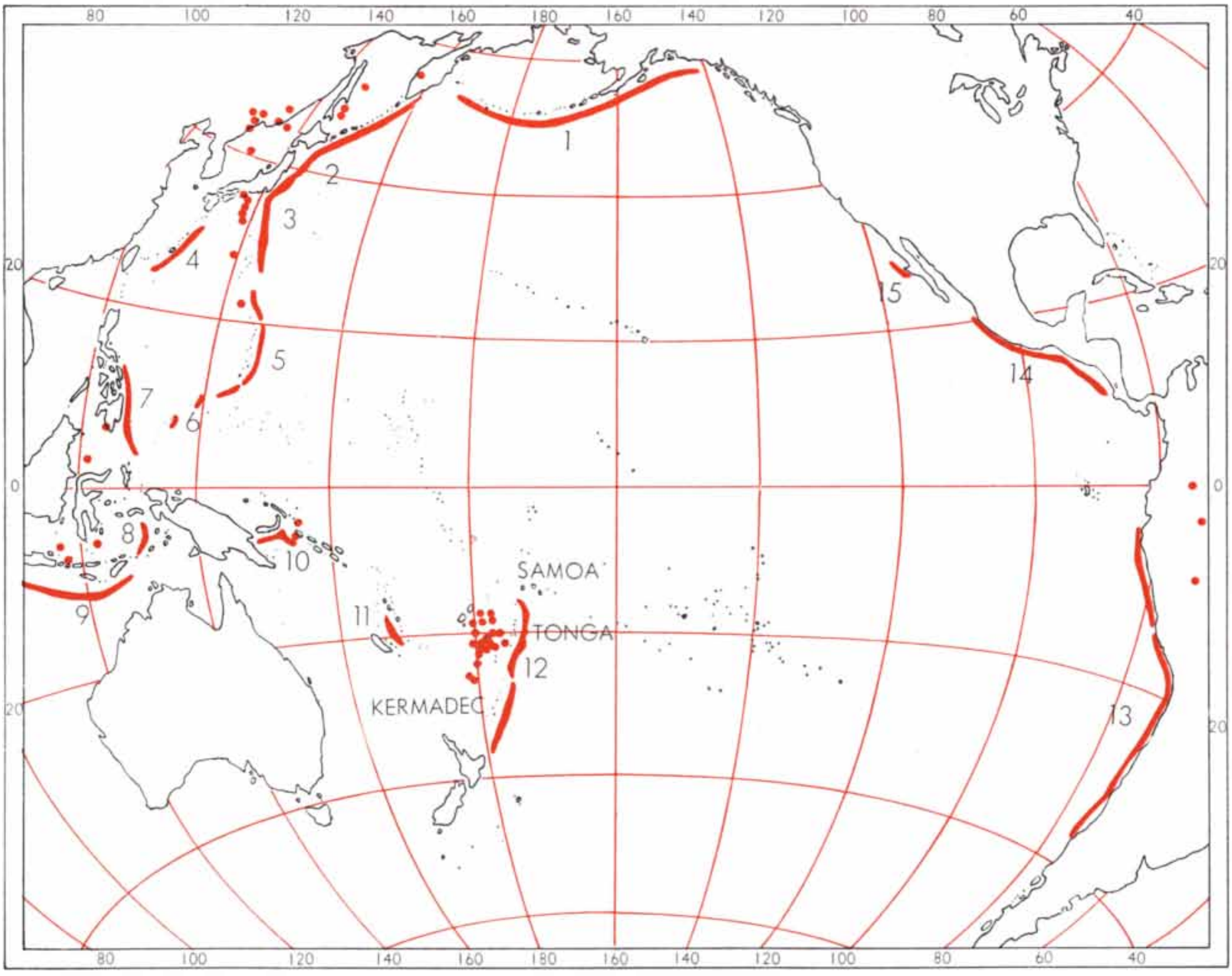
In a later stage the internal forces pulling or squeezing the crust downward under the trench become less active, and the trench begins to fill up with sediments. It acquires a flat bottom and a U shape as the accumulating sediments cover the topographic irregularities. The sediments may eventually pile up so high that the top of the pile rises above the sea, forming islands, when isostatic equilibrium is finally restored. The topmost sediments will be rock of the kind that is deposited in shallow water, like the limestones of Tonga and the Marianas.

Another process also may come into play if a thick layer of sediments accumulates. Because of their lower heat conductivity, the sediments would form an insulating blanket along the former trench. This would block the heat flow from the interior and cause a temperature rise which would partly melt the deep rocks. The melted material might then move upward and transform the heavy existing rock and the lower part of the sedimentary layer into light, granite-like rock. The thickness of the crust therefore should increase.

Some geophysicists have suggested that it was by such a sequence of events, occurring repeatedly during the geologic past, that the continents grew, at the expense of the ocean basins. The question then arises: Where on the continents are the ancient, filled-in trenches?

One naturally thinks at once of the long, narrow structures, called geosynclines, where sediments piled up and mountain ranges developed by compression and folding. Were some geosynclines originally deep trenches such as now exist on the sea floor? It has usually been thought that this is not so, because most of the sediments in geosynclines appear to have been laid down in shallow water rather than in deep trenches. However, this appearance may in some cases be an illusion. Sediment samples collected from even the deepest trenches resemble in many ways deposits laid down in shallow water.

It is true that the sedimentary rocks in geosynclines contain no recognizable fossils of deep-sea animals. But trenches have little life that could leave a distinctive record. The depths of a trench are completely dark, except for the fee-



RING OF TRENCHES around the central basin of the Pacific is shown in color. The colored dots represent deep centers of earthquake activity. Numbered serially are: Aleutian Trench (1), Kurile Trench (2), Japan Trench (3), Nansei Shoto Trench (4), Marianas Trench (5), Palau Trench (6), Philippine Trench (7), Weber Trough (8), Java Trough (9), New Britain Trench (10), New Hebrides Trench (11), Tonga-Kermadec Trench (12), Peru-Chile Trench (13), Acapulco-Guatemala Trench (14), Cedros Trough (15).

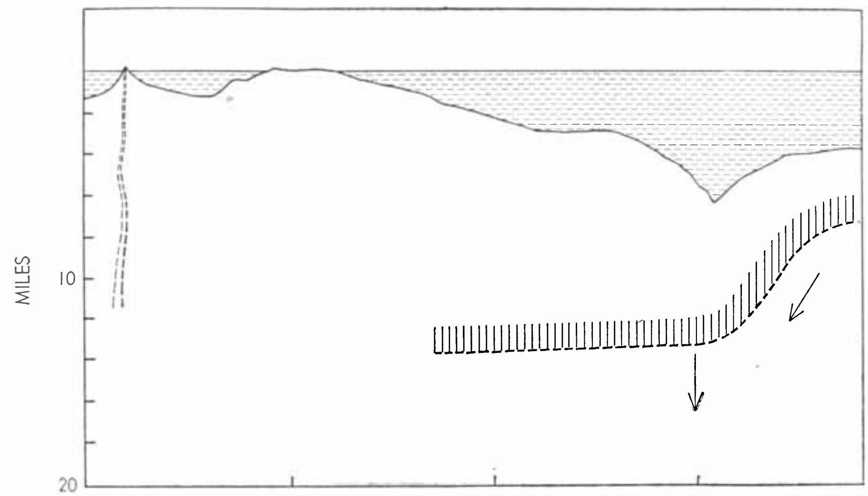
ble and flickering light produced by luminous organisms, and no plants can live there. The animals and bacteria of the abyss must gain their sparse food supply from plant and animal remains settling slowly from the upper layers of the sea. The waters are very cold: about 36.5 degrees Fahrenheit now, though they may have been some 20 degrees warmer in the geologic past. The pressure at the bottom of a trench is, of course, enormous—more than eight tons per square inch.

The Danish *Galathea* Expedition several years ago dredged up a few animals from the floors of trenches more than 30,000 feet deep. The principal animals recovered were sea cucumbers and a type of sea anemone, neither of which would be likely to leave distinctive fossils. Some worms, clams and crustaceans also were obtained, together with beautiful glass sponges.

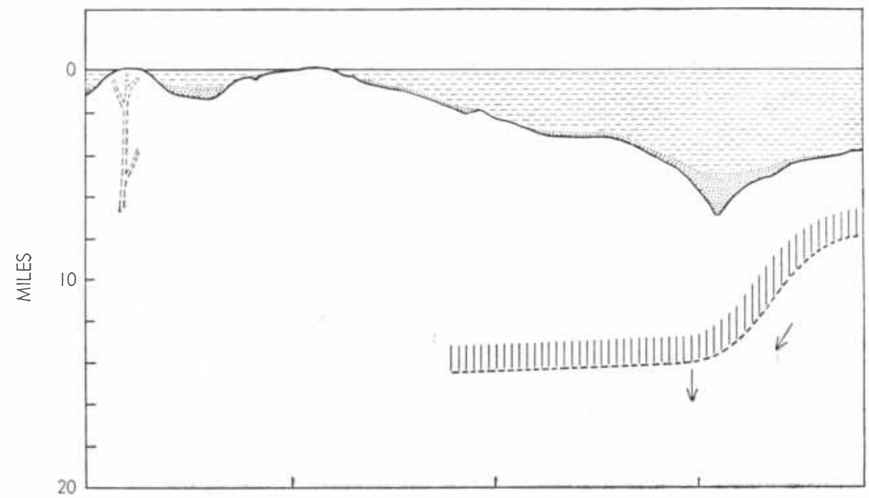
Materials which are usually supposed to be deposited only in shallow water have actually been found on the floor of some of the deep trenches. The *Galathea* recovered fine gray sand, pebbles, cobbles and land-plant debris from the floor of the Philippine Trench. The Lamont Geological Observatory of Columbia University found, in cores from the Puerto Rico Trough, the skeletons of plants and animals that live only at shallow depths. In the flat-bottomed northern part of the Acapulco Trench one core contained soft black mud, high in organic debris and stinking of hydrogen sulfide, while in other cores layers of gray, green and brownish sand and silt were interbedded with charred woody fragments and fine green mud.

However, it is clear that some geosynclines, notably those along what are now the Appalachian Mountains, could not have been deep sea trenches, for they contain deposits from marshes and flood plains interbedded with marine sediments, and therefore the deposits must have been laid down in shallow water.

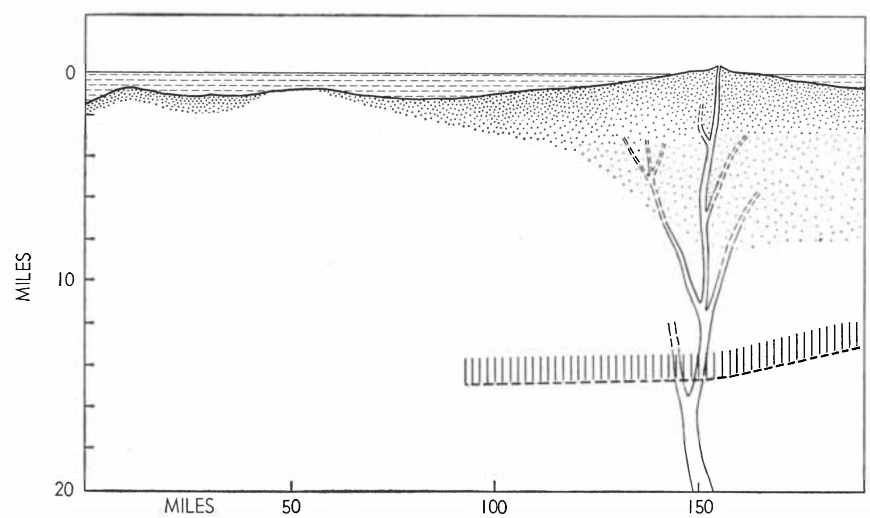
The question remains: Where are the trenches of yesteryear? Are we living in an exceptional geologic era; are the apparently young trenches of the present day unusual formations that have had no counterparts during most of geologic time? Such a speculation would be repugnant to many geologists, because it would be difficult to reconcile with the doctrine that the present is the key to the past. We must continue to search for ancient trenches—on the deep-sea floor, in the marginal shallow water areas and on the continents themselves.



POSSIBLE LIFE HISTORY of a trench is outlined in the three diagrams on this page. Here a force deep within the earth pulls down the floor of the ocean to form a V-shaped trench.



SEDIMENT COLLECTS in the bottom of the trench during the second stage, when the deep force weakens and relaxes its downward pull. Bottom is now flat and V changes to U.



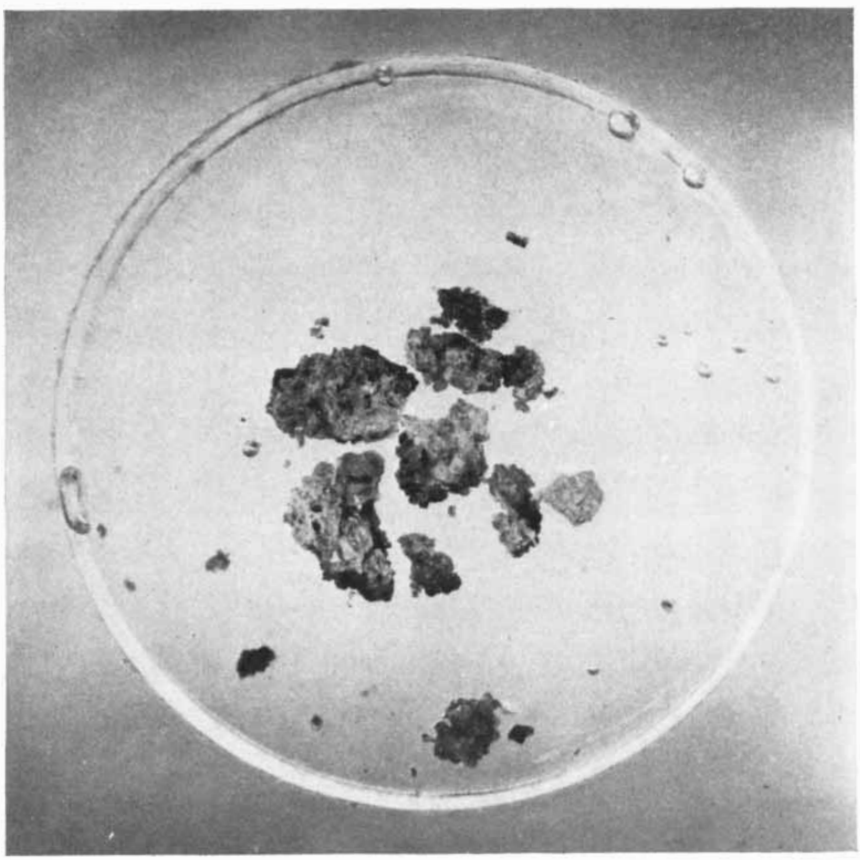
SEDIMENT BUILDS UP and, with isostatic adjustment of the crust, rises above the surface of the sea. Deep molten rock rises through the sediment and is released by volcanoes.

Synthetic Diamonds

Their recent production was the culmination of a hundred years of attempts, some of which were claimed to be successful. An account of these efforts and the thermodynamic laws defining the problem

by P. W. Bridgman

Now that the problem of synthesizing diamond has at last been solved, it is perhaps of interest to survey some of the highlights of the history of this long endeavor. The attempts to solve this glittering problem have revealed the whole human spectrum: those engaged in it have ranged from first-rate scientists to downright muckers and charlatans. There has been no little wishful thinking and self-deception, not unmixed with avarice. The project has generated an extensive literature in technical journals and many accounts in the popular press, based on rumors later proved unsubstantial. Many amateurs have done their own unpublished thinking about the subject. I suppose that over the last 25 years an average of two or three people a year have come into my office, offering to share the secret and the profit of making diamonds in return for my constructing the apparatus and reducing the idea to practice. The problem has got into the thriller literature, and I have often encountered the belief that the successful solver of this problem would be in danger of his life from the Diamond Syndicate.



DIAMONDS made in the General Electric Research Laboratory are enlarged about seven diameters. They were grown by H. P. Bovenkerk in the press depicted on the opposite page.

The beginning of a foundation for scientific attack on the problem was laid in 1797 when the Englishman Smithson Tennant showed that diamond is a form of elementary carbon. This may be proved by burning a pure diamond in an atmosphere of pure oxygen: it burns to carbon dioxide without any residue. The common crystalline form of carbon, of course, is graphite. Diamond has a density of 3.51 against 2.25 for graphite. Modern X-ray analysis has disclosed the structural differences between them. Diamond crystallizes in a cubic system, with each atom symmetrically surrounded by four others, all at the same distance and arranged at the corners of a regular tetrahedron. Graphite crystallizes in the hexagonal system: the atoms are arranged in layers; within each layer the pattern is not greatly different from the arrangement in diamond, but the layers are separated by comparatively large intervals. It is to this that graphite owes its lubricating properties, for the layers can slip over one another under the action of weak mechanical forces.

Paradoxically, although diamond is very dense and is the hardest substance known, its atoms are not packed in the closest possible geometrical arrangement. It would be much denser if each atom were surrounded by 12 other equidistant atoms instead of only four.

Willard Gibbs's work in thermodynamics at the turn of the 19th century made it possible to say theoretically under what conditions carbon might take the form of diamond in preference to graphite. Gibbs's studies made clear that graphite could not turn into diamond unless the "thermodynamic potential" of diamond was less than that of graphite. The thermodynamic potential plays for chemical reactions a role closely analogous to the ordinary potential of mechanics. Just as a weight falls from a higher to a lower position because its potential is less near the earth, so a chemical reaction tends to run in the direction in which its thermodynamic potential becomes less—or, expressing the rule more rigorously, a chemical reaction *can* run only in the direction in which its thermodynamic potential decreases.

Gibbs showed how to calculate the thermodynamic potential in terms of the specific heat, the thermal expansion and other measurable properties of materials. It appeared probable at the time, and later it became a certainty, that the thermodynamic potential of graphite is lower than that of diamond—which is another way of saying that under ordinary conditions graphite is thermodynamically the more stable form. It follows that if any transformation is to take place at all at ordinary temperatures and pressures, it is from diamond to graphite.

But there is a catch when it comes to using these considerations to predict what will happen. For although we can tell when a transformation *may* run, we cannot tell when it *will* run. Although diamond has thermodynamic permission to transform itself into graphite under ordinary conditions, it has no mandate to do so. (Thermodynamic stability is not the same as mechanical stability.) Everyone knows that diamonds do not spontaneously change to graphite, and my wife has worn her engagement ring these many years with no solicitude on that score.

The mathematical expression for the thermodynamic potential showed that if the pressure could be raised high enough, graphite would receive thermodynamic permission to transform, even at ordinary temperatures, to diamond. This pressure was calculated to be about 20,000 atmospheres. But here again permission does not mean that the reaction will inevitably run.

Just as we cannot say that graphite will change to diamond if only it has thermodynamic permission, so also we cannot say that when a carbon compound decomposes, or when carbon is precipitated from a solution, the form of carbon that separates will be the form thermodynamically preferred. We know from the thermodynamic potential that graphite is ordinarily the preferred form, but this does not enable us to say that the actual precipitate will be graphite and not diamond. As a matter of fact, there are many known instances in which an element's unstable form, corresponding to diamond, separates from a solidifying liquid or solution in preference to the more stable form.

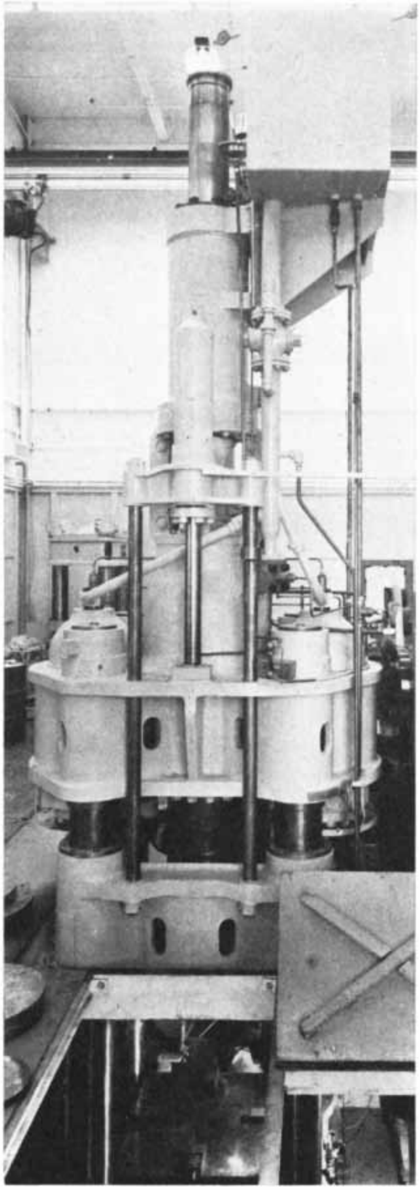
The possibility that diamond may be formed as an unstable phase under conditions where "nascent" (uncombined) carbon is liberated makes it impossible to rule out the chance of an accidental success. Thus I could never say to the hopeful amateur who walked into my office: "Your process *certainly* will not work." I could only say this when he proposed to transform graphite directly into diamond under thermodynamically impossible conditions. The aforementioned possibility has been one of the bogeys in the whole situation. Many geologists and mineralogists have been of the opinion that diamond is formed in nature under unstable conditions, which would mean that it might be a matter of anybody's lucky guess to find the proper conditions.

None of the sophistications we have considered entered into the early attempts to make diamonds. Many of those who made the attempt were guided simply by the fact that diamond is more dense than graphite, which naturally suggested the possibility that it might be formed by subjecting carbon to great pressure. There were then no means of producing anything like the 20,000 atmospheres later calculated to be necessary, but claims of success were numerous nonetheless.

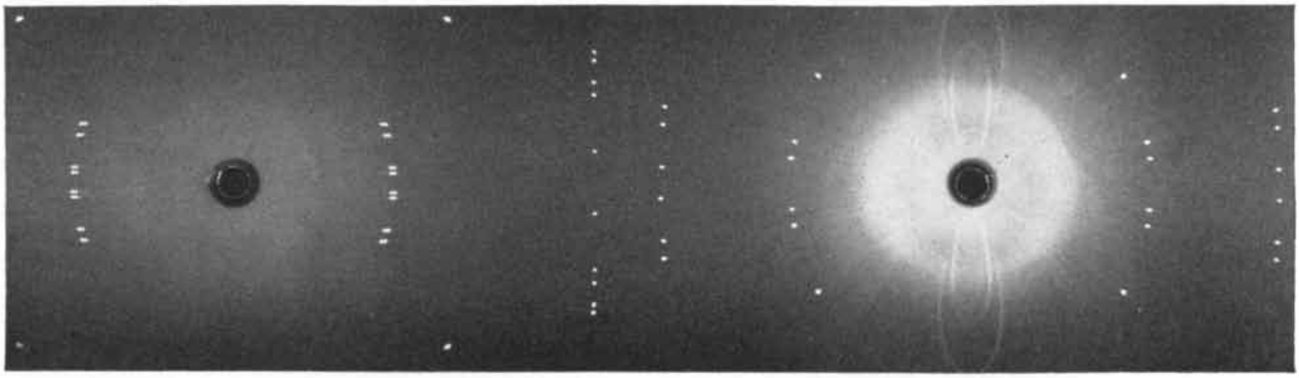
One of the earliest and still most discussed attempts was by a Scotsman, J. B. Hannay, in 1880. He mixed hydrocarbons, "bone oil" and lithium, sealed the mixture in a wrought-iron tube and heated it to redness in a forge. All but three of 80 tubes exploded. (The pressure in the tubes could not have been more than one or two thousand atmospheres.) In the residue of the unexploded tubes it was said that diamonds of density 3.5 were found. The claim was accepted at its face value and reported in the London *Times* by N. Story-Maskelyne. Subsequent attempts by a number of experimenters failed, however, to reproduce Hannay's results.

The matter was reopened in 1943 by the discovery in a forgotten corner of the British Museum of a small exhibit labeled "Hannay's Diamonds." These were analyzed with X-rays by F. A. Bannister and Kathleen Lonsdale, and found to be certainly diamonds, and of a somewhat rare type at that. On the theory that it was unlikely that diamonds fraudulently inserted would be of this rare type, Bannister and Mrs. Lonsdale argued that Hannay's claim was probably genuine. But there was also contrary evidence, in particular, as pointed out by Lord Rayleigh, some known instances of bad faith on Hannay's part. It seems to be the present consensus that Hannay was a fraud. Mrs. Lonsdale recently told me that she now also inclines to that view.

Perhaps the best known experiments of all are those of the Frenchman Henri Moissan, made in the 1890s when he was



HYDRAULIC PRESS in which the diamonds were grown is capable of exerting a force of 1,000 tons. The pressure chambers are located below the floor level (*bottom*).



X-RAY DIFFRACTION PHOTOGRAPHS were the most conclusive evidence that the synthetic diamonds were identical with natural diamonds. On this page is the diffraction pattern of natural diamond; on the opposite page, the pattern of synthetic diamond.

perfecting the electric furnace. Cast iron is known to dissolve fairly large quantities of carbon. Moissan melted a mixture of iron and graphite in his electric furnace and plunged the white-hot crucible into water. The iron of course solidified first on the outside. The inner core, on solidifying later, was supposed to expand against the rigid outer shell, thus producing a tremendous internal pressure, and the pressure was further enhanced by the contraction of the external shell as it cooled. (It is now known that the pressure produced could not have been more than a few thousand atmospheres, because, in the first place, hot cast iron is not strong enough to withstand greater pressures, and, in the second place, cast iron actually contracts when it solidifies instead of expanding as was then erroneously supposed.) After the crucible was cooled to room temperature, its contents were dissolved in acids and given other appropriate chemical treatment. In the end there was a small residue which Moissan reported to be diamond.

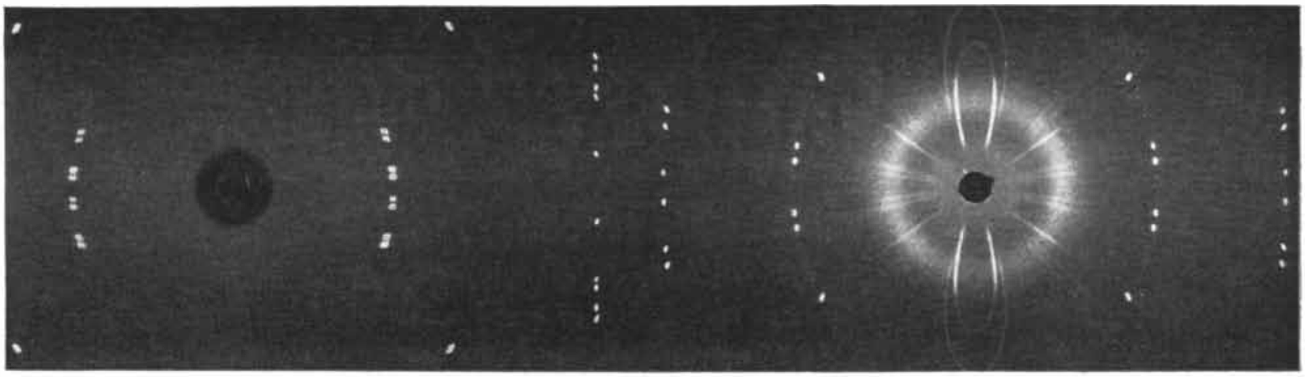
His experiments have been repeated a number of times, and a number of times with announced positive results. One attempt that seemed particularly convincing was by O. Ruff of Germany. In 1917 he made an elaborate investigation, trying all the methods of synthesis that had been reported successful. All gave negative results except the method of Moissan: according to Ruff's report this method did yield some diamonds. Later, however, he changed his opinion, and in a communication published as a footnote in a paper by other authors he stated that he believed his own supposed diamonds were not genuine. It must be remembered that it is an extraordinarily difficult matter to establish the true nature of material obtained in such small quantities as has been the case in most of the supposed synthetic diamonds.

Another celebrated repetition of Moissan's work was by Sir Charles Parsons, the shipbuilder who invented the steam turbine. The problem of diamond synthesis was Parsons' hobby; on it he spent hundreds of thousands of pounds. He had at his command the enormous hydraulic presses of his shipbuilding establishment, and he tried nearly every conceivable method feasible at that time. He decomposed all sorts of carbonaceous materials and generated enormous momentary pressures by firing projectiles into tapering dead-end cavities. In his presses he was not able to obtain static pressures of more than 10,000 atmospheres. Parsons in his early work believed that he had duplicated Moissan's supposed success, but later more careful repetition convinced him that he had been deceived and had obtained only various spinels (hard, crystalline minerals) instead of diamonds. In 1924 Parsons informed me that Moissan's widow had told him Moissan had been the victim of fraud by one of his assistants, who had introduced diamond fragments into the cookery, in order to please the old man and to avoid the tedium of the long digestions.

In the U. S. successful use of Moissan's method was reported by the late J. W. Hershey, a professor of chemistry at McPherson College in Kansas. Hershey was accustomed to assign the project of making diamonds by a slightly modified Moissan procedure to his senior chemistry class. It is stated that 50 diamonds have been made altogether. The largest is said to be 2 × 1.5 × 1 millimeters—a "record." A communication by Hershey in 1940, reporting his lack of success in attempts to make diamonds by another method, has been misquoted in a German paper as a repudiation by Hershey of his earlier claims, but so far as I know that claim has never been withdrawn. There is still a militant local sentiment among at least some of the inhabitants of McPherson, Kan., to the effect that diamonds are an old story and that the General Electric Company is trying to put something over.

Another method that has had a considerable following is the solidification of molten graphite. A number of people have been convinced that if only graphite could be melted, it would solidify to diamond. The reason for this conviction is not easy to see—perhaps it is because graphite is so hard to melt. At atmospheric pressure graphite when heated passes directly from the solid to the gaseous phase without melting, just as solidified carbon dioxide does. However, frozen carbon dioxide can be melted to the liquid state under pressures above 30 atmospheres, and presumably something similar would be expected for graphite. James Basset of France has asserted that graphite has a triple point (where the solid, liquid and gaseous states can exist) in the neighborhood of 4,000 degrees centigrade and about 100 atmospheres. Above these temperatures and pressures the melting curve rises like that of a normal substance with rising temperature and pressure. Basset has made many attempts at the diamond problem along these lines, without success. Thirty years ago John M. Morehead of the Union Carbide and Carbon Corporation attacked the problem from the same angle. He claimed to have melted graphite under pressure. His results were never published. One can now say that if diamond does crystallize out of molten graphite, it must be as the thermodynamically unstable phase.

A number of experimenters have claimed success in making diamonds with the help of the electrical "singing arc," which when first developed was



The photographs were made by mounting photographic film around the inside of a cylinder, at the axis of which was mounted the diamond. The beam of X-rays was directed through the side of the cylinder (*black holes in film*) while the diamond was rotated.

widely reported to be capable of melting graphite. In 1926 Professor M. La Rosa at the University of Palermo in Sicily showed me under the microscope a perfect little transparent octahedron which he said he thought was a diamond formed in his singing arc. It now appears almost certain that graphite could not have melted under these conditions, and that the appearance of melting was an effect of impurities, which doubtless were the origin of La Rosa's diamond.

In 1933 Hans Karabacek obtained a German patent for the formation of diamond by a complicated process involving the treatment of nascent carbon from carbon dioxide or monoxide with very high pressures attained by utilizing the thermal expansion attendant on cycles of heating and cooling. Karabacek was also an amateur fancier of minerals, of which he had accumulated a most remarkable collection. He put these on the market toward the end of his life, and Harvard University acquired a substantial part of them, along with some largish synthetic diamonds purportedly made according to his patent. For several years these diamonds were displayed in the Harvard Museum in a case labeled "Karabacek's synthetic diamonds." However, a member of the Harvard Society of Fellows, David Griggs, with the skepticism of youth, obtained permission to make a spectroscopic examination of one of them, and found all the characteristic impurities of the Cape diamonds. The label and the exhibit disappeared from the Museum thereafter.

Now let us shift the narrative to the more scientific attacks on the problem, made within the last 15 years, which have been based on the demands of thermodynamics, with the intention of attaining the conditions of thermodynamic stability. In 1938 F. D. Rossini and R. S. Jessup at the National Bureau of Standards published data of sufficient accuracy to indicate with fair certainty the thermodynamic limits. The calculations indicate that the pressure at which diamond begins to become more stable than graphite is of the general order of 10,000 atmospheres at absolute zero temperature, rises to something of the order of 20,000 atmospheres at room temperature, and continues to rise with increasing temperature. Above 1,000 degrees C. the data needed for the calculation do not exist, so that one can only extrapolate estimates of the pressures required at higher temperatures.

It soon appeared that mere pressure would not transform graphite to diamond at ordinary temperatures. I had applied prolonged pressures of 425,000 atmospheres to graphite at room temperature and of 70,000 at red heat, but no transformation had occurred, in spite of the fact that it unquestionably had thermodynamic permission at these pressures. Evidently something would have to be done to overcome the reluctance of the transformation to run, and for this a further rise of temperature suggested itself. But how high would it be necessary to go?

It is known that at atmospheric pressure diamonds start to change spontaneously to graphite when heated to somewhere in the neighborhood of 1,500 degrees C. This suggested that the reverse transition might run at the same temperatures if only the pressure could be raised high enough. The chances seemed good enough to justify a gamble on success, and early in 1941, largely through the interest of Zay Jeffries of the General Electric Company, General Electric's Carboloy Department, the Carborundum Company and the Norton Company jointly entered into a five-year agreement with me to finance the construction of apparatus and the conduct of experiments. The experiments were to combine high temperatures with pressures up to the 30,000 atmospheres or more which I was able to control in the laboratory. A 1,000-ton press was purchased and set up in the Harvard Geophysical Laboratory with the understanding that the apparatus could be used part time for experiments in geophysics. Very shortly, however, we were immersed in the war. Material became slow and difficult to procure, personnel was not available, and altogether the apparatus was used for less than two years of carbon experimenting instead of the five contemplated.

At first we attempted to get the requisite temperatures by heating graphite to 3,000 degrees C. outside the pressure vessel and then transferring it into the vessel and applying pressure as rapidly as possible. This attempt was given up because the graphite cooled too much before it could be put under pressure. A similar attempt at the impulsive application of pressure was made at about the same time in Germany by P. L. Guenther, P. Geselle and W. Rebentisch, also with negative results.

We next developed a method of heating the graphite within the pressure vessel by automatically setting off a stepped-up thermite type of reaction, which made it possible simultaneously to reach pressures of 30,000 atmospheres and temperatures of 3,000 degrees or more for a time of a few seconds. No diamonds were formed. The experiment did demonstrate for the first time, however, a pressure effect on the transition between graphite and diamond: at these pressures and temperatures the reverse transition from diamond to graphite was slowed down, and it stopped altogether at a pressure just on the edge of the maximum. The results encouraged the hope that diamonds might be produced if pressures could be got above 30,000.

At this juncture the five years of the agreement were up, the agreement was not renewed and the apparatus was removed to the Norton Company plant in Worcester. The Norton Company continued experiments of their own for the next five years. The results have been published only in part. It is known that the Norton workers synthesized a number of minerals of interest to geologists, including a brand-new form of silica christened Coesite. There has been talk to the effect that occasionally diamonds were produced, but that the conditions of formation were obscure and could not be reproduced. It would appear from the outside that the probability is not high that these were genuine: the conditions of thermodynamic stability were doubtless not attained, and X-rays, the only certain method, were not used in the analysis. At any rate, at the end of five years the Norton Company let it be known that they were through, and that if the problem was to be solved it would have to be by an organization with greater resources.

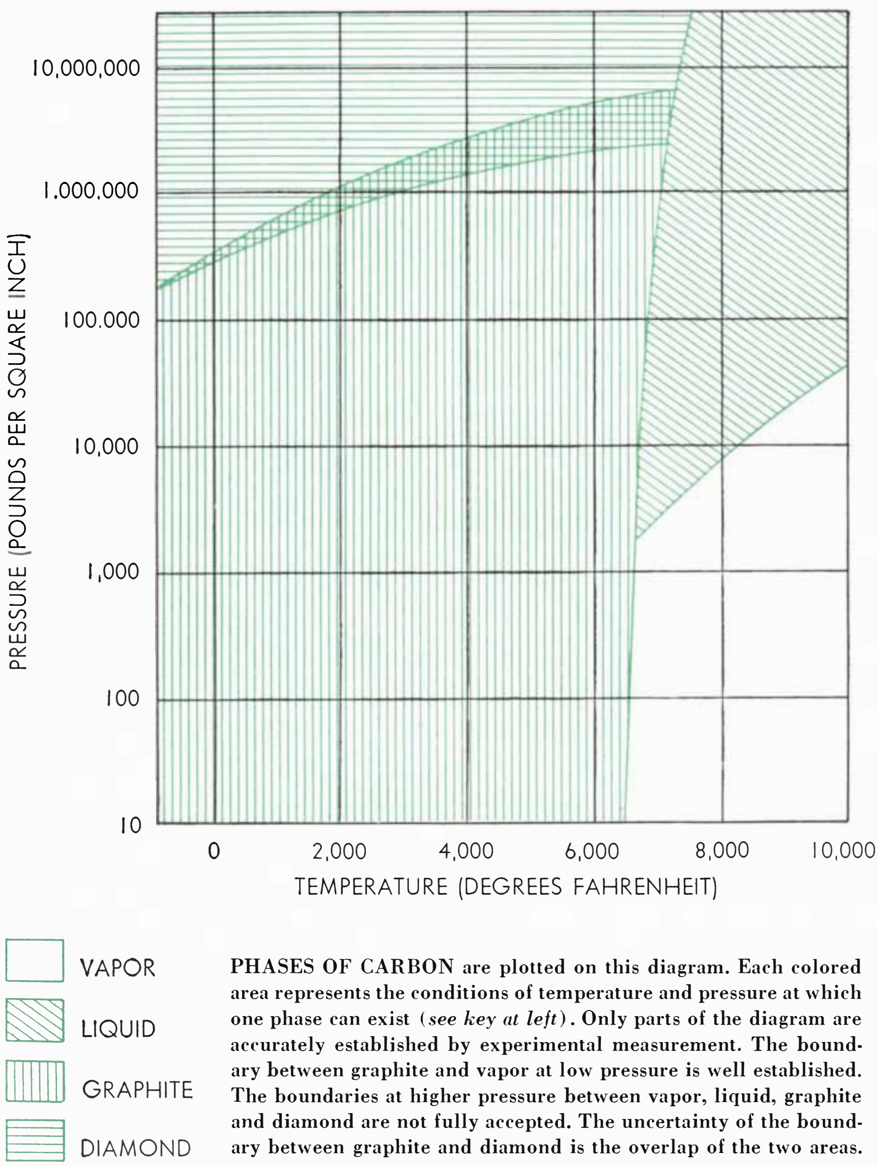
Then the Research Laboratory of the General Electric Company (distinct from the Carboloy Department) became interested. From a preliminary survey G.E. scientists concluded that the prospects were sufficiently promising to justify an all-out attack. By this time new theoretical light had been thrown on the problem by methods permitting estimates of the rates of transformation processes. Henry Eyring and F. W. Cagle, Jr., of the University of Utah demonstrated theoretically that the transformation rate would probably not change with temperature as simply as had been thought, so the estimate of the pressure required had to be revised materially upward. Even so, the prospects were such that a young official of the General Electric Company could say to me: "If G.E. goes into this, it is going to be successful."

Everyone now knows the results. Four years later a team of four G.E. physicists—F. P. Bundy, H. T. Hall, H. M. Strong and Robert Wentorf—could announce the successful conclusion of their labors. The stock of the de Beers Diamond Syndicate, which itself had been quietly trying to solve the synthetic diamond problem for its own purposes, dropped a few points on the announcement. But it recovered the next day, and no throats have been cut. The achievement is being taken in stride.

Full details of the process used by the G.E. group have not yet been announced. It is known that means have been found to maintain pressures of more than 100,000 atmospheres and temperatures of 2,500 degrees C. for hours at a time. The heating is electrical, and the pressures are attained by extending and improving methods which I had used. The diamond-synthesizing process is sure-fire: it works every time, and hundreds of batches have been made of diamonds which satisfy all the tests, including the conclusive X-ray test. The largest diamond so far is only one 16th of an inch long—but babies also are small in the beginning. The diamonds are produced under conditions of thermodynamic stability, which disposes of the old bogey that the problem might be solvable only by Edisonian methods of trying everything and waiting for luck to strike. In short, G.E. has solved this problem because it found out how to apply more pressure at a higher temperature and for a longer time than ever achieved before.

Doubtless the most important use for synthetic diamonds will be as an abrasive. Diamond abrasives are playing an increasingly indispensable role in modern machine-shop practice, so much so that the dependence of this country on foreign supply has become a matter of real concern to the Government.

The field of high temperatures and high pressures opened by the new techniques developed by the General Electric Company is a most inviting one for exploration. It is hard to put limits on what may legitimately be anticipated here in the way of new compounds or new alloys or new forms of old substances. Some day we may even be able to make the superdiamond that we would get if only the atoms of carbon could be compelled to assume a closer-packed arrangement than in our present diamonds.



PHASES OF CARBON are plotted on this diagram. Each colored area represents the conditions of temperature and pressure at which one phase can exist (*see key at left*). Only parts of the diagram are accurately established by experimental measurement. The boundary between graphite and vapor at low pressure is well established. The boundaries at higher pressure between vapor, liquid, graphite and diamond are not fully accepted. The uncertainty of the boundary between graphite and diamond is the overlap of the two areas.

Kodak reports to laboratories on:

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A gift horse's teeth

On the one hand, the educators, facing the oncoming hordes of kids by the unanticipated millions. With so pitifully few skillful and enthusiastic teachers to serve as infantry, reliance on the audio-visual artillery and cavalry must inevitably grow. Moreover, much of it is free, from public-spirited sources interested in the education of the young. Too bad that these gorgeously colored 16mm gift horses have to be looked so closely in the mouth to make sure they leave some more lasting kernel of truth than that Zilch's Flashlights pierce more gloom.

On the other hand, Zilch's advertising manager, no leering ogre but an intelligent, conscientious family man charged with much of the responsibility for keeping the people of the whole Zilchville Valley gainfully employed making dry cells. His is the task of explaining to young Zilch, the treasurer, how a film on basic principles of electrochemistry may possibly plant with the oncoming generation a seed of respect for the briefly seen Zilch trade-mark.

We're in the middle. We make projectors for the schools and film for Zilch's producer to use. We think both sides ought to be interested in the new booklet of the Association of National Advertisers, entitled "Criteria for Business-Sponsored Educational Films." ($2, from A. N. A.'s headquarters, 285 Madison Avenue, New York 17, N. Y.)

PbS on a slip of glass

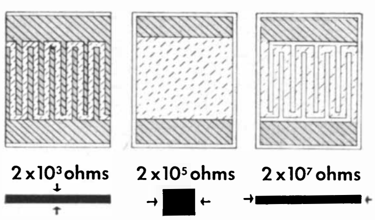
A little more than a year ago, in an advertisement that looked much like this one, there appeared an ecstatic announcement of a new type of photoconductive cell, y-clept *Kodak Ektron Detector*. No literature was offered—just the name of a man who could supply ordering information and transact business. If you had been one of those not repelled by such antediluvian merchandising technique, if, on the contrary, you had been sufficiently aroused to invest the price of an evening at a night club in a little .030″-thick rectangle of glass coated with lead sulfide, you might have found out for yourself some of the following facts about it:

Response extends from a few Å in the x-ray region through the whole ultraviolet and the visible, all the way to 3.5μ in the infrared. Probably the reason response stops there is the infrared transparency of lead sulfide. It can't very well respond to radiation it can't stop.

The sensitive area can be in the shape of a square a quarter millimeter on a side, a rectangle as big as a playing card, an etching of moonrise over Fujiyama, or a draftsman's nightmare inspired by Boolian algebra. It's just a coating on a plate—no envelope, nothing to shake loose. Moreover, signal response is strangely independent of sensitive area size. (Almost. At a given point in the range where response is linear with bias voltage, the signal is roughly proportional to the 0.1 power of area.)

Sensitivity of the surface is so uniform that, in general, an 0.25 mm^2 spot scanning a 250 mm^2 cell surface produces signals varying no more than 50% from the mean. Much better, of course, with a bigger spot.

Signal-to-noise ratio with infrared radiation is high. Cooling to dry ice temperatures boosts signal response much more than noise. Also, cutting current density cuts noise. Just by pattern changes, a cell of given size can have a 10,000:1 range of impedance, viz.:



Time constant may be anywhere from 400 to 1000 μsec. depending on the individual cell. At 60 C, frequency response is flat from 0 to 500 cycles; at 20 C, a drop is already noticeable at 120 cycles. When refrigerated for supersensitivity, drop in response with illumination chopping frequency is continuous. If the system can be operated at a sufficiently high frequency, response becomes virtually independent of temperature.

Now that a decent interval has elapsed for ambitious souls to pioneer with a new plaything, we have a booklet. It summarizes the properties of Kodak Ektron Detectors, *compares them quantitatively with other photocells, and gives some basic circuits and optical arrangements for them. For a free copy, address Eastman Kodak Company, Special Products Sales Division, Rochester 4, N. Y.*

Superior consommé

For photographic film and paper, we make and use a prodigious volume of gelatin; for that purpose it must be prepared even more carefully than for a journey through the alimentary canal. We make some that is purer still, having extremely low ash. When a laboratory needs a little of this superior consommé for some fussy purpose, such as the new technique for mounting microtome sections from undecalcified, plasticized bones to be autoradiographed (*Stain Technology*, *29*, 225, where we are mistakenly called "Eastman Chemical Corporation"), we sell them one of two gelatins under the Eastman Organic Chemicals label. We don't bother our shy daughter, Eastman Gelatine Corporation of Peabody, Mass.

Gelatin (Purified, Pigskin) *(Eastman 5247) and* Gelatin (Purified, Calfskin) *(Eastman 1099) go for $4.85 a hundred grams. Prices on the rest of some 3500 Eastman Organic Chemicals are in our List No. 39, available from Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

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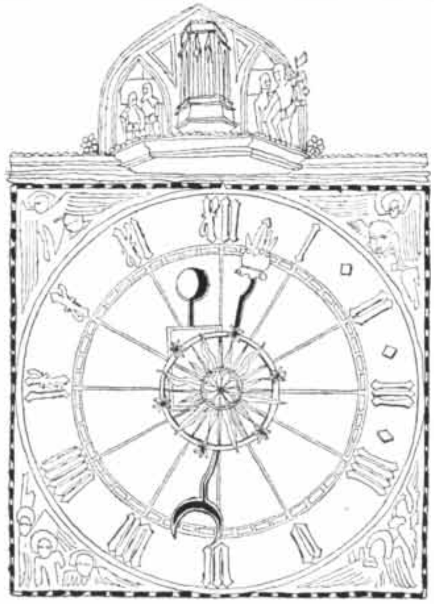
SCIENCE AND

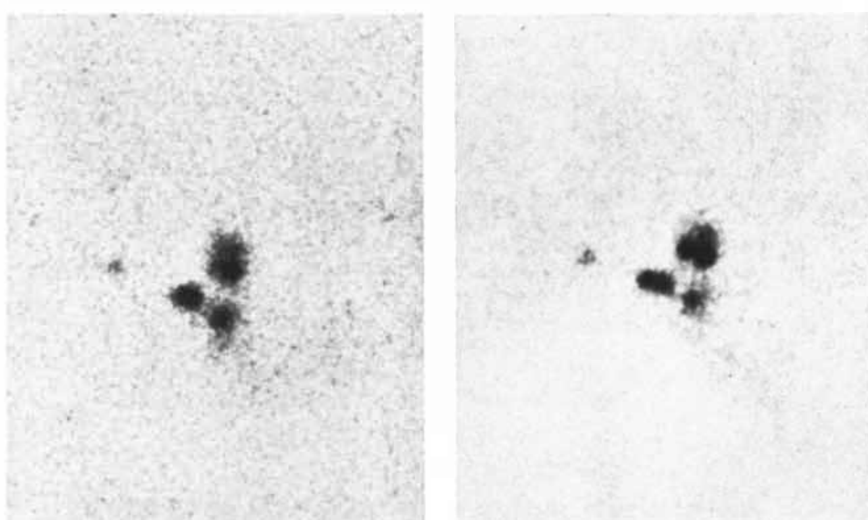


Eating, Exercise and Arteries

Atherosclerosis is a fatty degeneration of the artery walls which affects everyone, to some extent, as he grows older. If it becomes severe enough, it causes coronary thrombosis. Physicians suspect, although they have not yet proved, that high levels of cholesterol and certain other fat-containing molecules in the blood tend to hasten the process of atherosclerosis. They also suspect that such high levels can come from eating more food than the body needs.

Evidence in favor of this hypothesis was described recently in *The New England Journal of Medicine* by a group of nutrition researchers at Harvard University's School of Public Health. The group, headed by George V. Mann, experimented with three medical students, feeding them for many weeks a diet which contained twice their normal daily quota of calories but only the normal amount of fat. During the first half of the period the subjects kept their weight constant by vigorous daily exercise. The fat levels in their blood remained unchanged. Then they stopped exercising but continued to stuff themselves. They gained weight and their blood fat levels went up. Finally they were put on a reducing diet and their blood returned to normal.

At the beginning of the experiment the subjects had trouble getting all the extra food down, but after a few days of hard exercise they ate the food gladly and felt well. When the exercise was discontinued, the students lost their feeling of well-being but kept on gorging themselves quite willingly. The researchers suggest that their brief experiment is a capsule version of the average man's nutritional history. During his active early manhood he becomes accustomed to a high-calorie diet. Later he continues the high intake out of physiological habit long after his rate of energy expenditure has decreased. Thereby he builds up a high blood cholesterol level and, prob-



STAR CREATION may have been observed for the first time in these pictures. The photograph at the left, taken in 1947, shows a small section of the Orion Nebula which then contained three T Tauri stars. At right is the same area as photographed in 1954. Immediately to the left of each of the upper two original stars can be seen a new object. The two new bodies are actually separate from the older stars although they appear fused in this view.

ably, accelerates the degeneration of his arteries.

Stellar Birth?

About 1,600 years ago something unusual happened in the Orion Nebula. Light just now arriving on earth from that distant region indicates that two stars may have been born. If so, this is the first time astronomers have witnessed the birth of a star.

Evidence of the stellar birth was shown at the recent International Astronomical Union meeting in Dublin by George H. Herbig of Lick Observatory. He compared two photographs of a part of the Orion Nebula, one taken in 1947, the other in 1954. The 1947 picture shows three stars embedded in a dark cloud of dust and gas. Some time during the next seven years they were joined by two additional stars [*see photographs on the opposite page*].

Herbig was not wholly unprepared to find the two new stars. He and several other astronomers have been studying a peculiar type of star always found in the midst of dark interstellar clouds. They are called T Tauri stars because they are similar to the long-known variable star T Tauri. Much evidence indicates that this type of star is young and that it may be formed by condensation of a cloud.

The two new stars in Herbig's 1954 photograph may well be infant T Tauris. Herbig said cautiously: "Our understanding of what is taking place could hardly be more incomplete, but it may be that we have witnessed the opening phase of an episode in stellar evolution."

Chemical Society Meets

More than 6,500 chemists gathered in Minneapolis for the American Chemical Society's 128th national meeting, at which they read and discussed some 1,200 technical papers.

A group of St. Louis biochemists has taken apart and reassembled a virus without destroying its infectivity. This submicroscopic chemical surgery was announced by Barry Commoner of Washington University. The experimenters split tobacco mosaic viruses into protein particles and threads of ribonucleic acid, neither of which is infective by itself. When the pieces were mixed together, they regained about 1 per cent of the infectivity of the starting material. Two months earlier a University of California group had successfully performed the same feat.

At a special symposium in the ACS meeting chemists agreed that it may become possible to make use of enzymes to synthesize proteins—a task too complicated for ordinary chemical methods. Basically the process would be similar to making plastics or synthetic rubber by polymerization.

The association between severe anemia and advanced cancer was explained by Vincent E. Price and Robert E. Greenfield of the National Cancer Institute. The anemia of cancer patients has commonly been ascribed to general debilitation of the patient. Price and Greenfield have found, however, that tumors actually deprive the blood of iron. "In rats with far advanced lymphosarcomas," they reported, "the tumor contained even more iron than the liver, which is the major iron-storage organ of the body. Studies using radioactive iron have shown that the tumor obtains much of this iron from hemoglobin, and also that iron can be rapidly taken up from the plasma."

Another form of iron shortage, the depletion of high-grade ores in the U. S., may be countered by a new process described by Robert J. Priestley of Stamford, Conn. The method converts low-grade ores into magnetite, which can be charged into blast furnaces with little further refining. The process, developed by 10 years' work, consists of bubbling a gas such as producer gas rapidly through low-grade powdered hematite ore, removing part of the oxygen and reducing hematite to magnetite.

Heavy sulfur may become a new tool for tracing geological history. H. G. Thode of Hamilton College, Ontario, noted that in the sulfate form sulfur is considerably richer in the heavy isotope S-34 than in the sulfide form. This peculiarity indicates that many of the world's large native sulfur deposits came from sulfates, presumably reduced by bacteria. Preliminary measurements show that all the petroleum in any given oil field contains about the same proportion of heavy sulfur. On the other hand, this proportion varies greatly from field to field. This suggests that petroleum may originate in various ways.

Geneva Postscript

Weeks after they had returned from the Geneva Conference on the Peaceful Uses of Atomic Energy, U. S.

scientists were still reliving the pleasure and excitement of that extraordinary meeting.

One of the chief thrills for physicists was the extremely close agreement between U. S. and U.S.S.R. scientists in their measurements of nuclear cross sections, although their work had been supersecret and completely independent. The physicists pointed out that cross-section experiments are so difficult that there had been considerable doubt about the accuracy of the results. Said one U. S. physicist, "If the Russian figures had been different from ours, we shouldn't have been surprised. And we should have been by no means certain that ours were right and theirs wrong."

The declassification of cross sections brought at least one immediate scientific dividend. Aage Bohr, a son of Niels Bohr and a member of the Institute for Theoretical Physics in Copenhagen, brought to Geneva an unannounced paper on an improved theory of nuclear fission. He had arrived at the theory only after receiving copies of the conference papers, which had been sent to all official participants a few weeks before the meeting. From the newly published figures on fission cross sections he derived a theory which explains why nuclei sometimes break into almost equal fragments and sometimes into unequal ones, and why the fragments sometimes fly off in certain preferred directions. It also sheds new light on the exact shapes of heavy nuclei, which are not spherical but elongated and in some cases apparently pear-shaped.

According to several U. S. delegates to the Conference, the Soviet papers showed impressive progress in physics. The U.S.S.R. investment in reactors, accelerators and the other heavy machinery of nuclear physics appears to be less than half as large as that of the U. S., but it was said to be well planned to give the maximum scientific return.

The most interesting aspect of Soviet physics was their high-energy work, both theoretical and experimental. Their 600-million-electron-volt synchrocyclotron is the only proton accelerator in the world working at this energy, an important one for a number of theoretical investigations. (In the U. S. there is no proton machine working in the range from 400 to 3,000 Mev, although a 600-Mev model will soon be ready at the University of California.) The Soviet scientists will also have a 10-billion-electron-volt synchrotron in a year or so.

Physicists are paid very well in the U.S.S.R., both in money and prestige. The salary of a young senior scientist at a government laboratory is equivalent in buying power to a U. S. income, after taxes, of about $1,000 per month. One such physicist described his living conditions to his Western colleagues. He has a five-room apartment in Moscow (rent, about $50 per month), runs two cars, employs a full-time maid and a nurse for his two children. His two months' paid vacation is spent at his own summer cottage or at the best hotels in popular resorts.

The Soviet attitude toward the scientific manpower problem is indicated by the pay scale for young scientists. A new Ph.D. can expect about $400 a month. He has a choice of going into research or teaching, but gets a 20 per cent bonus if he chooses teaching. (The average industrial worker in the U.S.S.R. receives about $100 per month.)

Sensitive Subject

Hermann J. Muller, the Indiana University geneticist, went to Europe this summer prepared to read a paper at the Geneva Atoms for Peace Conference. His topic was to be "How Radiation Changes the Genetic Constitution," essentially the subject for which he was given a Nobel prize in 1946. Three weeks before the conference opened, Muller received a letter from the Atomic Energy Commission informing him that his paper had been removed from the program.

Last month the geneticist aired the incident in the press. The AEC explained that Muller's paper "was found to contain material referring to nonpeaceful uses of atomic energy, namely, the bombing of the Japanese city of Hiroshima." The Conference rules, it added, limited discussions to peaceful uses of the atom.

Muller insisted that "at a conference of this kind there should have been a full airing of the problem of the genetic damage produced by radiation." AEC Chairman Lewis L. Strauss later acknowledged at a press conference that the barring of Muller's presentation of his paper at Geneva was "a regrettable snafu." The paper will be published in the Conference Proceedings.

China Joins IGY

The Chinese Communist Government has indicated that it will participate in the program of the International Geophysical Year, according to a report last month from Brussels, where the special committee for the IGY was meeting. China will be the 41st nation to join,

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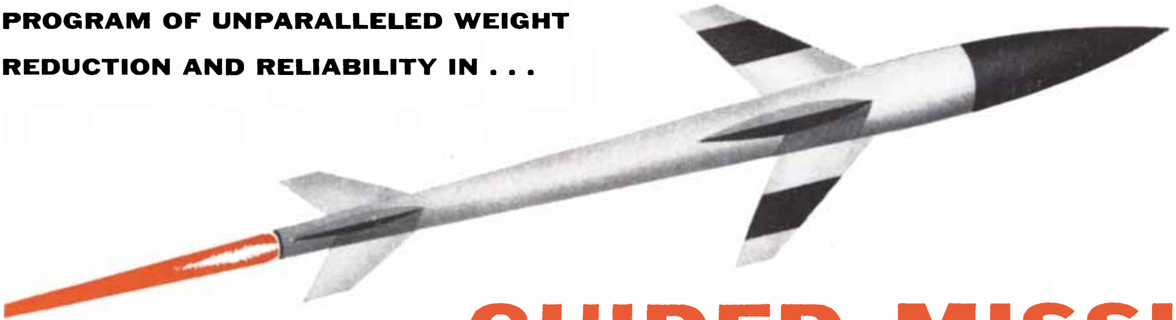

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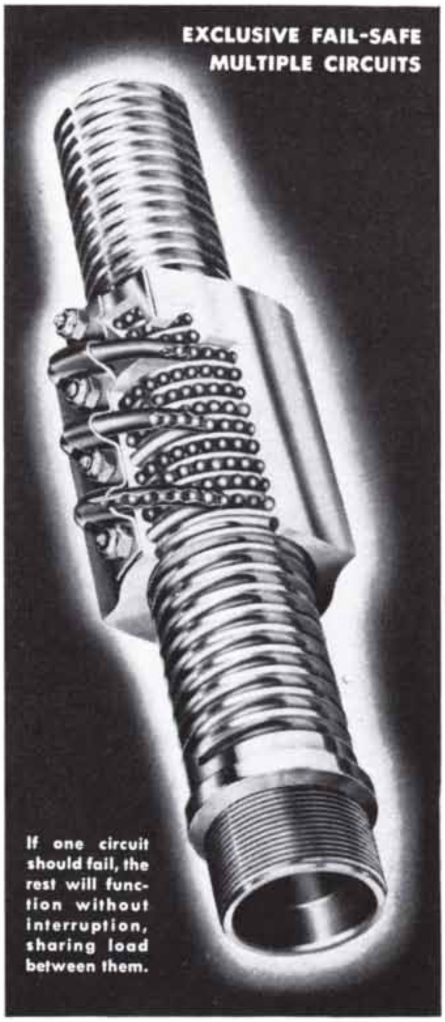

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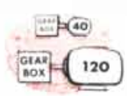

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following a few months after the U.S.S.R. and several other Communist countries.

Fusion Power Project

The Atomic Energy Commission last month released the first information about U. S. efforts to achieve thermonuclear power. Chairman Lewis L. Strauss said a "major research effort" is under way. Its object is to extract useful energy from a fusion reaction, and the fusion fuel under study is deuterium (heavy hydrogen). Strauss made clear that no break-through idea for solving the problem had yet appeared, but he thought "a fair guess" as to how long it might take was 20 years.

The essential problems, he observed, are (1) to contain and control a reaction which must take place at temperatures of several hundred million degrees, and (2) to turn the energy released into electrical power. Strauss indicated that it might prove possible to obtain electrical energy directly, without the use of steam-driven generators. He thought fusion power might prove cheaper than that from fission, and pointed out that it would avoid the troublesome problem of disposing of radioactive fission products. He added that the oceans contain enough deuterium to supply the world with power for a billion years.

The U. S. research program on fusion power possibilities is called Project Sherwood. It is being carried out chiefly at Princeton University and at AEC laboratories operated by the University of California at Livermore, Calif., and at Los Alamos. Some studies are also being done at Oak Ridge National Laboratory and at New York University.

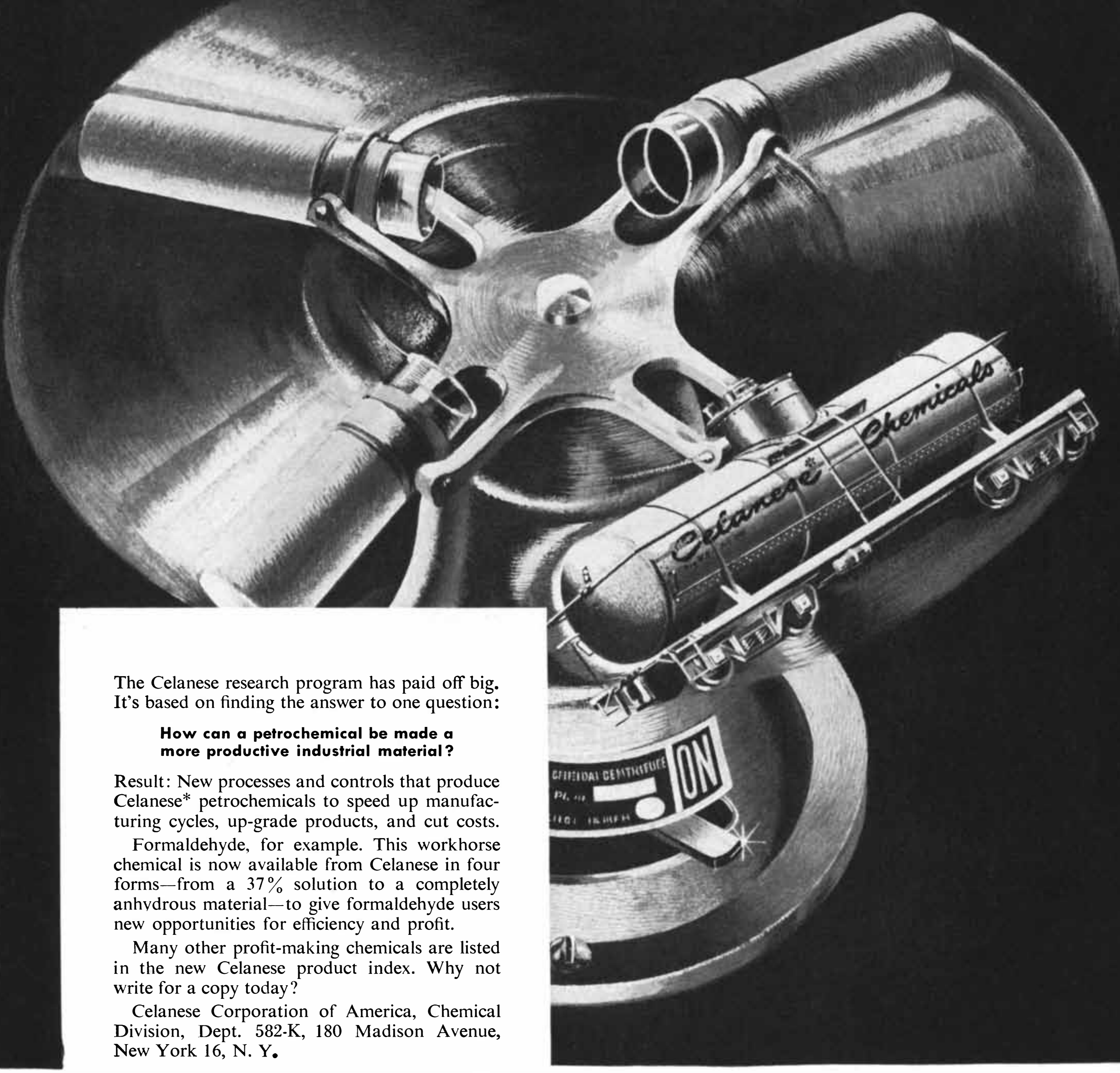
Lyman Spitzer, professor of astronomy at Princeton, is in charge of the research there. This work has been going on since 1951, when Spitzer suggested to the AEC an idea for containing and controlling thermonuclear reactions.

Other scientists taking part in the program include Edward Teller, associate director of the Livermore laboratory and head of the AEC's national steering committee on controlled thermonuclear reactions; Harold Grad, professor of mathematics at N.Y.U.; E. D. Shipley, John S. Luce and Albert Simon of the Oak Ridge National Laboratory.

Why Metals Slide

A vast deal of work has gone into efforts to develop smooth metals—for bearings, pistons, gear teeth and so on—but very little is known about what

Research by the payload



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makes metals slide or stick. Now a comprehensive new theory has just been published in the *General Motors Engineering Journal.* It explains the performance of bearings in terms of the atomic size and crystalline structure of the two rubbing metals. Carl L. Goodzeit and the late Arvid E. Roach were the co-authors of the report.

They started by comparing the sliding of some 40 metallic chemical elements when rubbed against iron. Metals stick when atoms on the surface of one piece are pressed against surface atoms of the other piece and form strong interatomic chemical bonds. If the atoms of the other metal are about the size of iron atoms, there are many points of contact where bonds can form. Thus good bearing metals must have atomic diameters larger than 2.68 Angstrom units, about 15 per cent larger than iron atoms. Another factor is the type of chemical bond formed at the contact points. Some metallic atoms are joined to iron atoms by covalent bonds, in which the atoms share electrons. This sort of bond is weak and does not impede smooth sliding. So, according to the theory, the best bearing metals are those which have large atoms and form covalent compounds with iron.

Most of the well-known bearing materials, such as Babbitt, are alloys. They may be combinations of good and poor bearing metals. Such alloys will slide smoothly if the good bearing metal has a lower melting point; in that event the metal when melted by overheating smears a film over the bearing surface and insulates the journal from the poor bearing metal.

Does this theory apply to metals other than iron? Since preparing their report, the authors have tested the sliding of pure metals against both copper and silver. The unpublished results confirm that bearing quality depends entirely on atomic size and chemical bonding, no matter what two metals rub together.

Eagle Robs Lion's Nest

England, whose habit of impressing American seamen into the Royal Navy kicked up considerable fuss some years back, now appears to be getting her comeuppance technologically. Commenting on Britain's shortage of scientists and engineers, the magazine *Discovery* recently complained: "The position has been aggravated by the fact that American firms have taken to using this country as one of their hunting grounds, and the latest development is that American firms are flying British graduates over for interviews in the U. S.!"

RADIATION AND HUMAN MUTATION

In which the fundamental process of human evolution is discussed, with special reference to trends that may be caused by artificial radioactivity, medical X-rays and the preservation of harmful genes

by H. J. Muller

The revolutionary impact on men's minds brought about by the development of ways of manipulating nuclear energy, both for destructive and for constructive purposes, is causing a public awakening in many directions: physical, biological and social. Among the biological subjects attracting wide interest is the effect of radiation upon the hereditary constitution of mankind. This article will consider the part which may be played by radiation in altering man's biological nature, and also the no less important effects that may be produced on our descendants by certain other pertinent influences under modern civilization.

At the cost of being too elementary for readers who are already well informed on biological matters it must first be explained that each cell of the body contains a great collection—10,000 or more—of diverse hereditary units, called genes, which are strung together in a single-file arrangement to form the tiny threads, visible under the microscope, called chromosomes. It is by the interactions of the chemical products of these genes that the composition and structure of every living thing is determined. Before any cell divides, each of its genes reproduces itself exactly or, as we say, duplicates itself. Thus each chromosome thread becomes two, both structurally identical. Then when the cell divides, each of the two resulting cells has chromosomes exactly alike. In this way the descendant cells formed by successive divisions, and, finally, the individuals of subsequent generations derived from such cells, tend to inherit genes like those originally present.

However, the genes are subject to rare chemical accidents, called gene mutations. Mutation usually strikes but one gene at a time. A gene changed by mutation thereafter produces daughter genes having the mutant composition. Thus descendants arise that have some abnormal characteristic. Since each gene is capable of mutating in numerous more or less different ways, the mutant characteristics are of many thousands of diverse kinds, chemically at least.

Very rarely a mutant gene happens to have an advantageous effect. This allows the descendants who inherit it to multiply more than other individuals in the population, until finally individuals with that mutant gene become so numerous as to establish the new type as the normal type, replacing the old. This process, continued step after step, constitutes evolution.

But in more than 99 per cent of cases the mutation of a gene produces some kind of harmful effect, some disturbance of function. This disturbance is sometimes enough to kill with certainty any individual who has inherited a mutant gene of the same kind from both his parents. Such a mutant gene is called a lethal. More often the effect is not fully lethal but only somewhat detrimental, giving rise to some risk of premature death or failure to reproduce.

Now in the great majority of cases an individual who receives a mutant gene from one of his parents receives from the other parent a corresponding gene that is "normal." He is said to be heterozygous, in contrast to the homozygous individual who receives like genes from both parents. In a heterozygous individual the normal gene is usually dominant, the mutant gene recessive. That is, the normal gene usually has much more influence than the mutant gene in determining the characteristics of the individual. However, exact studies show that the mutant gene is seldom completely recessive. It does usually have some slight detrimental effect on the heterozygous individual, subjecting him to some risk of premature death or failure to reproduce or, as we may term it, a risk of genetic extinction. This risk is commonly of the order of a few per cent, down to a fraction of 1 per cent.

If a mutant gene causes an average risk of extinction of, for instance, 5 per cent, that means there is one chance in 20 that an individual possessing it will die without passing on the same gene to offspring. Thus such a mutant gene will, on the average, pass down through about 20 generations before the line of descent containing it is extinguished. It is therefore said that the "persistence" of that particular gene is 20 generations. There is some reason to estimate that the average persistence of mutant genes in general may be something like 40 generations, although there are vast differences between genes in this respect.

The Human Store of Mutations

Observations on the frequency of certain mutant characteristics in man, supported by recent more exact observations on mice by W. L. Russell at Oak Ridge, indicate that, on the average, the chance of any given human gene or chromosome region undergoing a mutation of a given type is one in 50,000 to

100,000 per generation. Moreover, studies on the fruit fly *Drosophila* show that for every mutation of a given type there are at least 10,000 times as many other mutations occurring. Now since it is very likely that man is at least as complicated genetically as Drosophila, we must multiply our figure of 1/100,000, representing our more conservative estimate of the frequency of a given type of mutation, by at least 10,000 to obtain a minimum estimate of the total number of mutations arising in each generation among human germ cells. Thus we find that at least every tenth egg or sperm has a newly arisen mutant gene. Taking the less conservative estimate of 1/50,000 for the frequency of a given type of mutation, our figure would become two in 10.

Every person, however, arises from both an egg and a sperm and therefore contains twice as many newly arisen mutant genes as the mature germ cells do, so the figure becomes two to four in 10. When we say that the per capita frequency of newly arisen mutations is .2 to .4, we mean that there are, among every 10 of us, some two to four mutant genes which arose among the germ cells of our parents. This is the frequency of so-called spontaneous mutation, which occurs even without exposure to radiation or other special treatment.

Far more frequent than the mutant genes that have newly arisen are those that have been handed down from earlier generations and have not yet been eliminated from the population by causing death or failure to reproduce. The average per capita frequency of all the mutant genes present, new and old, is calculated by multiplying the frequency of newly arisen mutations by the persistence figure.

The greatly simplified diagram on page 66, in which we suppose the frequency of new mutations in each generation to be .2 and the persistence to be only four generations, shows why this relation holds. We start with 10 individuals. Let us suppose that in this first generation eight persons contain no mutant genes while each of the other two has one newly arisen mutant gene. In the second generation these two mutant genes are passed along and two new ones are added to the group, making the total frequency 4/10. By the fourth generation the frequency is 8/10. After that the frequency remains constant because each mutant gene lasts only four generations and is assumed to be replaced by a normal gene.

Of course in any actual case neither the multiplication nor the distribution of mutant genes among individuals is as regular as in this simplified illustration, but the general principle holds. However, as previously mentioned, the persistence of mutant genes is of the order of 40 generations, instead of only four. Thus the equilibrium frequency becomes not 8/10 but 8. In other words, each person would on the average contain, by this reckoning, an accumulation of about eight detrimental mutant genes.

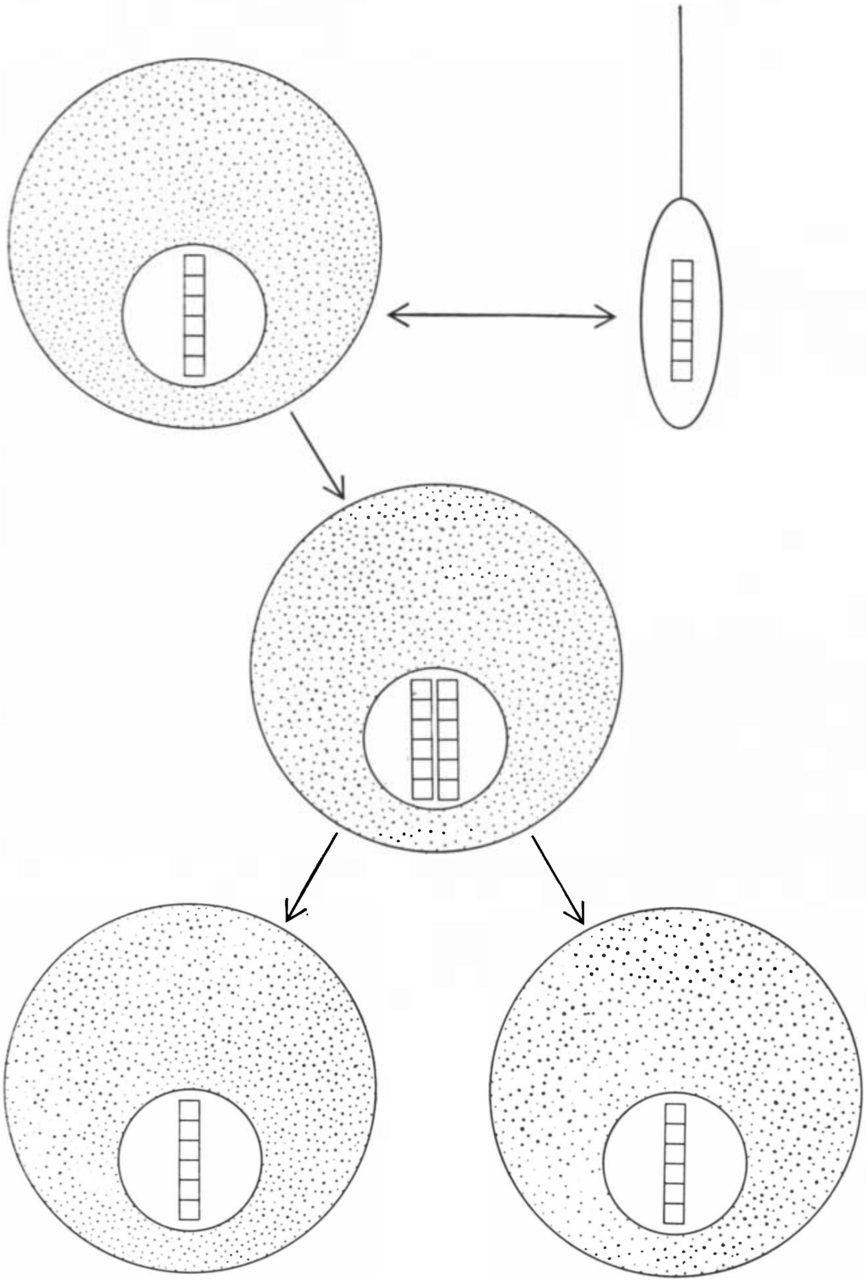
It happens that this very rough, "conservative" estimate, made by the present writer six years ago, agrees well with the estimate arrived at a few months ago by Herman Slatis, in a study carried out in Montreal by a more direct method. His method was based on the frequency with which homozygous abnormalities appeared among the children of marriages between cousins.

The eight mutations estimated above,

HUMAN CHROMOSOMES, which are much more difficult to photograph than those of fruit flies, are clearly revealed as dark bodies in this photomicrograph by T. C. Hsu of the M. D. Anderson Hospital and Tumor Institute in Houston, Tex. The chromosomes, which are enlarged approximately 3,000 diameters, are in a human spleen cell. The cell was grown in a laboratory culture after spleen tissue had been removed from a four-month-old fetus. Human body cells normally contain 48 chromosomes; human germ cells, 24.

it should be understood, do not include most of the multitude of more or less superficial differences, sometimes conspicuous but very minor in the conduct of life, whereby, in the main, we recognize one another. The latter mutations probably arise relatively seldom yet become inordinately numerous because of their very high persistence. Thus the value that we arrive at for the frequency of mutant genes depends very much upon just where the line is drawn in excluding this mutational "froth." As yet little attention has been given to this point. The number eight, at any rate, includes only mutant genes which when homozygous give rather definite abnormalities. In the great majority of cases these genes are only heterozygous and usually are but slightly expressed. Yet they do become enough expressed to cause, in each individual, his distinctive pattern of functional weaknesses, depending upon which of these mutant genes he contains and what his environment has been. The influence of environment on gene expression is often important.

Even the genes that give only a trace of detrimental effect, or are detrimental only when homozygous, play an important role, because of their high persistence and consequent high frequency. When conditions change, certain combinations of these genes may occasionally happen to be more advantageous than the type previously prevailing, and so tend to become established.



FUNDAMENTAL PROCESS of heredity is depicted in highly schematic form. At the upper left is an egg cell; at the upper right, a sperm cell. Each contains a single chromosome bearing only six genes (*square segments of chromosome*). The chromosomes are paired in the fertilized egg (*center*), resulting in an organism with a complete set of genes from each parent. When the organism produces its own germ cells (*bottom*), the chromosomes are separated, leaving one set of genes to combine with those of a mate in the new generation.

The Effects of Mutant Genes

In general each detrimental mutant gene gives rise to a succession of more or less slight impairments in the generations that carry it. Even if only slightly detrimental, it must finally result in extinction. Moreover, even though an individual suffers less from a slightly detrimental gene than from a markedly detrimental or lethal one, nevertheless the slightly detrimental gene, being passed down to a number of individuals which is inversely proportional to the amount of harm done to each individual, occasions a total amount of damage comparable to that produced by the very detrimental gene. Although each of us may be handicapped very little by any one of our detrimental genes, the sum of all of them causes a noticeable amount of disability, which is usually felt more as we grow older.

The frequency of mutant genes levels off at an equilibrium only when conditions for both mutation frequency and gene elimination have remained stable (or have at any rate fluctuated about a given average) for many generations. During such a period about as many mutations must be eliminated as are arising per generation. If, however, the mutation rate or the average persistence or both changed significantly because of increased radiation or a change in environmental conditions which made mutant genes more or less harmful than previously, then the frequency would move toward a new level. But it would be a long time before the new equilibrium was reached. If the average persistence of mutant genes was 40 generations, the new equilibrium would still be very incompletely attained after 1,000 years.

The Effects of Radiation

We may next consider how a given dose of ionizing radiation would affect the population. Such radiation, when absorbed by the germ cells of animals, usually induces mutations which are similar to the spontaneous ones. They are induced at a frequency which is proportional to the total amount of the radiation received, regardless of the duration or time-distribution of the exposure. Russell's data on mice—the nearest experimental object to man that has been used in such studies—show that it would take about 40 roentgen units of radiation to produce mutations in them at a frequency equal to their spontaneous frequency. If the frequency of spontaneous mutations is two new mutations per generation among each 10 individuals, a dose of 40 roentgens, by adding two induced mutations to the two spontaneous ones, would result in a total mutation frequency of four new mutations per generation among 10 individuals. Now assuming the total mutant gene content is eight per individual to begin with, the radiation dose would raise this figure from 8 to 8.2, an increase of only 2.5 per cent. This effect on the population would ordinarily be too small to produce noticeable changes in important characteristics. One must also bear in mind that an actual mean change in a population may be masked by the great genetic differences among individuals and by differences in environment between two groups that are to be compared. These considerations explain why even Hiroshima survivors who had been relatively close to the blast, and who may have absorbed several hundred roentgens, showed no statistically significant increase in genetic defects among their children. However, offspring of U. S. radiologists who (judging by the incidence of leukemia) probably were exposed during their work over a long period to about as much radiation as these Hiroshima survivors, do show a statistically significant increase in congenital abnormalities, as compared with the offspring of other medical specialists. This was recently established in a study by Stanley Macht and Philip Lawrence.

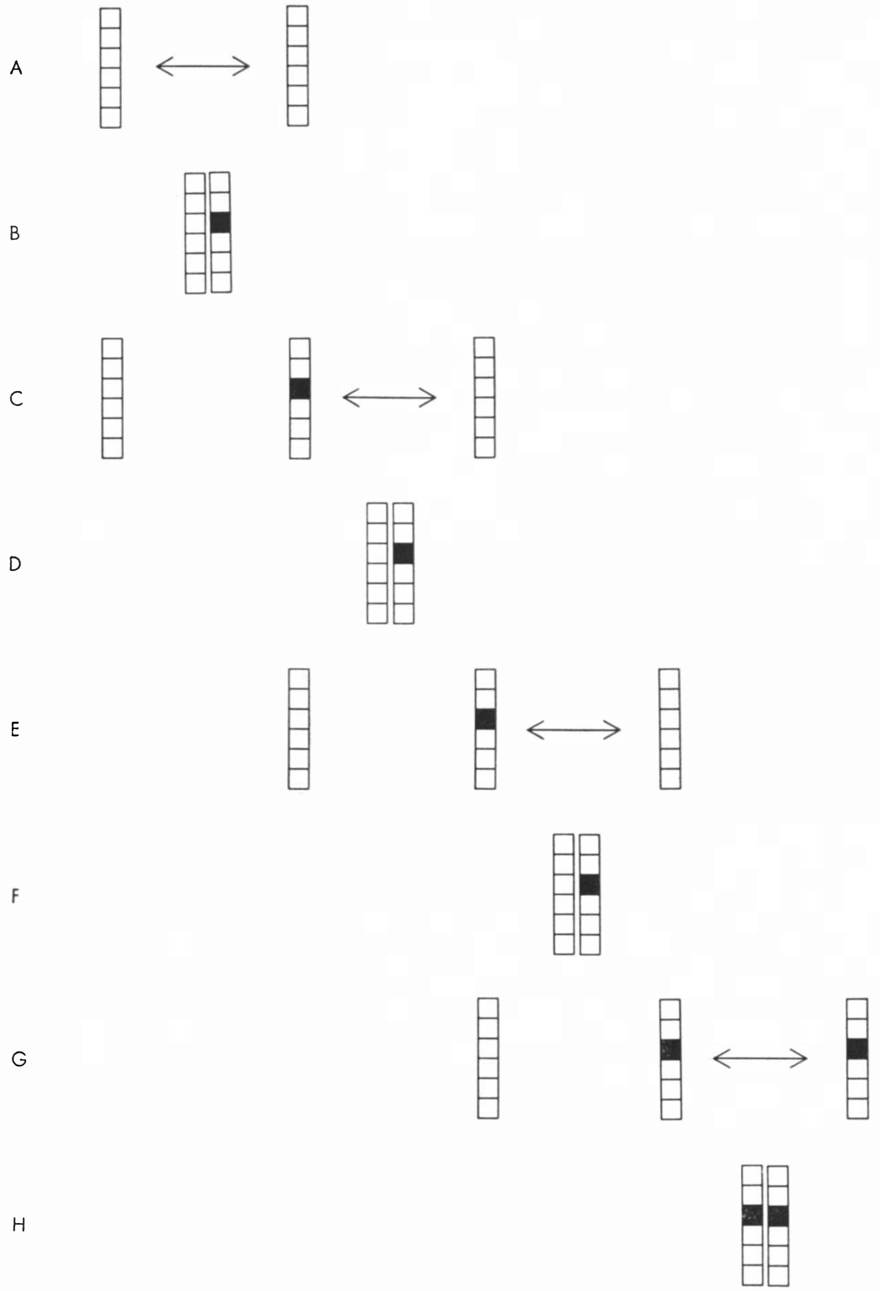
The toll taken by mutant genes upon the descendants of exposed individuals is spread out over more than a thousand years—40 generations. It is too small to be demonstrable in any one generation of descendants. In the first generation of offspring of a population exposed to 40 roentgens, where the induced mutation rate is .2 per individual and the average risk of extinction for any given mutant gene is 1/40, the frequency of extinctions occasioned by these mutant genes would be .2/40 or 1/200. This would mean, for example, that in a total population of 100 million some 500,000 persons would die prematurely or fail to reproduce as a result of having mutant genes that had been induced in their parents by the exposure. Moreover, a much larger number would be damaged to a lesser extent. The total of induced extinctions in all generations subsequent to the exposure would be .2 times 100 million, or 20 million, and the disabilities short of extinction would be numbered in the hundreds of millions. And yet the amount of genetic deterioration in the population due to the exposure would be small in a relative sense, for the induced mutations would have added only 2.5 per cent to the load of mutant genes already accumulated by spontaneous mutation.

The situation would be very different if the doubling of the mutation frequency by irradiation in each generation were continued for many generations, say for 1,500 years. For after 1,500 years the mutant gene content would have been raised from eight to nearly 16 per individual. Along with this doubled frequency of detrimental genes there would of course be a corresponding increase in the amount of disability and in the frequency of genetically occasioned extinction of individuals.

It is possible that all this would be ruinous to a modern human population, even though in most kinds of animals it could probably be tolerated. For, in the first place, human beings multiply at a low rate which does not allow nearly as rapid replacement of mutant genes by normal ones as can occur in the great majority of species. Secondly, under modern conditions the rate of human multiplication is reduced much below its potential. Thirdly, the pressure of natural selection toward eliminating detrimental genes is greatly diminished, under present conditions at least, through the artificial saving of lives. Under these circumstances a long-continued doubling of the mutation frequency might eventually mean, if the situation persisted, total extinction of the population. However, we do not now have nearly enough knowledge of the strength of the various factors here involved to pass a quantitative judgment as to how high the critical mutation frequency would have to be, and how low the levels of multiplication and selection, to bring about this denouement. We can only see that danger lies in this direction, and call for further study of the whole matter.

Bomb Effects

In the light of the facts reviewed, we are prepared to come to some conclusions concerning the problem of the genetic effects of nuclear explosions. Let us start with the test explosions. J. Rotblat of London has estimated that the



HARMFUL RECESSIVE MUTATION may persist for generations before it is fully expressed. This diagram is based on the schematic chromosomes depicted on page 60. In row A the chromosomes of two parents are paired (*arrow*). In row B a gene of their offspring mutates (*black*). In row C the mutant gene has been transmitted to the next generation. If the mutant gene is recessive (*i.e.*, if the corresponding gene of the paired chromosome has a dominant effect), it is masked. Here a new set of genes is introduced (*second arrow*) from another line of descent. In rows D, E and F the mutant gene is passed along. In row G a mutant gene of the same character is introduced from still another line of descent. In offspring of this union (*row H*), the harmful effect of the paired recessive genes is expressed.

tests of the past year approximately doubled the background radiation for the year, in regions of the earth remote from the explosions. In the U. S. they raised the background radiation from about .1 to about .2 of a roentgen for the year. The natural background radiation of about .1 roentgen per year causes, we estimate, about 5 per cent of the spontaneous mutations in man. Hence a doubling of it would cause a rise of the same amount in the occurrence of new mutant genes. Although this influence, if continued over a generation, would induce an enormous number of mutations—of the order of 20 million in the world population of some two billion—nevertheless the effect, in relation to the already accumulated store of detrimental mutations, would be comparatively small. It would raise the per capita content of mutant genes at most by only a few tenths of 1 per cent.

Much more serious genetic consequences would follow from atomic warfare itself, in the regions subject to the fall-outs of the first few days. As for regions remote from the explosions (say the Southern Hemisphere), Rotblat and Ralph Lapp have reckoned that a hydrogen-uranium bomb like those tested in the Pacific would deliver an effective dose of about .04 roentgen throughout the whole period of radioactive disintegration. Thus 1,500 such bombs would deliver about 60 roentgens—an amount which might somewhat more than double the mutation frequency for one generation. Since there would be relatively little residual radioactivity in these remote regions after the passage of a generation, and since it is scarcely conceivable that such bombing would be repeated in many successive generations, it seems probable that most of the world's inhabitants below about the Tropic of Cancer would escape serious genetic damage. However, they would be likely in the course of centuries to become contaminated by extensive interbreeding with the survivors of the heavy irradiations in the North. For although an attempt might be made to establish a genetic quarantine, this would, for psychological reasons, be unlikely to be maintained with sufficient strictness for the hundreds of years required for the success of such a program.

In the regions subject to the more immediate fall-outs, pattern bombing could have resulted in practically all populous areas receiving several thousand roentgens of gamma radiation. Even persons well protected in shelters during the first week might subsequently be subjected to a protracted exposure adding up to some 2,500 roentgens. Moreover, this estimate fails to take into account the soft radiation from inhaled and ingested materials which under some circumstances, as yet insufficiently dealt with in open publications, may become concentrated in the air, water or food and find fairly permanent lodgment in the body. Now although some 400 roentgens is the semilethal dose (that killing half its recipients) if received within a short time, a considerably higher dose can be tolerated if spread out over a long period. Thus it is quite possible that a large proportion of those who survive and reproduce will have received a dose of some 1,000 to 1,500 roentgens or even more. This would cause a 12-fold to 40-fold rise in the mutation frequency of that generation.

Such an increase, assuming that the population was already loaded with an accumulation of mutant genes amounting to 40 times the annual spontaneous mutation rate, would at one step cause a 30 to 100 per cent increase in the mutant gene content. In fact, the detrimental effect would be considerably greater than that indicated by these figures, because the newly added mutant genes, unlike those being "stored" at an equilibrium level, would not yet have been subjected to any selective elimination in favor of the less detrimental ones. It can be estimated that this circumstance might cause the total detrimental influence to be twice as strong for each new mutant gene, on the average, as for each old one. Therefore the increase in detrimental effect would be between 60 and 200 per cent.

Owing to these circumstances, an effect would be produced similar to that of a doubled accumulation of genes, such as we saw would ensue from a doubled mutation frequency after about a thousand years of repetition. Thus offspring of the fall-out survivors might have genetic ills twice or even three times as onerous as ours.

The worst of the matter is that the effects of this enormous sudden increase in the genetic load would by no means be confined to just one or two generations. Here is where the inertia of mutant-gene content, which in the case of a moderately increased mutation frequency works to spread out and thus to soften its impact, now shows the reverse side of its nature: its extreme prolongation of the effect. That is, the gene content is difficult to raise, but once raised, it is equally resistant to being reduced.

Supposing the average content of markedly detrimental genes per person to be only doubled, from 8 to 16, more than 50 per cent of the population would come to contain a number of these mutant genes (16 or more) that was as great or greater than that now present in the most afflicted 1 per cent, if the distribution followed the Poisson principle. When we consider the extent to which we are already troubled with ills of partly or wholly genetic origin, especially as we grow older, the prospect of so great an increase in them in the future is far from reassuring.

It is fortunate, in the long run, that sterility and death ensue when the accumulated dose has risen beyond about 1,000 to 3,000 roentgens. For the frequency of mutations received by the descendants of an exposed population is thereby prevented from rising much beyond the amount which we have here considered. This being the case, it is probable that the offspring of the survivors, even though considerably weakened genetically, would nevertheless—some of them—be able to struggle through and reestablish a population which could continue to survive.

Yet, supposing the population were able to re-establish its stability of numbers within, say, a couple of centuries, what would be the toll among the later generations in terms of premature death and failure to reproduce? If 40 roentgens produce .2 new mutant genes per person, then 1,000 roentgens must on the average add five mutant genes to each person's composition. All of these five genes must ultimately lead to genetic extinction. But if, to be conservative, we suppose that two to three genes, on the average, work together in causing extinction, we reach the conclusion that, in a population whose numbers remain stable after the first generation following the exposure, there will ultimately be about two cases of premature death or failure to reproduce for each first-generation offspring of an exposed individual.

If, however, the descendants multiply and re-establish the original population size in a century or two, then the number of extinctions will be multiplied also. Over the long run the number of "genetic deaths" will be approximately twice as large, altogether, as the population total in any one generation. The future extinctions would in this situation be several times as numerous as the deaths that had occurred in the directly exposed generation.

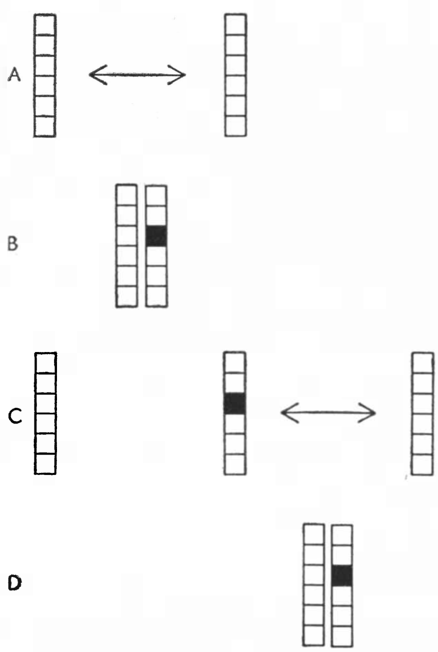
Even though it is probable that mankind would revive ultimately after exposure to radiation, large or small, let us not make the all-too-common mistake of gauging whether or not such an exposure is genetically "permissible" merely by the criterion of whether or not humanity would be completely ruined by it. The instigation of nuclear war, or indeed of any other form of war, can hardly find a valid defense in the proposition, even though true, that it will probably not wipe out the whole of mankind.

Radiation from Other Sources

It is by the standard of whether individuals are harmed, rather than whether the human race will be wiped out, that we should judge the propriety of everyday practices that may affect the human genetic constitution. We have to consider, for one thing, the amount of radiation which the population should be allowed to receive as a result of the peacetime uses of atomic energy.

How much effort, inconvenience and money are we willing to expend in the avoidance of one genetic extinction, one frustrated life and other partially frustrated lives, not to be beheld by us? Shall we accept the present official view that the "permissible" dose for industrially exposed personnel may be as high as .3 roentgen per week, that is, 300 roentgens in 20 years—a dose which would cause such a worker to transmit somewhere between .5 and 1.5 mutations per offspring conceived after that time?

Exactly the same questions apply in medical practice. A U. S. Public Health survey conducted three years ago showed that at that time Americans were receiving a skin dose of radiation averaging about two roentgens per year per person from diagnostic examinations alone. Of course only a small part of this could have reached the germ cells, but if the relative frequencies of the different types and amounts of exposure were similar to those enumerated in studies recently carried out in British hospitals, we may calculate that the total germ-cell dose was about a thirtieth of the total skin dose, namely, about .06 roentgen per person per year. This is about 12 times as much as the dose that had previously been estimated to reach the reproductive organs of the general population (not the hospital population) in England. However, the U. S. is notoriously riding "the wave of the future" in regard to the employment of X-rays; it is still expanding their use rapidly, while other countries are following as fast as they can.



HARMFUL DOMINANT MUTATION, as opposed to a recessive one, is quickly eliminated. Here the mutation (*black*) occurs at the same stage as in the diagram on page 62. It occurs in a germ cell, so its effect is not expressed in that generation. When the chromosome bearing the mutant gene is paired with another, however, the mutation is expressed in the offspring of the union.

Now this dose of .06 roentgen per year, the only estimate for the U. S. that we have, is of the same order of magnitude (perhaps twice as large) as the annual dose received in the U. S. over the past four years from all the nuclear test explosions. It seems rather disproportionate that so much furor should be raised about the genetic effects of the latter and so little about the former.

The writer's personal conviction is that, at the present stage of international relations or at least at the stage of the past several years, the tests have been fully justified as warnings and defensive measures against totalitarianism, despite the future sacrifices that they inexorably bring in their train, although it is to be hoped that this stage is now about to become obsolete. On the other hand, it seems impossible to find justification for the large doses to which the germ cells of patients are exposed in medical practice. It would involve comparatively little care or expense to shield the gonads or take other precautions to reduce the dose being received by the reproductive organs and other parts not being examined. And the deliberate irradiation of the ovaries to induce ovulation, and of the testes to provide an admittedly temporary means of avoiding pregnancies, should be regarded as malpractice.

We must remember that nuclear weapons tests and possibly nuclear warfare may be dangers of our own turbulent times only, whereas physicians will always be with us. It is easier and better to establish salutary policies with regard to any given practice early than late in its development. If we continue neglectful of the genetic damage from medical irradiations, the dose received by the germ cells will tend to creep higher and higher. It will also be joined by a rising dose from industrial uses of radioactivity. For the industrial and administrative powers-that-be will tend to take their cue in such matters from the physicians, not from the biologists, even as they do today. It should be our generation's concern to take note of this situation and to make further efforts to start off the expected age of radiation, if there is to be one, in a rational way as regards protection from this insidious agent, so as to avoid that permanent, significant raising of the mutation frequency which in the course of ages could do even more genetic damage than a nuclear war.

Chemical Agents

Radiation is by no means the only agent that is capable of drastically increasing the frequency of mutation. Diverse organic substances, such as the mustard gas group, some peroxides, epoxides, triazene, carbamates, ethyl sulfate, formaldehyde and so forth, can raise the mutation frequency as much as radiation.

The important practical question is: to what extent may man be unwittingly raising his mutation frequency by the ingestion or inhalation of such substances, or of substances which, after entering the body, may induce or result in the formation of mutagens that penetrate to the genes of the germ cells? As yet far too little is known of the extent to which our genes, under modern conditions of exposure to unusual chemicals, are being subjected to such mutagenic influences.

A surprising recent finding by Aaron Novick and Leo Szilard at the University of Chicago is that in coli bacteria the feeding of ordinary purines normal to the organism more than doubled the spontaneous mutation frequency, while methylated purines, and more especially caffeine (as had been found by other workers), had a much stronger mutagenic effect. Thus far, however, caffeine has not proved mutagenic in fruit flies, although it is possible that it is destroyed in their gut. In Novick and Szilard's work compounds of purines with ribose (*e.g.* adenosine) counteracted the mutagenic effect of the purines. Furthermore, adenosine and guanosine even acted as "antimutagens" when there had been no addition of purines to the nutrient medium, as though a considerable part, about a third, of the spontaneous mutations were being caused by the purines naturally present in the cells. This work, then, indicates both the imminence of the mutagenic risks to which we may be subject and also the fact that means of controlling these risks and, to some extent, even of controlling the processes of spontaneous mutation themselves, are already coming into view.

Other large differences in the frequency of so-called spontaneous mutations were found in my studies in 1946 on the mutation frequencies characterizing different stages in the germ-cell cycle of the fruit fly. Moreover, J. B. S. Haldane, dealing with data of others, adduced some evidence that the germ cells of older men have a much higher frequency of newly arisen mutant genes than those of young men. If this result for man, so different from what we have just noted for fruit flies, should be confirmed, it might prove to be more damaging, genetically, for a human population to have the habit of reproduction at a relatively advanced age than for its members to be exposed regularly to some 50 roentgens of ionizing radiation in each generation.

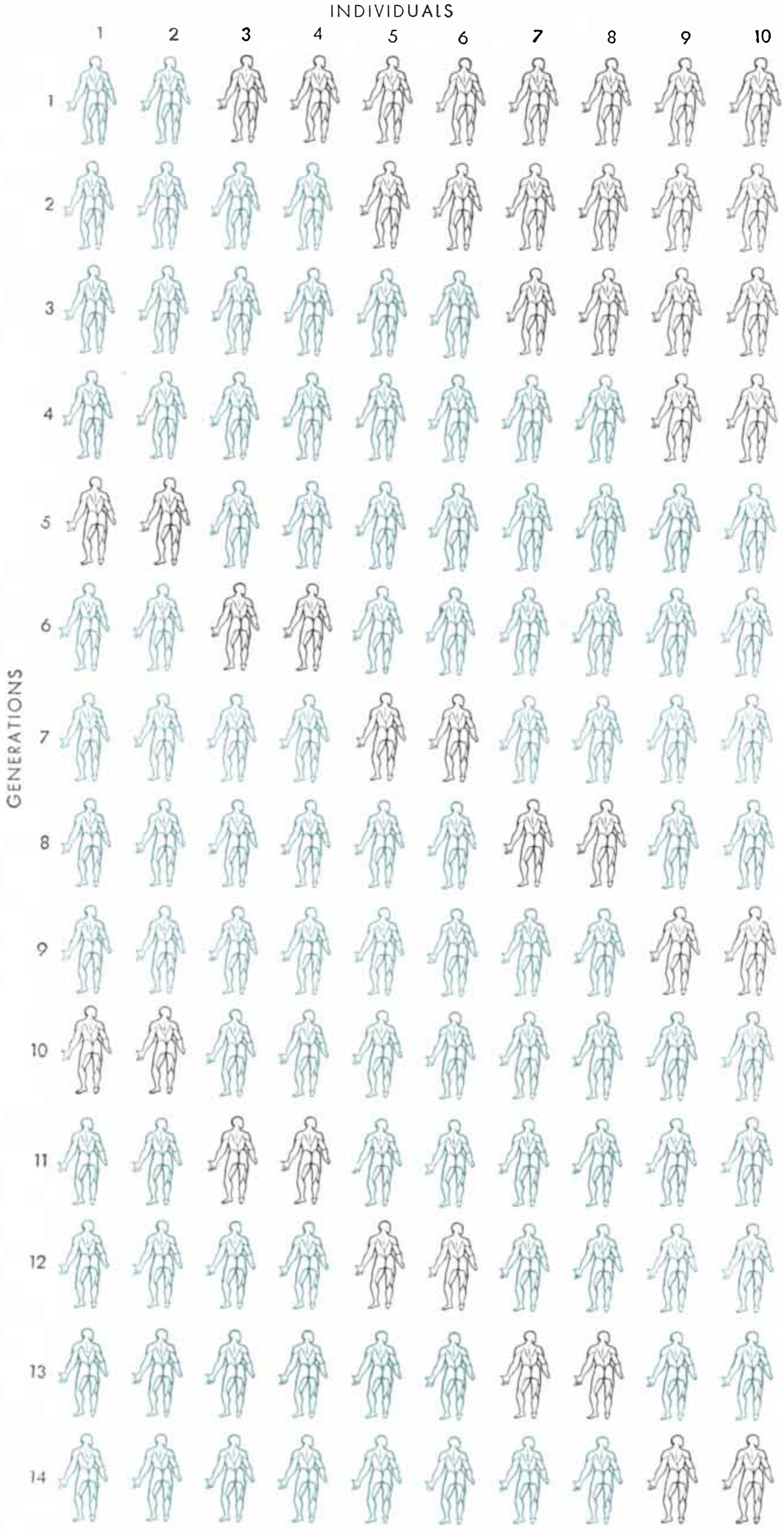
It is evident from these varied examples that the problem of maintaining the integrity of the genetic constitution is a much wider one than that of avoiding the irradiation of the germ cells, inasmuch as diverse other influences may play a mutagenic role equal to or greater in importance than that of radiation.

The view has been expressed that, since some chemical mutagenesis and even radiation mutagenesis occur naturally, the effects of such normal processes should cause us no great concern. Aside from the fact that not everything that is natural is desirable, we must always be conscious of the hazards added by civilization. Certain civilized practices, such as the use of X-rays and radioactivity (and possibly reproduction at an advanced age or the drinking of coffee and tea), are causing genetic damage to be done at a significantly more rapid rate than in olden times.

Relaxed Selection

It is evident that the rate of elimination of mutant genes is just as important as the mutation frequency in the determination of the human genetic constitution. What we really mean here, of course, is "selective" elimination. The importance of this distinction is seen in the fact that in the ancestors of both men and mice much the same mutations must have occurred, but that the different conditions of their existence—the ever more mousy living of the mouse progenitors and the manlier living of the pre-men—caused a different group of genes to become selected from out of their common store.

A very distinctive feature of our modern industrial civilization is the tremendous saving of human lives which would have been sacrificed under primitive conditions. This is accomplished in part by medicine and sanitation but also by the abundant and diverse artificial aids to living supplied by industry and widely disseminated through the operation of modern social practices. The proportion of those who die prematurely is now so



EQUILIBRIUM IS ATTAINED by recessive mutant genes under the conditions assumed here. The first assumption is that in each generation (*horizontal rows*) two new mutant genes (*colored figures*) arise among 10 individuals. The second assumption is that each line of descent bearing the mutant gene dies out four generations after the mutation has occurred. In the diagram this extinct line is then replaced by a new one. Thus after three generations the number of individuals bearing a mutant gene is stabilized at eight out of 10.

small that it must be considerably below the proportion who would have to be eliminated in order to extinguish mutant genes as fast as new ones arise. In other words, many of the saved lives must represent persons who under more primitive conditions would have died as a result of genetic disabilities. Moreover, the genetically less capable survivors apparently do not have a much lower rate of multiplication than the more capable; in fact, there are certain oppositely working tendencies.

It is probably a considerable underestimate to say that half of the detrimental genes which under primitive conditions would have met genetic extinction, today survive and are passed on. On the basis of this conservative estimate we can calculate that in some 10 generations, or 250 to 300 years, the accumulated genetic effect would be much like that from exposure of a population to a sudden heavy dose of 200 to 400 roentgens, such as was received by the most heavily exposed survivors of Hiroshima. If the techniques of saving life in our civilization continue to advance, the accumulation of mutant genes will rise to ever higher levels. After 1,000 years the population in all likelihood would be as heavily loaded with mutant genes as though it were descended from the survivors of hydrogen-uranium bomb fall-outs, and the passage of 2,000 years would continue the story until the system fell of its own weight or changed.

The process just depicted is a slow, invisible, secular one, like the damage resulting from many generations of exposure to overdoses of diagnostic X-rays. Therefore it is much less likely to gain credence or even attention than the sensational process of being overdosed by fall-outs from bombs. This situation, then, even more than the danger of fall-outs, calls for basic education of the public and publicists, if they are to reshape their deep-rooted attitudes and practices as required.

It is necessary for mankind to realize that a species rises no higher, genetically, and stays no higher, than the pressure of selection forces it to, and that it responds to any relaxation of that pressure by sinking correspondingly. It will in fact take as much rope in sinking as we pay out to it. The policy of saving all possible genetic defectives for reproduction must, if continued, defeat its own purposes. The reason for this is evident as soon as we consider that when, by artificial devices, a moderately detrimental gene is made less detrimental, its frequency will gradually creep upward toward a new equilibrium level, at which it is finally being eliminated anyway at the same rate as that at which it had been eliminated originally, namely, at the rate at which it arises by mutation. This rate of elimination, being once more just as high as before medicine began, will at the same time reflect the fact that as much suffering and frustration (except insofar as we may deaden them with opiates) will then be existing, in consequence of that detrimental gene, as existed under primitive conditions. Thus, with all our medicine and other techniques, we will be as badly off as when we started out.

Not all genetic disabilities, however, would simply be made less detrimental. Some of them would be rendered not detrimental at all under the circumstances of a highly artificial civilization, in the sense that they were enabled to persist indefinitely and thus to become established as the new norm of our descendants. The number of these disabilities would increase up to such a level that no more of them could be supported and compensated for by the technical means available and by the resources of the social system. The burden of the individual cases, up to that level, would have become largely shifted from the given individuals themselves to the whole community, through its social services (a form of insurance), yet the total cost would be divided among all individuals and that cost would keep on rising as far as it was allowed to rise.

Ultimately, in that Utopia of Inferiority in the direction of which we are at the moment headed, people would be spending all their leisure time in having their ailments nursed, and as much of their working time as possible in providing the means whereby the ailments of people in general were cared for. Thus we should have reached the acme of the benefits of modern medicine, modern industrialization and modern socialization. But, because of the secular time scale of evolutionary change and the inertia which retards changes in gene frequency, this condition would come upon the world with such insensible slowness that, except for a few long-haired cranks who took genetics seriously, and perhaps some archaeologists, no one would be conscious of the transformation. If it were called to their attention, they would be likely to rationalize it off as progress. It is hard to think of such a system not at length collapsing, as people lost the capabilities and the incentives needed to keep it going. Such a collapse could not be into barbarism, however, since the population would have become unable to survive primitive conditions; thus a collapse at this point would mean annihilation.

Countermeasures

There is an alternative policy, and I am hopeful it will be adopted. The alternative does not by any means abandon modern social techniques or call for a return to the fabulous golden age of noble savages or even of rugged individualism. It makes use of all the science, skills and genuine arts we have, to ameliorate, improve and ennoble human life, and, so far as is consistent with its quality and well-being, to extend its quantity and range. Medicine, especially that of a far-seeing and a promoting kind, seeking actively to foster health, vigor and ability, becomes, on this policy, more developed than ever. Persons who nevertheless had defects would certainly have them treated and compensated for, so as to help them to lead useful, satisfying lives. But—and here is the crux of the matter—those who were relatively heavily loaded with genetic defects would consider it their obligation, even if these defects had been largely counteracted, to refrain from transmitting their genes, except when they also possessed genes of such unusual value that the gain for the descendants was likely to outweigh the loss. Only by the adoption of such an attitude towards genetics and reproduction, an attitude seldom encountered as yet, will it be possible for posterity indefinitely to sustain and extend the benefits of medicine, of technology, of science and of civilization in general.

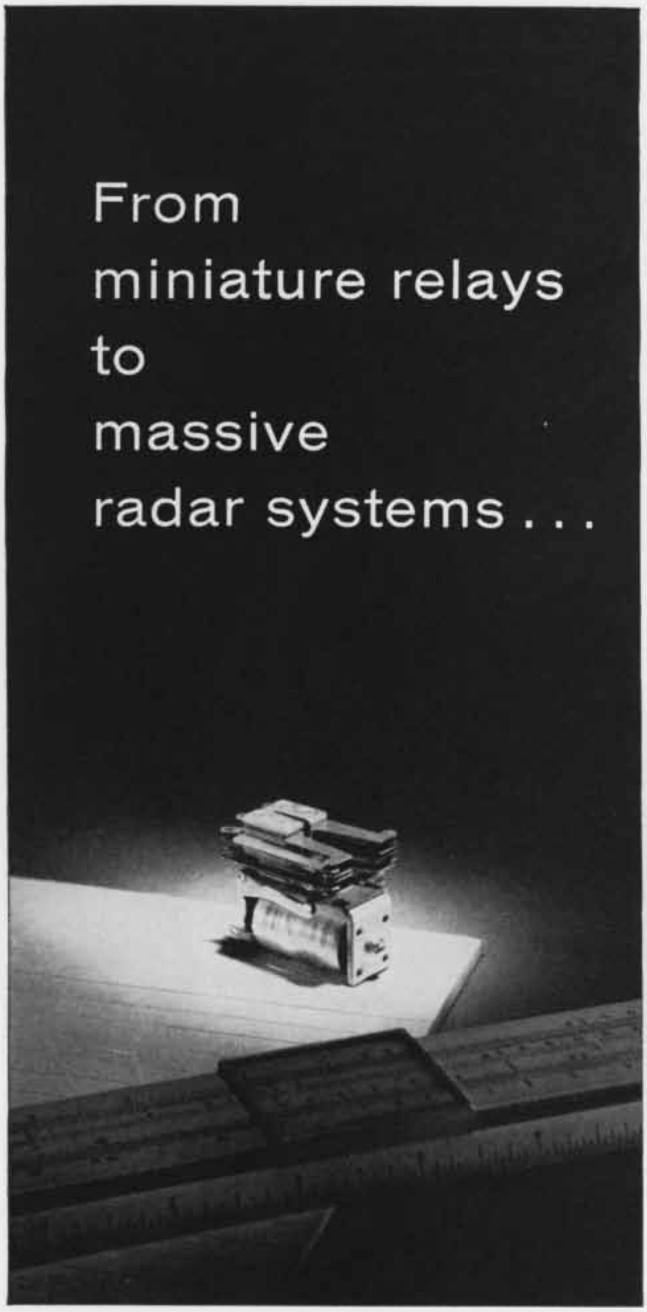
With advance in realistic education should come a better realization of man's place in the great sweep of evolution, and of the risks and the opportunities, genetic as well as nongenetic, which are increasingly opening up for him.

It is evident from these considerations that the same change in viewpoint that leads to the policy of voluntary elimination of detrimental genes would carry with it the recognition that there is no reason to stop short at the arrested norm of today. For all goods, genetic or otherwise, are relative, and, so far as the genetic side of things is concerned, our own highest fulfillment is attained by enabling the next generation to receive the best possible genetic equipment. What the implementation of this viewpoint involves, by way of techniques on the one hand, and of wisdom in regard to values on the other hand, is too large a matter for treatment here. Nevertheless, certain points regarding the genetic objectives to be more immediately sought do deserve our present notice.

For one thing, the trite assertion that one cannot recognize anything better than oneself, or in imagination rise above oneself, is merely a foolish vanity on the part of the self-complacent. Among the important objectives to be sought for mankind are all-around health and vigor, joy of life and longevity. Yet they are far from the supreme aims. For these aims we must search through the most rational and humane thought of those who have gone before us, and integrate with it thinking based on our present vantage point of knowledge and experience. In the light of such a survey it becomes clear that man's present paramount requirements are, on the one hand, a deeper and more integrated understanding and, on the other hand, a more heartfelt, keener sympathy, that is, a deeper fellow-feeling, leading to a stronger impulse to cooperation—more, in a word, of love.

It is wishful thinking on the part of some psychologists to assert that these qualities result purely from conditioning or education. For although conditioning certainly plays a vital role, nevertheless *Homo sapiens* is both an intelligent and a cooperating animal. It is these two complex genetic characteristics, working in combination and serviced by the deftness of his hands, which above all others have brought man to his present estate. Moreover, there still exist great, diverse and numerous genetic differences in the biological bases of these traits within any human population. Although our means of recognition of these genetic differences are today very faulty and tend to confound differences of genetic origin with those derived from the environment, these means can be improved. Thus we can be enabled to recognize our betters. Yet even today our techniques are doubtless more accurate than the trials and errors whereby, after all, nature did manage to evolve us up to this point where we have become effective in counteracting nature. Certainly then it would be possible, if people once became aware of the genetic road that is open, to bring into existence a population most of whose members were as highly developed in regard to the genetic bases of both intelligence and social behavior as are those scattered individuals of today who stand highest in either separate respect.

If the dread of the misuse of nuclear energy awakens mankind not only to the genetic dangers confronting him but also to the genetic opportunities, then this will have been the greatest peacetime benefit that radioactivity could bestow upon us.



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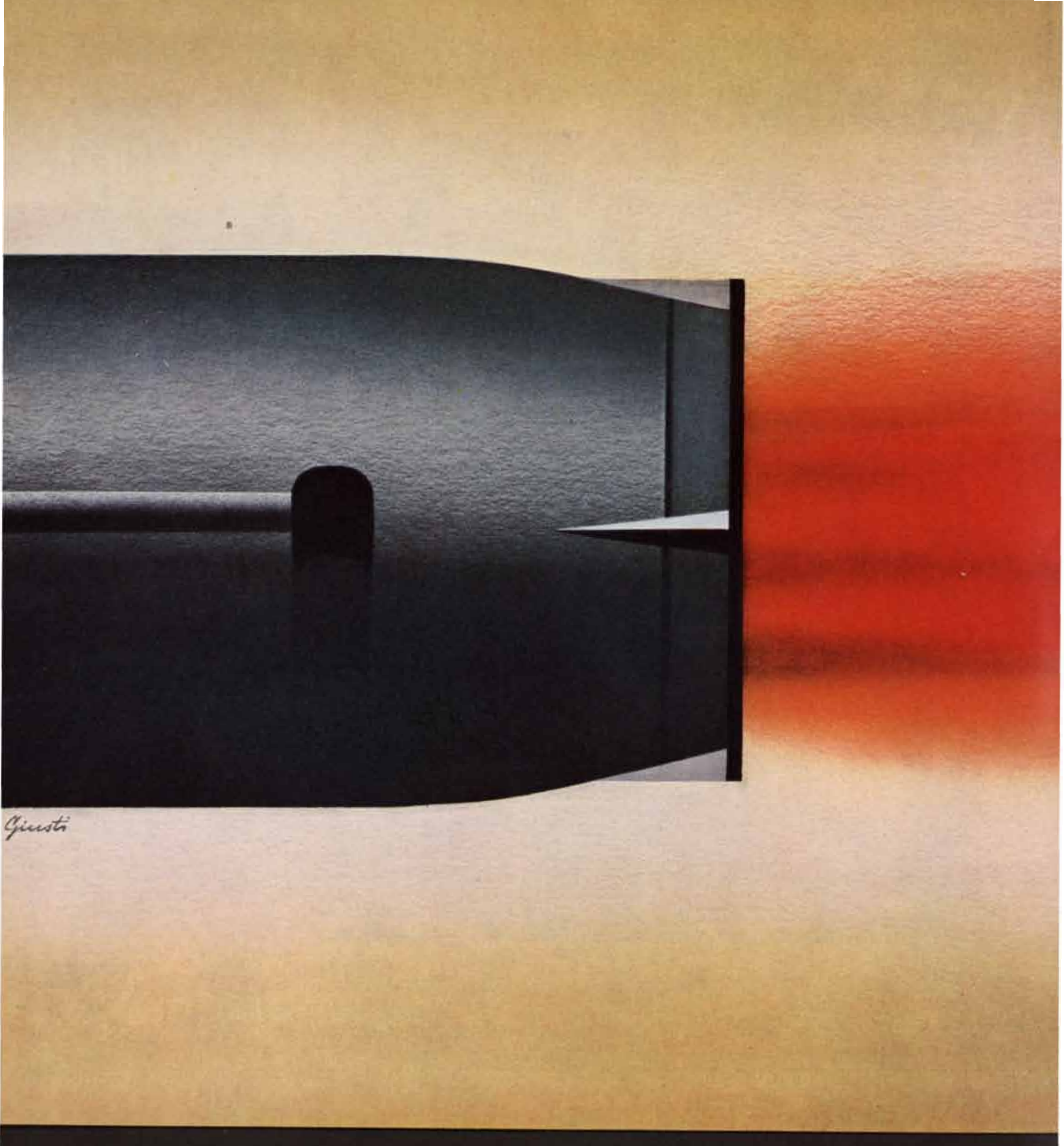
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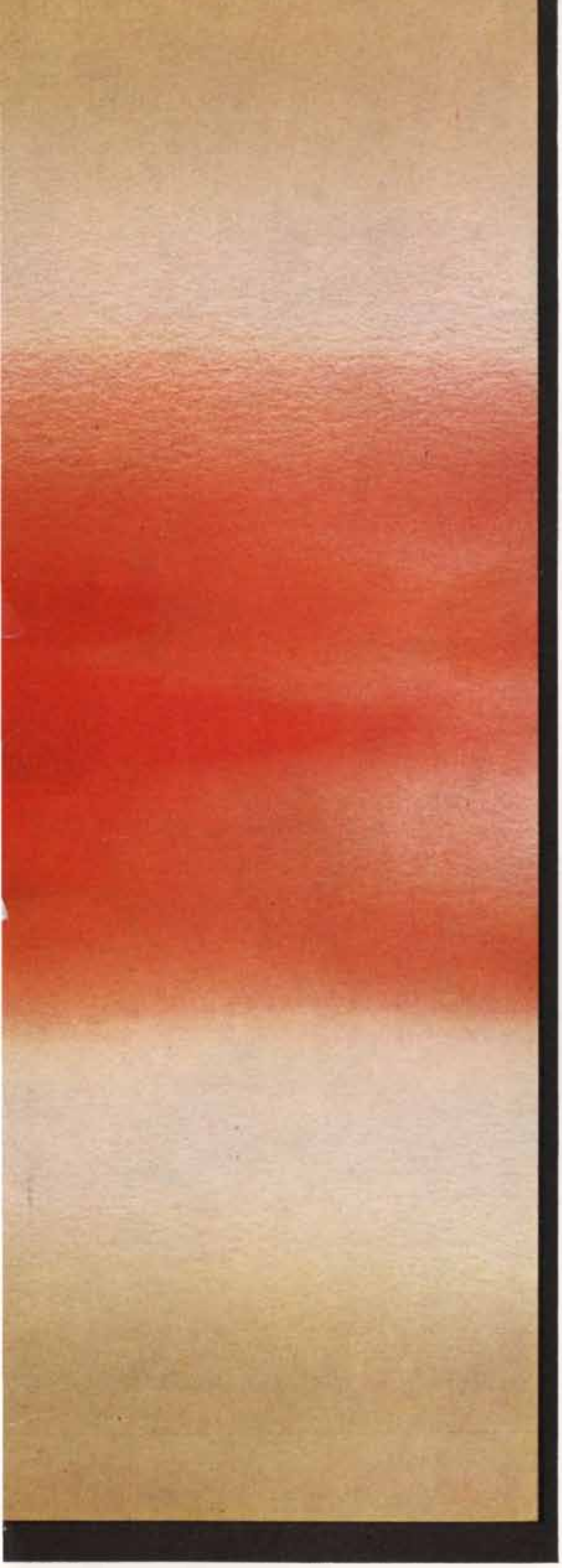

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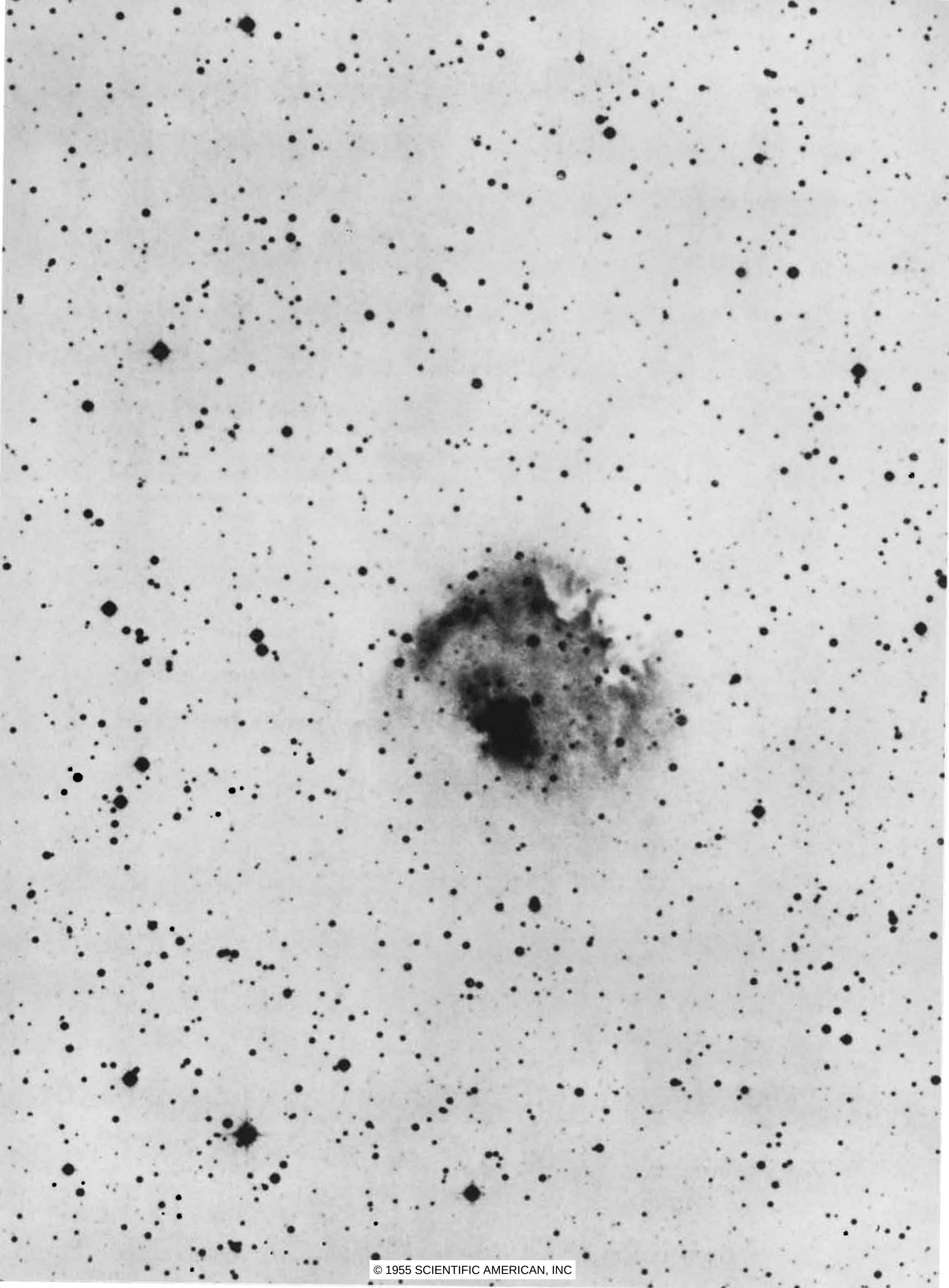


"Empty" Space

The vast reaches between stars contain about one atom per cubic centimeter, perhaps a quarter of the matter in our galaxy. This substance is made visible by the ultraviolet radiation of stars

by H. C. van de Hulst

For those wishing to dream away into the universe the stars are lights on little islands in an infinite sea. They are familiar beacons for a traveler, and the stellar landmarks would still look reassuringly familiar even if he sailed away from the earth into space. The earth and moon and planets would fade away; the sun would become an inconspicuous star; Sirius might grow dimmer and other stars brighter; but for a long time the constellations would keep their well-known outlines. At any random point of the journey the starry sky would look much as it does on a clear night on earth.

Yet while the distant scene might look much the same, how strange would seem the cold, black, silent interstellar space through which the traveler was moving! The dark void of the heavens has always frightened and mystified mankind. And it has not invited investigation. Until this century interstellar space failed to capture the imagination of astronomers, because it did not seem to do anything to their instruments. Apparently its only property was to let the light of the stars pass through.

In the last 25 years the situation has changed drastically. Interstellar space has become an exciting field of research.

LUMINOUS NEBULA was photographed by the 48-inch Schmidt telescope for the National Geographic Society–Palomar Observatory Sky Survey. Located in the constellation of Cygnus, the nebula represents a local concentration of interstellar dust and gas. Due to overexposure its illuminating star is not visible. On this positive print the stars and the luminous gas are dark and the obscuring dust is light. Prints of this kind are used by astronomers partly to increase the contrast between light and dark areas. Copyright National Geographic Society–Palomar Observatory Sky Survey.

Theoretical studies and observations by new techniques, proceeding hand in hand, have disclosed that the so-called "empty space" of the universe is far from empty.

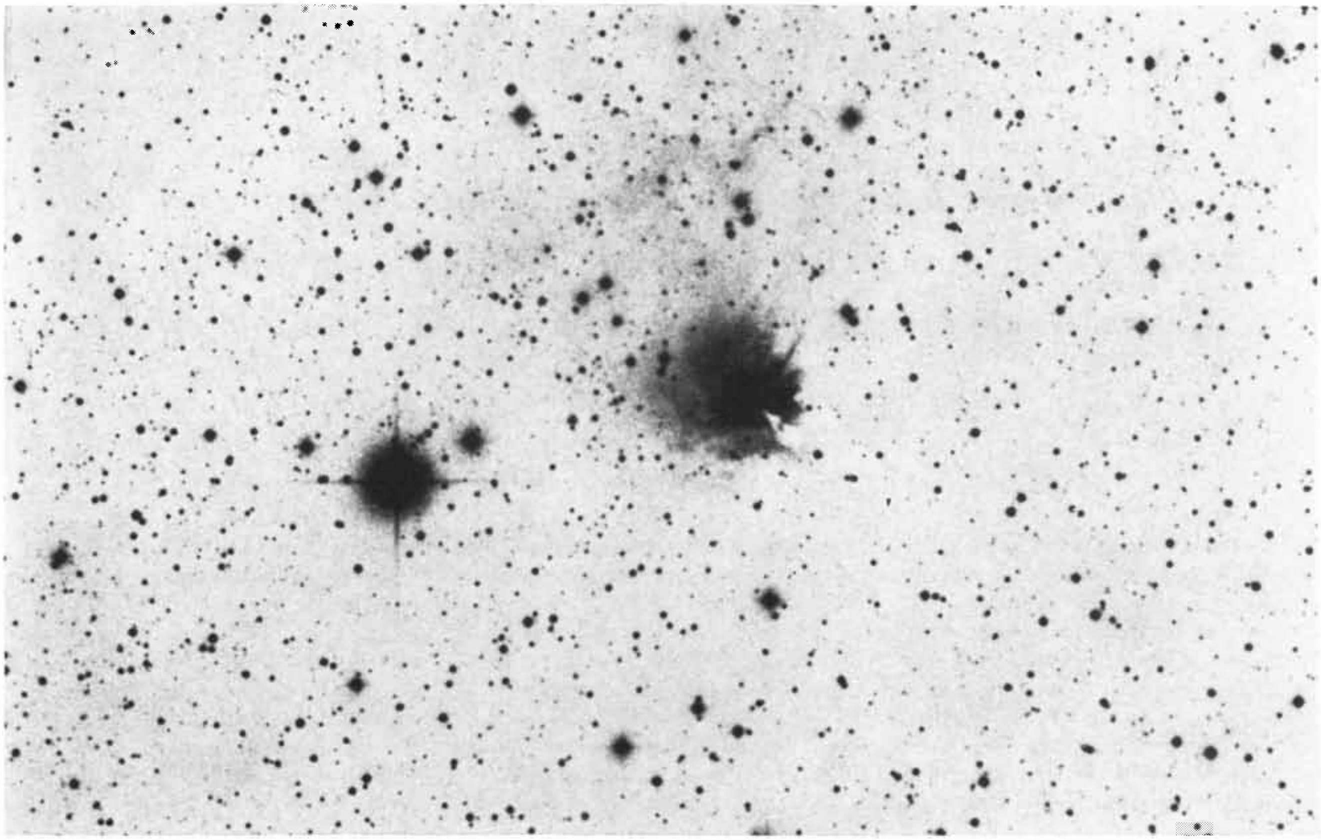
In 1925 the Dutch astronomer Jan H. Oort, then only 25 years old, demonstrated by an indirect method that the space between the stars must contain a considerable amount of matter. He measured the weight of a large volume of space, including the stars and everything else it contained, by determining the gravitational action of this volume upon the motions of stars toward and away from the plane of the Milky Way. Oort found that the gravitational effect of the region in question could not be accounted for by the weight of the stars alone; it must contain other matter. We now know that the additional weight consists mostly of hydrogen gas in the interstellar space. The hydrogen gas amounts to about one atom per cubic centimeter, and there are smaller quantities of other atoms and molecules mixed in as "impurities." In the neighborhood of the solar system interstellar gas makes up about one quarter of the total weight of a given volume, stars accounting for the rest.

Another proof that interstellar space is not empty came from a quite different angle. About 1930 astronomers discovered with some shock that as the light of the stars passes through certain regions of interstellar space it is dimmed and scattered in various directions. Up to that time astronomers had the attitude toward interstellar absorption of light that some people have toward ghosts: they didn't believe in its existence and yet they were afraid of it. It is obvious what the astronomers were afraid of. If there was indeed an interstellar haze which dimmed the light of distant stars or made them altogether invisible, then many of their calculations of star distances and their picture of our galaxy were wrong. Further studies proved that the fear was justified. Starlight passing through the crowded regions of our galaxy loses roughly half of its energy by absorption and scattering in every 2,000 light-years of its travel. As a result, even with our most powerful telescopes we cannot see the center of our galaxy, some 25,000 light-years away. Beyond about 6,000 light-years from our observing station most of our studies of the galaxy are literally lost in the fog.

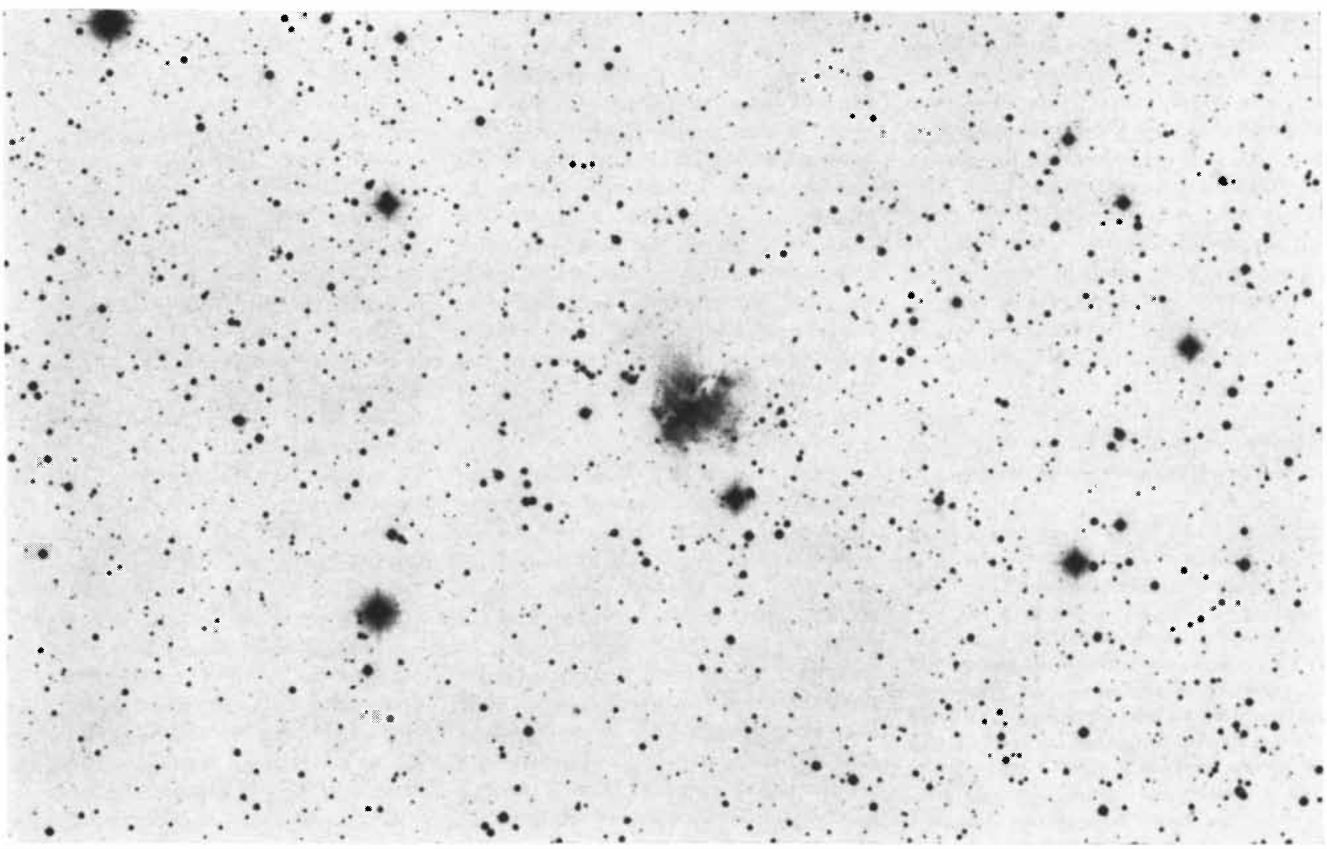
What is the agent that absorbs and scatters sunlight? It cannot be hydrogen or any other gas. This can be proved by a little computation. The column of air over each square centimeter of the earth weighs about one kilogram. We know from everyday experience that this density of air is almost perfectly transparent to sunlight and starlight. Now the hydrogen gas in interstellar space is so thin (one atom per cubic centimeter) that a centimeter-square column weighing one kilogram would be roughly 5,000 times longer than the diameter of our whole galaxy! Obviously the hydrogen gas within the galaxy must be completely transparent.

We can find clues to what the obscuring agent really is in certain other facts of our everyday experience. Water molecules in vapor form are transparent to light. But when the same water molecules in the air condense and collect in drops, which in turn form clouds, they block light. On the other hand, if they fall as rain and fill a shallow basin, the water becomes transparent again.

So we see that the effectiveness with which matter blocks light depends upon the size of the particles. Of all particle



NEBULA IN AURIGA was also photographed by the 48-inch Schmidt. The small triangular area (*bright in this positive print*) at the edge of the nebula is a dark cloud of very high opacity. Copyright National Geographic Society–Palomar Observatory Sky Survey.



ANOTHER NEBULA IN AURIGA is photographed by the 48-inch Schmidt. The four faint points around many of the star images are due to diffraction around the supports of the plate holder. Copyright National Geographic Society–Palomar Observatory Sky Survey.

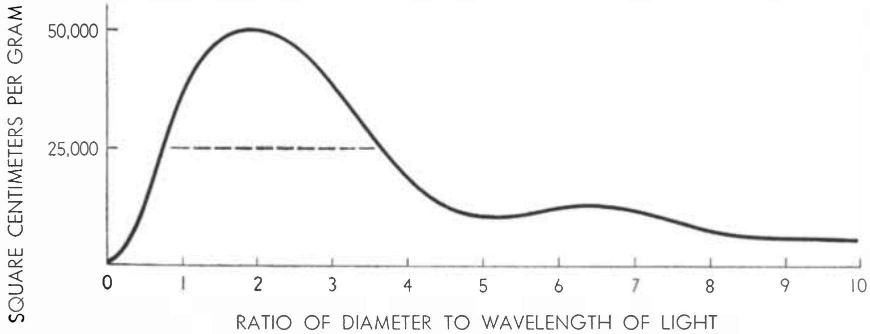
sizes, those in a cloud of smoke or dust scatter light most efficiently in proportion to weight. A wisp of cigarette smoke weighing only a tiny fraction of a gram can form an opaque screen. Thus we have to infer that the agent which scatters starlight in space is smoke or dust. Either the color of the scattered light or the color of the light that penetrates a cloud may identify the particle size. From accurate measurements of the color of starlight passing through obscuring clouds in space it is possible to estimate the size of the particles and the weight of the clouds. It appears that on the average the dust in the clouds of interstellar space accounts for only 1 or 2 per cent of their total weight. The rest is gas.

These results, obtained from a fairly straightforward explanation of astronomical observations, set the stage for an eventful story. Space between the stars is not empty. It is occupied by at least two different things: gas, mostly hydrogen, and smoke or dust, consisting of small solid grains. Do these live a peaceful coexistence, or is one devoured by the other; that is, does gas gradually condense into solid grains or do grains evaporate into gas? Do the stars, sailing slowly through space, shed matter or collect it from interstellar clouds by gravitation?

This is a set of characters for an exciting plot. And the plot has to be written by theoretical astrophysicists rather than by observing astronomers, for there is so little to go by that the hope of a direct interpretation of observational data is awfully slim.

Let us pose one simple question first: How cold is interstellar space? This question, simple as it seems, cannot be answered, for it makes no sense. It all depends on what thermometer one uses. The interstellar gas and the dust grains, which are thermometers of a kind, reach quite different temperatures. This state of affairs is due to the extremely diluted state of interstellar matter.

In the familiar case of a gas on the earth the temperature of the gas is a measure of the general degree of commotion among the molecules: molecules in a hot gas move faster on the average than molecules in a cold gas. (Molecules in a solid body move, too, but most of them are bound to positions and move like leaves on a tree.) The motion of an individual molecule cannot be predicted, but the average speed of the molecules is accurately fixed by the temperature. It is logical to choose the temperature scale so that zero temperature means no



SIZE OF COSMIC DUST GRAINS can be computed as shown above. Solid curve indicates the screening efficiency (in square centimeters of obscuring area per gram of suspended material) for dust particles of various sizes. Broken line shows the observed screening efficiency of interstellar dust. Thus the particles must have diameters between about one and four wavelengths of light, or between about one half and two thousandths of a millimeter.

motion at all. This fixes the scale of absolute temperatures. Zero degrees Kelvin is the absolute zero; 273 degrees K. corresponds to the temperature of freezing water, and 373 degrees K. to that of boiling water.

The concept of temperature presupposes a lot of energy exchange which distributes the energy fairly evenly among all the molecules. To measure the temperature of a room we do not have to be very careful about where or how we position the thermometer; in any case there will be energy exchange by manifold molecular collisions which will let the thermometer take part in the general commotion.

Interstellar space is set to a slower pace. Any atom has to travel millions of miles before it hits another. This takes weeks or months. The number of collisions in the gas is still sufficient to insure an even temperature in large portions of it. The concept of temperature can also be applied to a single solid particle, because its molecules are packed close together. However, the temperature of the solid particles need not be the same as the gas temperature; in fact, it would be surprising if it were, because the particles and gas atoms exchange energy very infrequently and react to radiation from the stars in quite different ways. Furthermore, no real thermal equilibrium can exist in interstellar space, as it does in the more or less enclosed places on the earth. In space matter is exposed at one side to the hot but distant stars providing the heat and on the other side to the dark depths of space into which the heat is lost. The situation in interstellar space is not altogether unlike that in a house with a hot furnace in a freezing winter climate. All we can say offhand is that the room temperature will be somewhere between the temperature in the furnace and the temperature outdoors. We can make it hot by constructing a system of effective energy transport from the furnace to the room and by insulating the room against heat losses to the outer air. Or we may make it cool by closing the radiators and opening the windows.

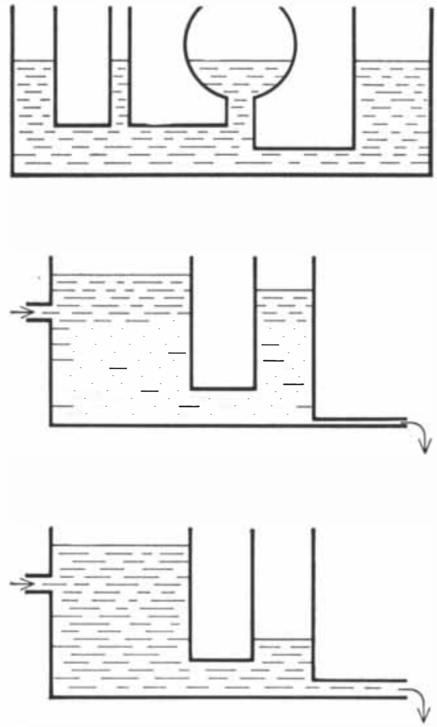
Computing the temperature of interstellar matter therefore is a problem of estimating the gains and losses, being quite careful that we do not forget any leaks! A. S. Eddington estimated in 1916 that the gas should be blazing hot and the dust deadly cold. Although we now have to qualify his statement, it is still basically correct. A gas atom moving with high speed through interstellar space has no way of radiating its kinetic energy and stands little chance of being slowed down by collisions. The same holds for electrons and ions. So the gas temperature is maintained at a high level—probably about 10,000 degrees K.—in the neighborhood of hot stars where hydrogen is ionized. The gas gets rid of some of the energy absorbed (radiating it away when ions are raised to a higher energy state by collision with electrons), but in general it is well insulated against heat losses.

The dust, however, is as poorly insulated as a person sitting at a great distance from an open fire. The particles shed heat into cold space more readily than they absorb it from the stars. Nevertheless, their radiation is limited by the fact that the dust grains are much smaller than the infrared heat waves (perhaps one ought to say cold waves) they have to emit to get rid of their energy, so that their temperature does not fall below about 10 or 20 degrees K. This is still low enough to freeze anything but helium and hydrogen.

The real problem child of space astrophysicists is the behavior of the gas in the vast reaches of space far distant from stars. In about 90 per cent of space the hydrogen atoms are too far from stars to be ionized. These clouds of neutral hydrogen have a much smaller energy budget; that is, their income and expenditure of energy are at a lower level. Theoretical calculations based on this budget led Lyman Spitzer of Princeton University to predict that the neutral clouds should be at least 100 times cooler than the hot (10,000-degree) gas in the ionized regions; their probable temperature should be about 50 degrees K.

In 1951 it became possible to study the cold regions of interstellar gas directly by means of radio astronomy, through the discovery of the 21-centimeter wavelength emission of hydrogen atoms in space. These studies indicated that the temperature of the cool hydrogen clouds is about 125 or 150 degrees K. Astronomers at first were highly enthusiastic about this result, for it confirmed the theoretical prediction that vast regions of the interstellar gas were very cold. But the discrepancy between the predicted figure of 50 degrees and the 125 degrees actually observed could not be ignored. Astronomers therefore had to consider what source of heat might raise the temperature of the hydrogen clouds. Some suggested that the source might be radiation from dark giant stars. But Franz Kahn of Manchester has proposed a more plausible idea. He suggests that about once in seven million years one hydrogen cloud collides with another and the collision heats both to several thousand degrees. The clouds thereafter behave like someone who has received a large legacy. They spend most of the new energy in a short time but then taper off and spend the rest slowly over a long period. Thus Kahn estimates that a collision-heated cloud may cool rapidly from 3,000 degrees to 500 and then very gradually from 500 to 50 degrees. The 125-degree temperature observed by radio astronomy may be an average; further studies with the big new radio telescopes which are now under construction may show large temperature variations from cloud to cloud.

Where does the dust in space come from? In the last years of World War II several Dutch astronomers and physicists in occupied Holland tackled this question theoretically. The most plausible explanation seems to be that the dust particles are basically grains of ice, for oxygen combines easily with hydrogen and it is the next most abundant element in the universe after hydrogen



HEAT BUDGET of interstellar matter is illustrated by hydraulic analogy. For equilibrium (*top*) all parts of the system stay at the same height (*temperature*) regardless of the size of the channels connecting them. Where interstellar dust (*right-hand vessel in two lower pictures*) loses heat, it will stand lower (*cooler*) than the reservoir if the channel is wide (*bottom*) than if narrow (*middle*).

and helium. It is not hard to picture how such grains might grow in space. Each particle is so cold that any gas atom or molecule colliding with it will freeze and stick to its surface. The particle will continue to grow even though most of the hydrogen and helium atoms attaching themselves to it soon evaporate. But as we know, the particles do not grow beyond a certain small size. This must mean that they are destroyed from time to time; considering their observed size, their average lifetime cannot be more than about 10 million years. Very likely they evaporate when clouds collide.

An interesting problem arose when it was discovered in 1949 that dust clouds in space polarize light. The discovery indicated that the dust grains are not neat spheres but must be egg-shaped, disk-shaped or perhaps even needle-shaped, and aligned to some extent in the same direction. There remain also some uncertainties about the composition of the particles; one theory is that many of them may be flakes of graphite. But the nature of the dust in space is considered now to be at least partly solved.

In 1949 a group of 50 experts in as-

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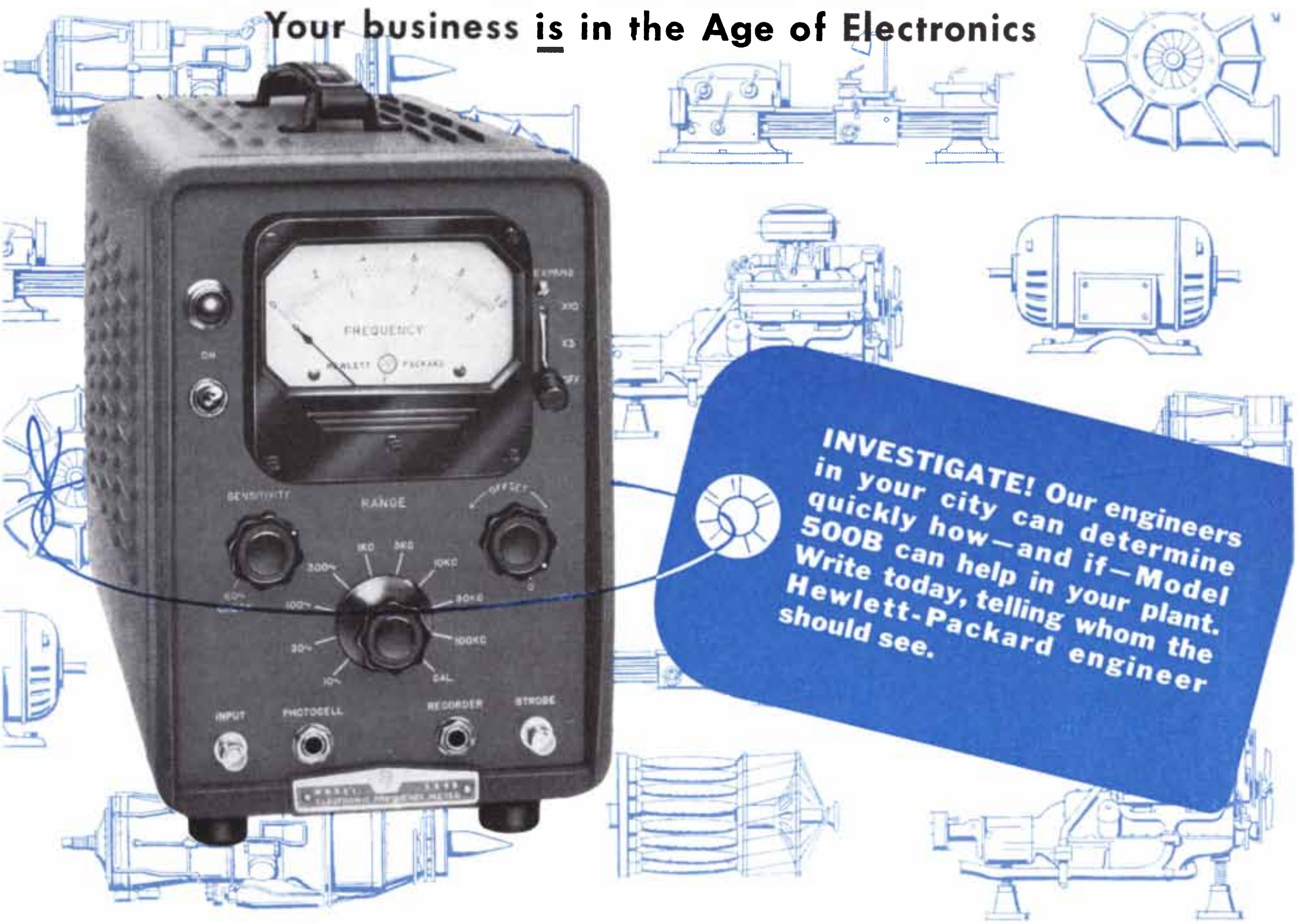
tronomy and gas dynamics met in Paris for a week to discuss the unsolved problems concerning the gas in interstellar space. Why does the gas collect in clouds? What is the driving force that moves these clouds through space? How can one account for the fact that the clouds seem to have an intricate structure and rapid internal motions? The experts could do little more than define the problems. Four years later they met again in Cambridge, England. The problems were not yet by any means completely solved, but they were more clearly defined and some reasonable answers could be given. Here is how the present ideas run.

The interstellar gas is the dominant matter in space. Its dynamics molds the shape of the clouds and probably of whole spiral arms in our galaxy. Compared to it the dust is unimportant. For astronomers the obscuring dust is usually just a nuisance, except for the one helpful circumstance that it shows where the invisible gas is concentrated, as the smoke from a chimney may show the direction of the invisible wind. Concerning the driving energy that moves the clouds, the experts now doubt that the rotational motion of the galaxy is sufficient to account for their motion in the face of energy losses by friction, collisions and the formation of cosmic rays. A more powerful driving mechanism is needed, and the answer may be the temperature differences between the ionized and nonionized regions of the interstellar gas. If one part of a mass of gas is 100 times hotter than another part, the enormous pressure difference set up would start a kind of explosion which would shoot out portions of the mass as clouds traveling at high speeds. Thus the energy of the clouds' motion may derive from the radiation of the hot stars that heat the gas, and the energy of the stars in turn derives from nuclear reactions in their interiors. In short, nuclear power appears to be the driving power even of the motions of interstellar clouds.

The hot stars that produce such heating of the gas can have only a short lifetime—one to 10 million years. Stars of this kind must be formed continually from the same complexes of interstellar matter that they finally manage to blow apart as a chick breaks its eggshell. Thus the formation of stars and the formation of interstellar clouds are parts of one and the same problem for astronomers. So far the astronomers are occupied with too many other questions to worry much about the question as to which came first: the chicken or the egg?



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What Makes Leaves Fall?

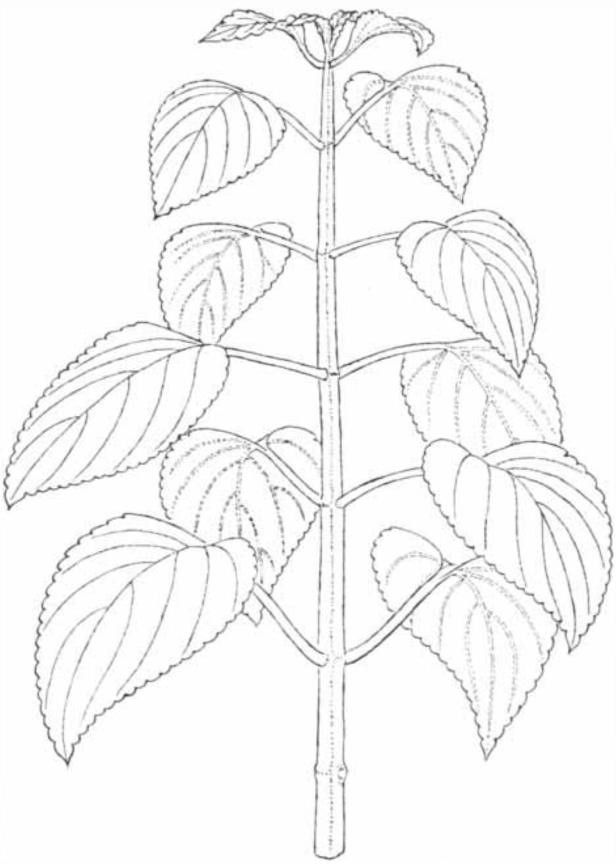
Plants shed their leaves not only in the fall, but continuously. New experiments indicate that they do so when old leaves flag in their production of the hormone auxin and young leaves make more

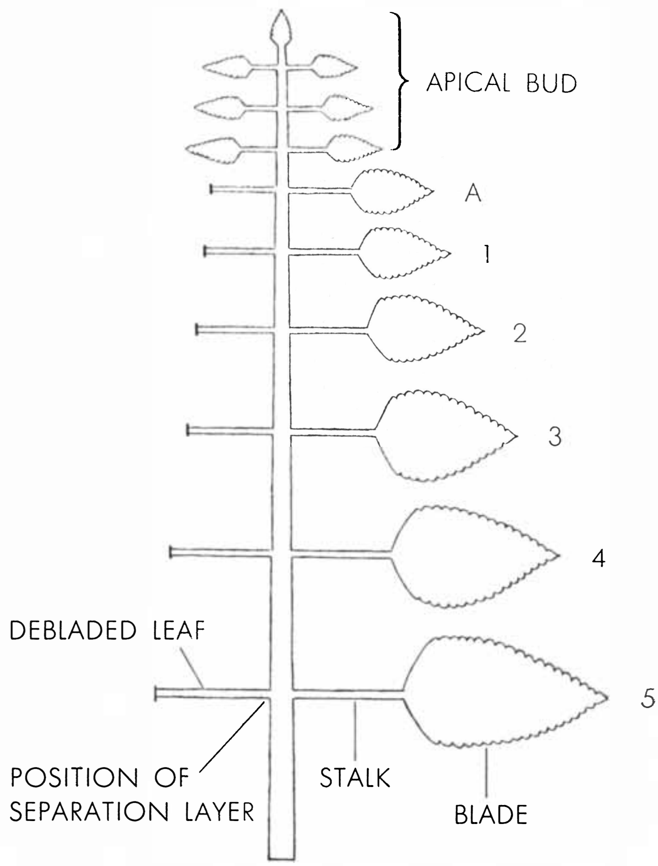
by William P. Jacobs

The falling of the sere and yellow leaf symbolizes autumn, but leaf fall is not limited to that season. All summer long in temperate zones and all the year round in the tropics there is a steady, though inconspicuous, rain of leaves from trees. Plants continually shed tissues (not only leaves but also fruits, flowers and other organs) as the organs grow old. This gives them certain enviable advantages denied to most of the animal kingdom. If man, for example, could shed his aging extremities and grow new ones to take their place, Renoir would not have had to strap his brush to his old and trembling hand in order to paint what his still "young" mind could conceive.

Botanists have been trying for nearly a century to discover the process by which plants shed their leaves. One of the first clues that attracted their attention was the fact that some plants develop a distinct layer of cells at the base of the leaf stalk and the leaves then break off at that point. But the so-called "separation layer" proved to be a false clue. Many plants have no such layer, and many others have one but their leaves do not separate at that place.

The leaf-shedding process, whatever its physiology, is speeded in the autumn by the shortening of the day; this was





EXPERIMENTAL PLANT was Coleus, called the "beefsteak plant" because of its deep red leaves. It has a bud at the top and six pairs of mature leaves. In the schematic drawing at the right the apical bud has been opened out to show the immature leaves within it.

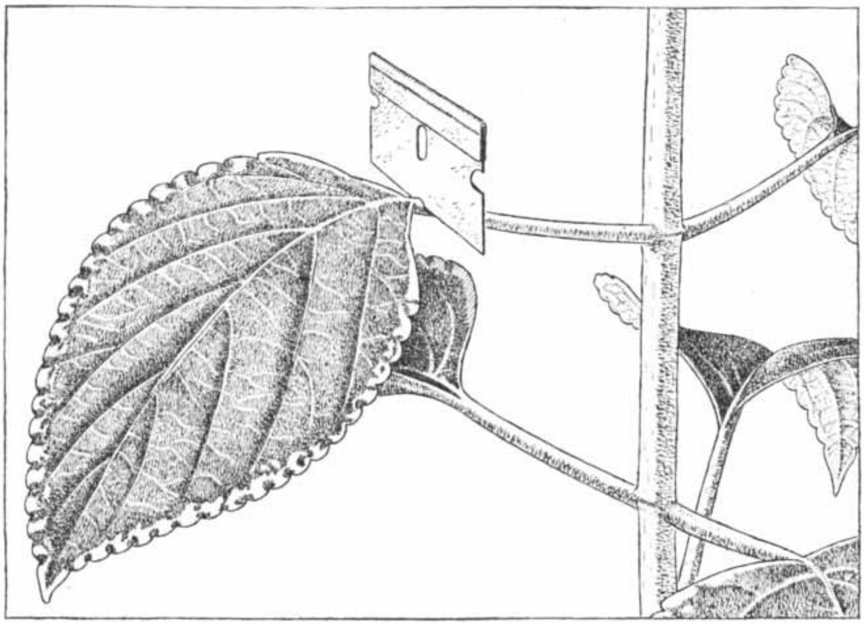
confirmed long ago by experiments which demonstrated that when the day was lengthened by artificial light, trees held their leaves later than usual. But various other factors also were found to influence the process. And among these the one that has been the greatest help in unraveling the mystery is the observation, made almost 100 years ago, that when the blade of a leaf is cut off or severely damaged, the leaf stalk falls off the plant very soon afterward.

This lead has been pursued with much zest and profit in recent years by laboratory experiments. For precise and extensive experimentation trees are remarkably inconvenient. Most of us do not have a musculature which would make us look forward to manipulating oaks and maples. And trees take so long to do almost anything! So for the same reasons that animal biologists are much better acquainted with the physiology of mice than of elephants, plant physiologists like to work with greenhouse plants. The favorite plant for studying leaf fall is the familiar house plant *Coleus*, also called the "beefsteak plant" because of its deep red leaves. When grown in the greenhouse under the cultural conditions which we have used for our experiments, Coleus keeps a fairly constant number of leaves on its main stem. Every seven to ten days the oldest pair of leaves falls off at the bottom of the stem and a new pair forms at the apex. Coleus has the further great advantage that it is easy to grow from cuttings, so that a large collection of genetically identical plants can be developed from a single original parent. In our experiments we have used some 3,000 plants, all derived from one original plant: in effect our subjects have been "identical twins" multiplied 1,500 times! With this uniformity of heredity, it is possible to measure reliably very small treatment effects even with small sample sizes.

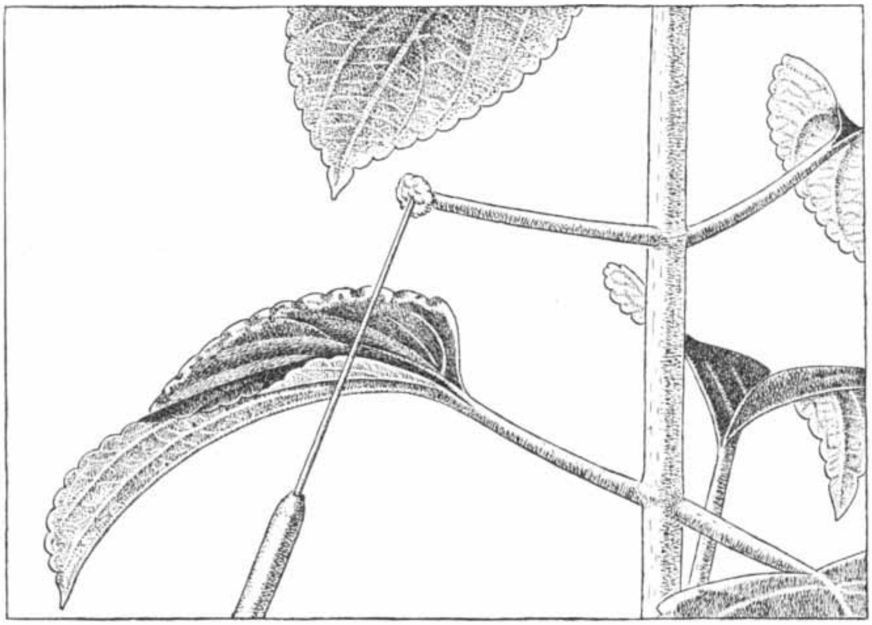
The two major parts of a leaf are the flat blade and the stalk by which the blade is attached to the plant stem. When the blade of a leaf is cut off, the remaining leaf stalk soon separates and drops from the stem. For instance, a young, fast-growing Coleus leaf, which normally takes 35 to 40 days to reach the age of natural fall, will fall in only five or six days if it is debladed. The first substantial hint as to the internal mechanism controlling fall came when it was found that if even only a tiny piece of the leaf blade was left on the stalk, the leaf would stay on the stem just as long as if it had a complete blade. This indicated that the substance in the blade that prevented the fall of the leaf must be active in very minute amounts. It could not be a general nutrient such as sugar; most likely it was a hormone.

The hormone was soon identified. It is the plant growth substance known as auxin [see "Plant Hormones," by Victor Schocken; Scientific American, May, 1949]. An alert German investigator applied the hormone to debladed Coleus leaves and found that the substance not only kept the leaves growing but "increased their longevity," that is, delayed their fall.

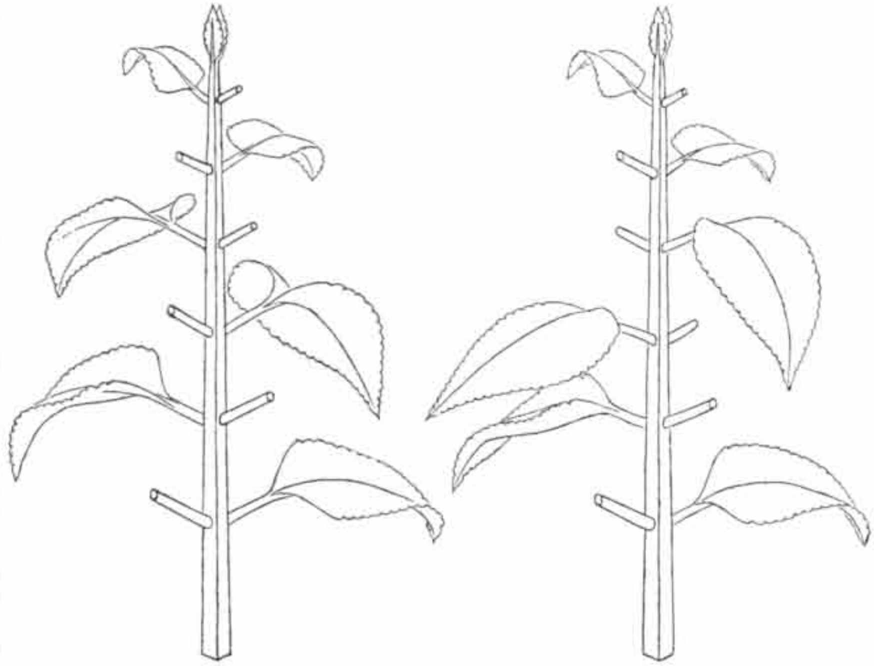
It was later established that the leaf blades of Coleus produce substantial amounts of auxin, and a clear and direct relation between auxin production and leaf fall was worked out. The more auxin a leaf produces, the longer it takes to fall [*see chart on page 86*]. The fastest-growing leaves produce most auxin; the maximum production occurs when the young leaf is 60 to 100 millimeters long (between two and a half and four inches).



LEAF WAS DEBLADED by making the cut indicated in this drawing. Technically the leaf consists not only of the blade but also of the stalk that connects it to the stem of the plant.



AUXIN WAS APPLIED in a dab of paste placed on the end of the cut stalk. In this way it was investigated whether auxin made by the leaf blade affected other parts of the plant.



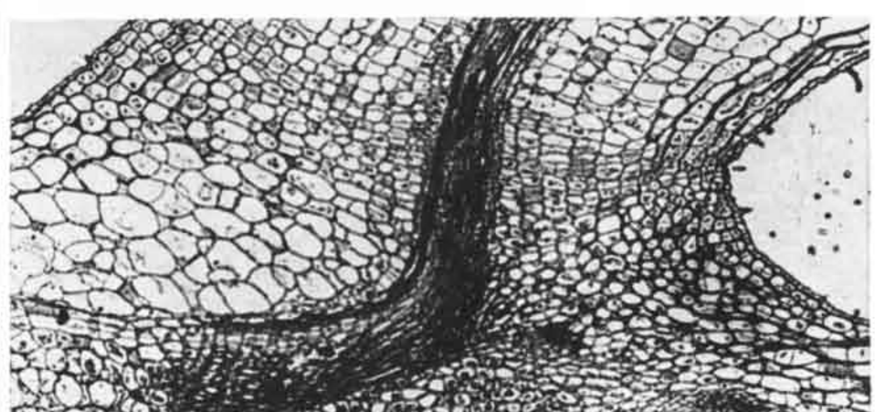
DIFFERENT PATTERNS of leaf-blade removal were tried to ascertain the effect of the rest of the plant on leaf fall. At left is a "two-sided" pattern; at right, a "spiral" pattern.

The oldest leaves produce little or no auxin.

Quantitative experiments, in which synthetic auxin was applied to debladed leaves in the amounts that would normally be manufactured by the blade, showed that it had exactly the same effect in inhibiting leaf fall. The general conclusion was that auxin produced in the leaf blade moves down into the leaf stalk, and there inhibits leaf fall in direct relation to how much auxin there is. This conclusion was confirmed in a qualitative way for the leaves of other plants and for a number of kinds of fruits. In fact, spraying apple trees with auxin has become a fairly routine method of preventing premature dropping of the fruit.

The control of leaf fall by auxin seemed to be completely clear. It was, in fact, *too* clear. As often happens when our interpretations of nature seem marvelously simple, the simplicity turns out to reside in us, not in nature.

While thinking over this theory of leaf fall, I was struck by the odd circumstance that each leaf seemed to be acting as an independent entity. The theory implied that the fall of a leaf depended only on how much auxin was coming into its stalk from its own blade. Now in most cases that we know of, the behavior or development of one part of a plant is subject to inhibitions and stimulations from other parts of the plant. One therefore had to suspect the completeness of the hypothesis that leaf fall was totally independent of influence from the rest of the plant. Furthermore, while the hypothesis seemed to explain what pre-



SEPARATION LAYER in the leaf stalk was an early, but misleading, clue to the process of leaf fall. It is the band of smaller cells running across the top of this photomicrograph.

vented leaves from falling, it left unclear what causes them to fall when they do.

With these thoughts in mind, we planned some experiments to try to detect influences from the rest of the plant. These involved trials of various patterns in deblading the leaves of a plant. Coleus leaves grow in pairs, the two members of each pair coming from opposite sides of the stem [*see drawing on page 82*]. The usual practice had been to deblade one of each pair, leaving the "sister" leaf intact as a control. Now if the fall of each leaf was controlled independently within itself, it should be immaterial in what pattern the leaves up the stem were debladed, or how many of them were. But experiments showed that the pattern of deblading did make a consistent, though small, difference in the time of leaf fall, and that when *all* the leaves (except those in the bud at the apex of the stem) were debladed, the fall was strikingly slowed down!

The most obvious conclusion was that the presence of intact leaves in some way speeded the fall of debladed leaves. Indeed, their presence accelerated the fall even of old leaves that were not debladed, for when the blades were removed from all the younger leaves, the old ones remained on longer than they would have otherwise.

It seemed, then, that leaf blades produce not only a substance (auxin) which inhibits falling but also a substance which speeds falling. What might this substance be? The most likely candidate was ethylene. This ingredient of illuminating gas has long been known to cause trees' leaves to fall, and recently it has been learned that some ethylene is naturally present in plant tissues; it is emitted by ripening fruit and by leaves. However, we were unable in an extensive series of experiments to find any evidence that ethylene from leaves speeded leaf fall.

Although we scoured the research literature, we could find no other leads that proved fruitful. We therefore decided to look more closely at the experimental plants. It was then we noticed something we should have seen before. In every experiment we had left untouched the tiny leaves in the apical bud at the top of the stem. And every treatment that speeded the fall of leaves lower on the stem had at the same time accelerated the growth of the apical leaves. We now noticed a clear correlation between this growth and the time of the debladed leaves' fall. They fell just when the bottom leaves of the apical bud above them reached a length of 70 to 80 millimeters. Fast leaf fall seemed to be closely tied up with the presence just above of leaves 70 to 80 millimeters long.

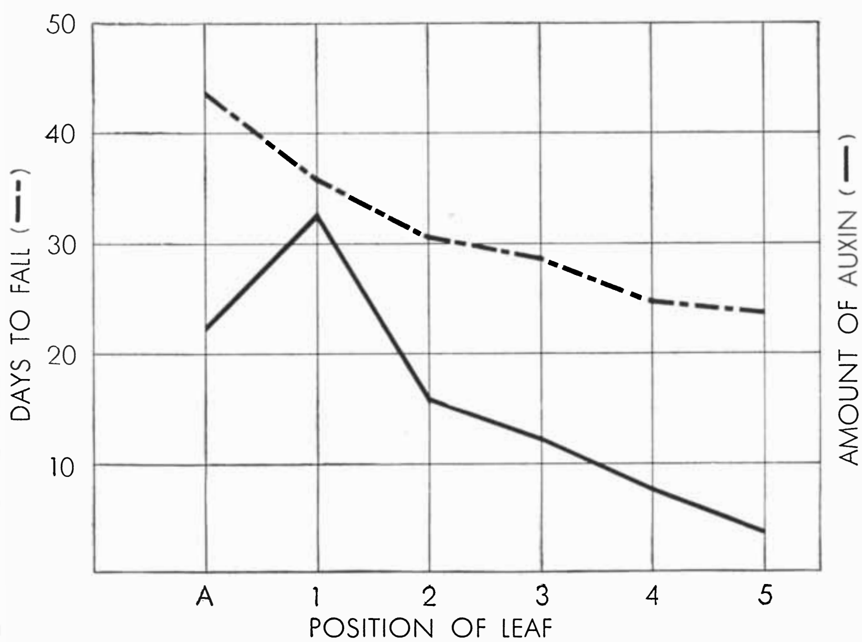
Why should this particular length of the apical leaves be so important? The answer is that when a leaf reaches this size it attains its maximum production of auxin. It was beginning to look as if the primary cause of speeded leaf fall was auxin production by the apical bud leaves above the debladed leaves. Further analysis indicated that the presence of intact leaves lower on the stem speeds leaf fall indirectly by speeding the growth of these apical leaves.

This view was confirmed by the following experiment. Many plants were prepared in which the young leaves were debladed and the older leaf pairs left intact. As in earlier experiments, the presence of the older leaves low on the stem speeded the fall of the debladed leaves above them, so long as the apical bud was left intact. But when the apical bud was cut off, the debladed leaves in that set of plants fell much more slowly. If, however, synthetic auxin was applied in place of the cut-off bud, the debladed leaves fell as fast as if the bud were on. Thus the experiments confirmed our surmise that auxin from the apical bud speeds the fall of debladed leaves.

These experiments, along with others which there is not space to describe, show that the fall of leaves is controlled by an "auxin-auxin balance." Auxin both slows and speeds leaf fall. So long as a leaf's own blade produces enough auxin to overcome the effect of auxin coming from younger leaves above, the leaf will stay on the plant. But as soon as its production of auxin drops to less than the critical rate—because of old age, too much shade, insect attack or deblading—the auxin from the younger, more vigorous leaves above causes the leaf to fall. Such a system has obvious adaptive value. The old and infirm are shed by the action of a hormone from the young and vigorous.

It is a great surprise that the same hormone should act as both the stimulator and the inhibitor of leaf fall. Apparently its contrary effects depend simply on the direction from which it comes. We can only marvel at the frugality of nature, which has endowed plants with a single hormone that can do so many different things.

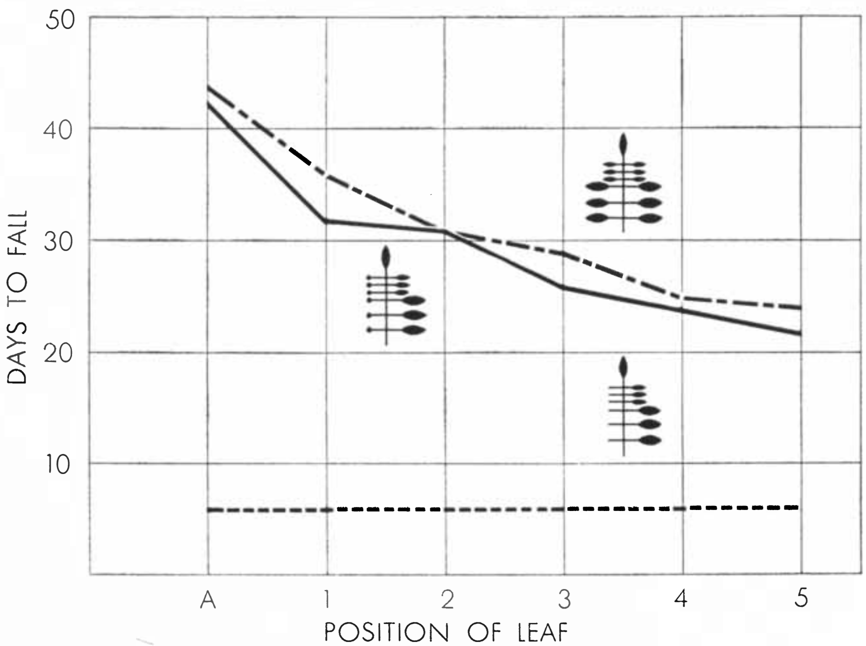
So much for Coleus. How much of this applies to trees? Since detailed experiments of the sort described here have never been done with trees, we do not know. In fact, it seems unlikely that such experiments ever will be done on trees: to perform tree experiments equivalent to those with our 3,000 genetically identical Coleus plants one would need some 10,000 trees grown from seed. However, there is reason to believe that an auxin-auxin balance is at work in trees as in Coleus. Artificial lengthening of the daylight has been found to increase the



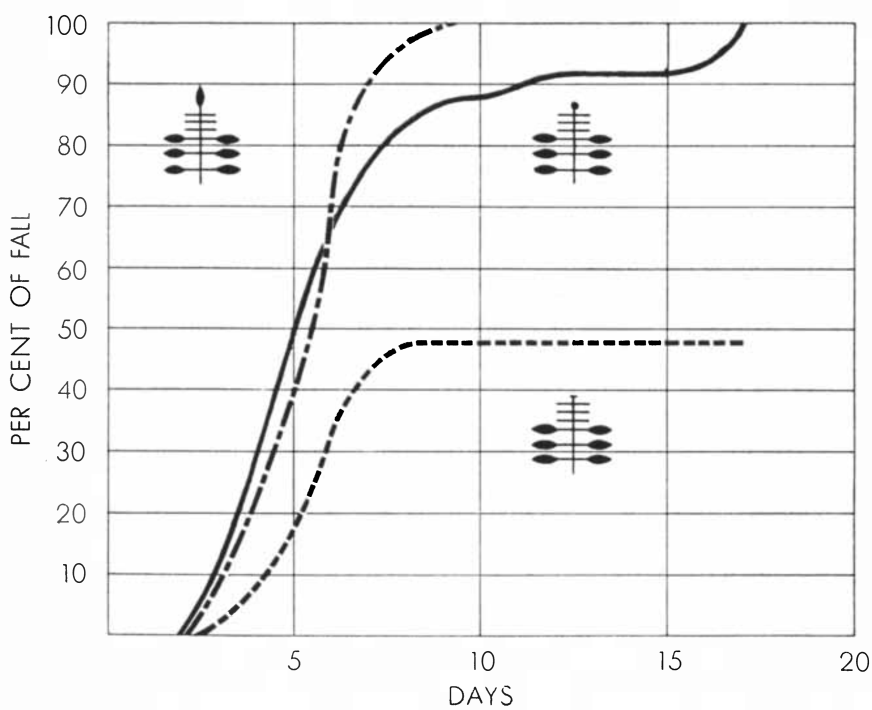
AMOUNT OF AUXIN produced by each leaf (*right*) is related to the number of days it takes the leaf to fall (*left*). The position of the leaf on the stem of the plant (*bottom*) is indicated by the symbols used in the drawing at the right in the illustration on page 82.

amount of auxin produced by the blades of tree leaves. The fast growth of a new branch in spring is accompanied by the production of a big gush of auxin by the new branch, which presumably speeds the fall of the older leaves.

There is as yet no evidence as to the role of auxin in the shedding of leaves by trees in the autumn. But until more specific evidence is available, we will adopt the biologist's usual attitude in such cases: "Organisms are presumed the same until proved different." According to such a view the leaves of a tree, like the leaves of Coleus, remain on the tree until their own production of auxin becomes so small that auxin produced by other leaves can force them to fall.



REMOVAL OF LEAF BLADES in a spiral pattern caused their stalks to fall sooner (*bottom curve*). When the blades were removed, but auxin applied to the cut stalks (*middle curve*), the stalks fell at about the same time as the intact leaves of a normal plant (*top curve*).



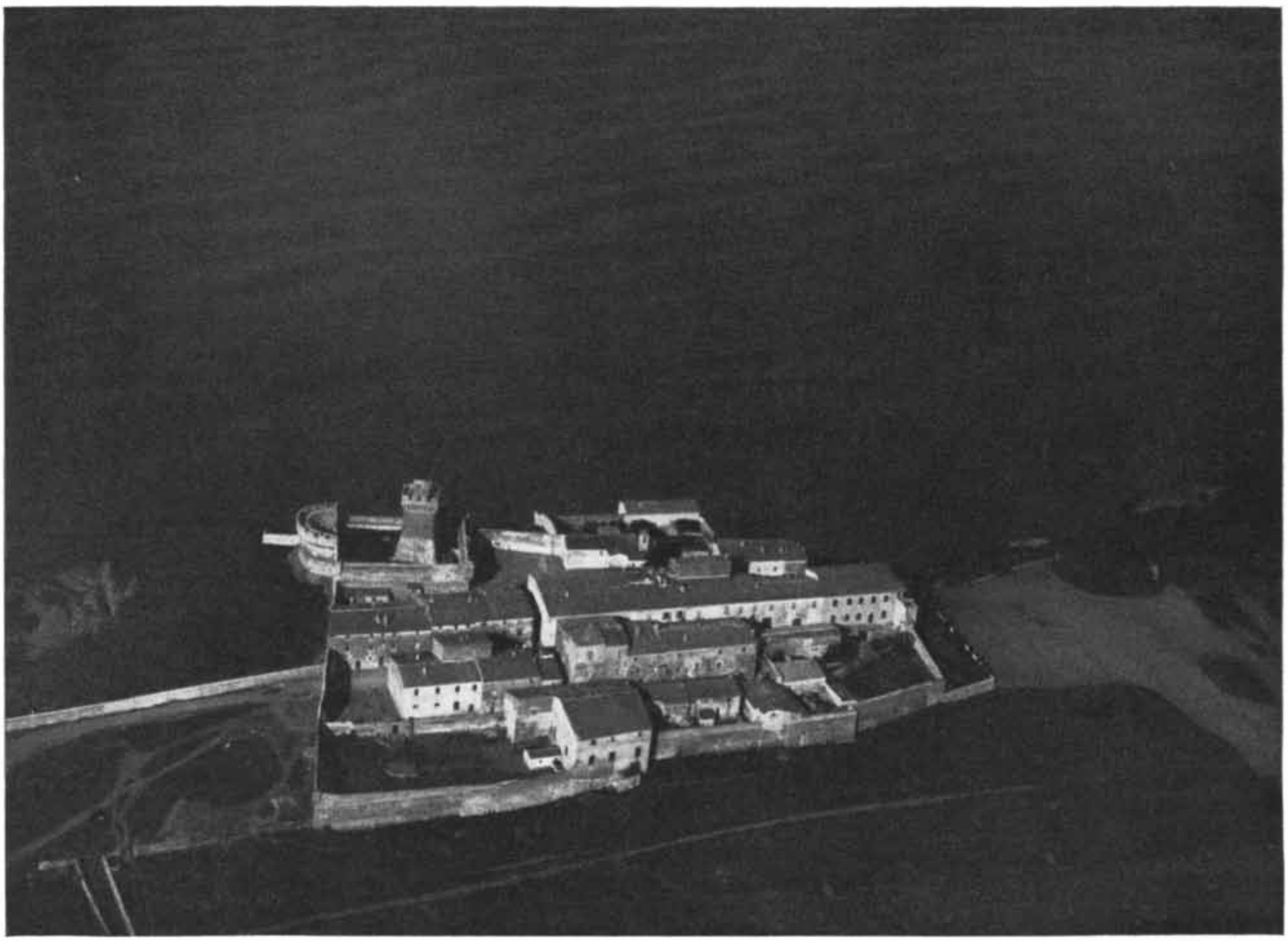
REMOVAL OF APICAL BUD cut the fall of debladed leaves (*short dashes*), compared to plants with the leaves off but the bud on (*long and short dashes*). When the bud was replaced with auxin, the rate of fall (*solid curve*) was much the same as in the plant with the bud.

ETRUSCAN METALLURGY

Ancient Etruria, which extended roughly from Rome to Florence, was the birthplace of metallurgical industry. Today metallurgists seek the formula of its remarkable bronze and mine its slag heaps

by Aldo Neppi Modona

The Etruscan civilization bloomed in central Italy from the seventh to the first century B.C. It is one of those ancient cultures whose birth and death are surrounded with a certain degree of mystery. Like an exotic flower, the brilliant Etruscan civilization sprang up as if from nowhere and disappeared in the same way. Historians are not entirely certain about who the Etruscan people were, though the evidence now seems fairly clear that they came from Asia Minor and the islands of the Aegean Sea, settled on the west coast of Italy on the shores of the Tyrrhenian Sea and gradually spread over the middle of the Italian peninsula. By the fifth century B.C., at the height of their power, the Etruscans were the masters of all central Italy from the Po River on the north to the provinces around Rome on the south. But when, some four centuries later, the Romans marched forth to conquer an empire, the Etruscan civilization was



ETRUSCAN PITTSBURGH was Populonia, now the site of a mere hamlet. Here ore from Elba and the Metallurgic Mountains was smelted, and metals shipped all over the Mediterranean. Medieval castle stands on the foundations of the ancient city's citadel.

completely swallowed up. Its writings and language disappeared; its cities withered away, and its arts and industries were eventually buried under the soil blanket of time.

It was the archaeologists who rediscovered the Etruscan culture. In the 18th century they began to dig into the long-buried Etruscan sites, and they turned up astonishing treasures. Paintings, sculptures, jewelry and beautiful metal work came from the diggings in a rich stream. Etruscan objects of art now adorn museums all over Europe and in America. Etruscan architecture attracts visitors from every land to the exhumed towns of ancient Etruria. But to modern eyes perhaps the greatest marvel is the Etruscans' metallurgy. It was carried out with such skill and on such a scale that Etruria can justly be called the birthplace of civilized man's metallurgical industry.

The rediscovery of the magnitude and character of the Etruscans' metallurgy began only a few decades ago. In the early years of the 20th century the rebuilders of Italy drained and reclaimed a deserted stretch of the Tyrrhenian coast which for centuries had been a malaria-ridden marshland. Practically the only surviving settlement along this stretch of coast was a hamlet called Populonia—a small cluster of houses within the crumbling stone walls of an ancient castle. After the land had been reclaimed, geologists visiting the area were greatly interested by a curious range of rounded hillocks that dotted the flat coastal plain near Populonia. When they dug through the surface earth, they found it to be underlain by what appeared to be a dark, spongy soil. This material did not at first receive much attention, for further digging soon unearthed a large cemetery of ancient Etruria.

One after another, three distinct layers of tombs emerged in Populonia's necropolis—city of the dead. At the top were Roman tombs of the first and second centuries B.C. Beneath these were Etruscan tombs going back several centuries earlier. And at the lowest level were simple circular graves of the Iron Age, dating from about the eighth and ninth centuries B.C. All the tombs contained ornaments, tools and other objects, since the Etruscans, like other peoples of antiquity, buried the deceased's favorite personal possessions with him, believing that they would be of use in the nether world. Thus archaeologists have been able to trace at Popu-

BRONZE HAND MIRROR has fine detail incised in its decorative back. Although the metal is impure, the Etruscans had an unknown process for molding it with a perfect finish.

lonia the evolution of the Etruscans' customs, crafts, architecture and industries through the centuries of their flourishing civilization.

The architecture of the tombs shows the Etruscans' progressive development of the vault: the earliest tombs were pits in the shape of a well, capped with a pseudo cupola built cone-fashion with successively narrower blocks of stone set on one another; the later tombs were square chambers surmounted with a true vault and a round cupola. This later style, beginning in the eighth century B.C., shows traces of oriental influence—support for the theory that its builders came from the Near East.

The Populonia graves yielded finds of great historical and documentary interest: in the earliest tombs there were glass necklaces, bronze rings and bracelets, fine specimens of bronze oil lamps and

BRONZE HELMET AND LAMP are typical of the well-made metal artifacts that have been found in Etruscan tombs. Oil lamps of this design still light some homes in rural Italy.

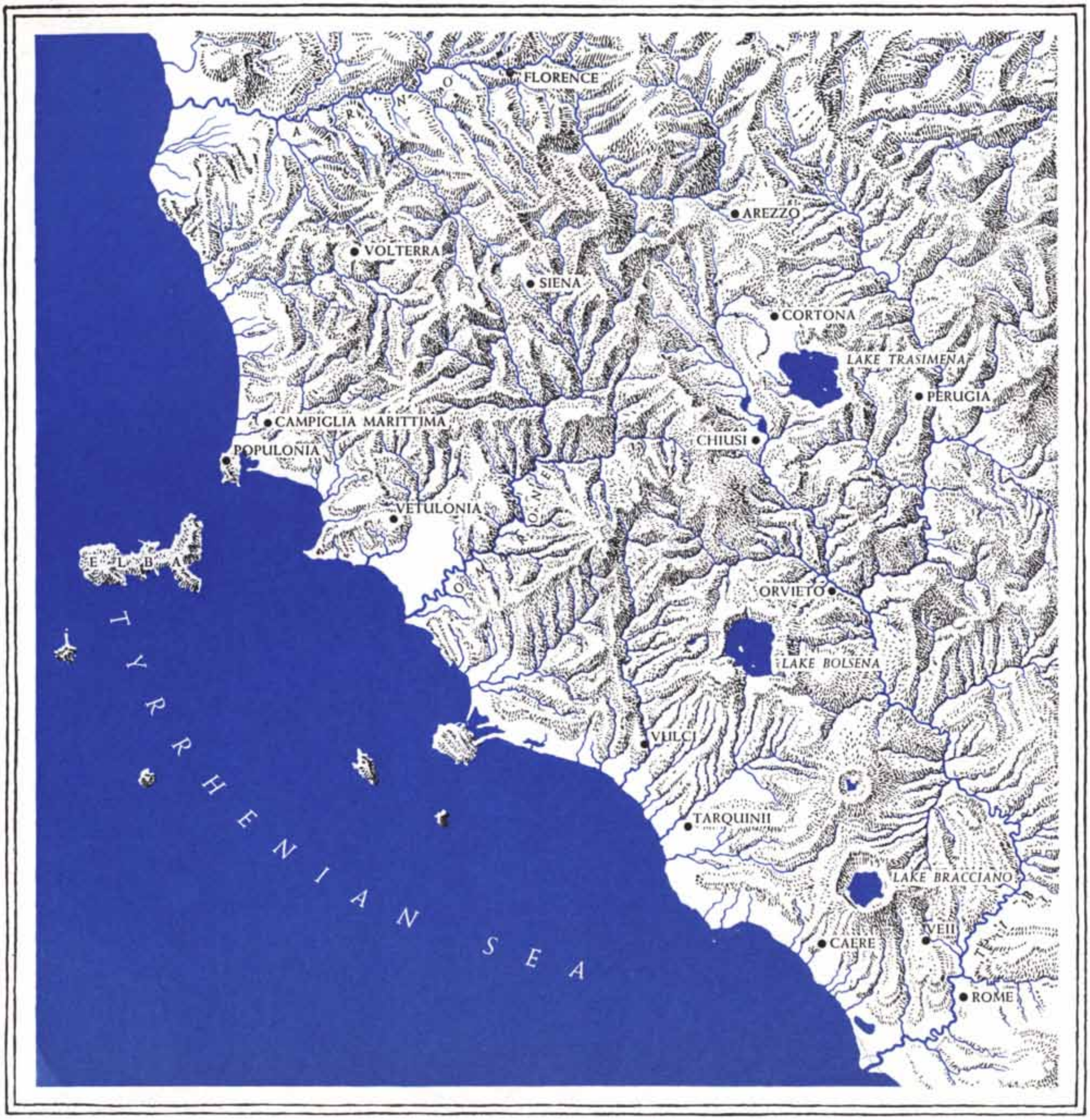
many other significant objects; the later graves contained coins, mirrors, ivories, helmets, beautifully decorated vases, gold and silver ornaments laced with the finest filigree, large bronze ritual fans, parts of chariots and an exquisitely wrought statuette of Ajax in the act of killing himself.

But among all the excavations at Populonia none was more exciting than the uncovering of its principal industry—metallurgy. The hillocks at the site of the ancient city, now covered with grass, wheat and olive groves, proved to be huge heaps of slag from the Etruscans' forges and furnaces. Three striking evidences of the importance of this industry have been uncovered at Populonia: first, a furnace area which spreads over nearly 45 acres and contains masses of slag totaling upward of two million tons; second, great heaps of ore at the Populonia harbor, where they were unloaded from ships; and third, a smelting and refining area beneath the castle, or citadel, of the ancient city.

Populonia was clearly the industrial center and most important commercial town of the Etruscans. Indeed, the city was renowned in antiquity; it is mentioned in the writings of both Greek and Roman historians. The heavily fortified town (its citadel walls were built of enormous stones) guarded a rich region of minerals, which were the source of the Etruscans' prosperity. Six miles offshore from the city lies the island of Elba, with a fabulous wealth of iron ore. Behind the town is a hinterland of mountains with a profusion of minerals which have been known and mined since prehistoric times. It abounds in iron, copper, tin, lead and silver ores—colorful minerals bearing romantic names such as cinnabar, ocher, ironstone, galena, blende, ilviate, tourmaline and cassiterite.

The Etruscan prospectors appear to have been endowed with exceptional, not to say supernatural, gifts for discovering minerals. Without any of the technical aids now at our disposal, they managed to stake out most of the principal riches in the undersoil of central Italy. They mined copper and iron on Elba, and tin, copper, lead, iron and silver in other parts of Etruria. By digging small test pits they traced the bounds of the underground veins and then excavated shafts to take the ore. These underground caves also served a religious purpose, affording a means for a devout approach to the Etruscans' underground deities.

The mines were worked by gangs of slaves, convicts and prisoners of war,

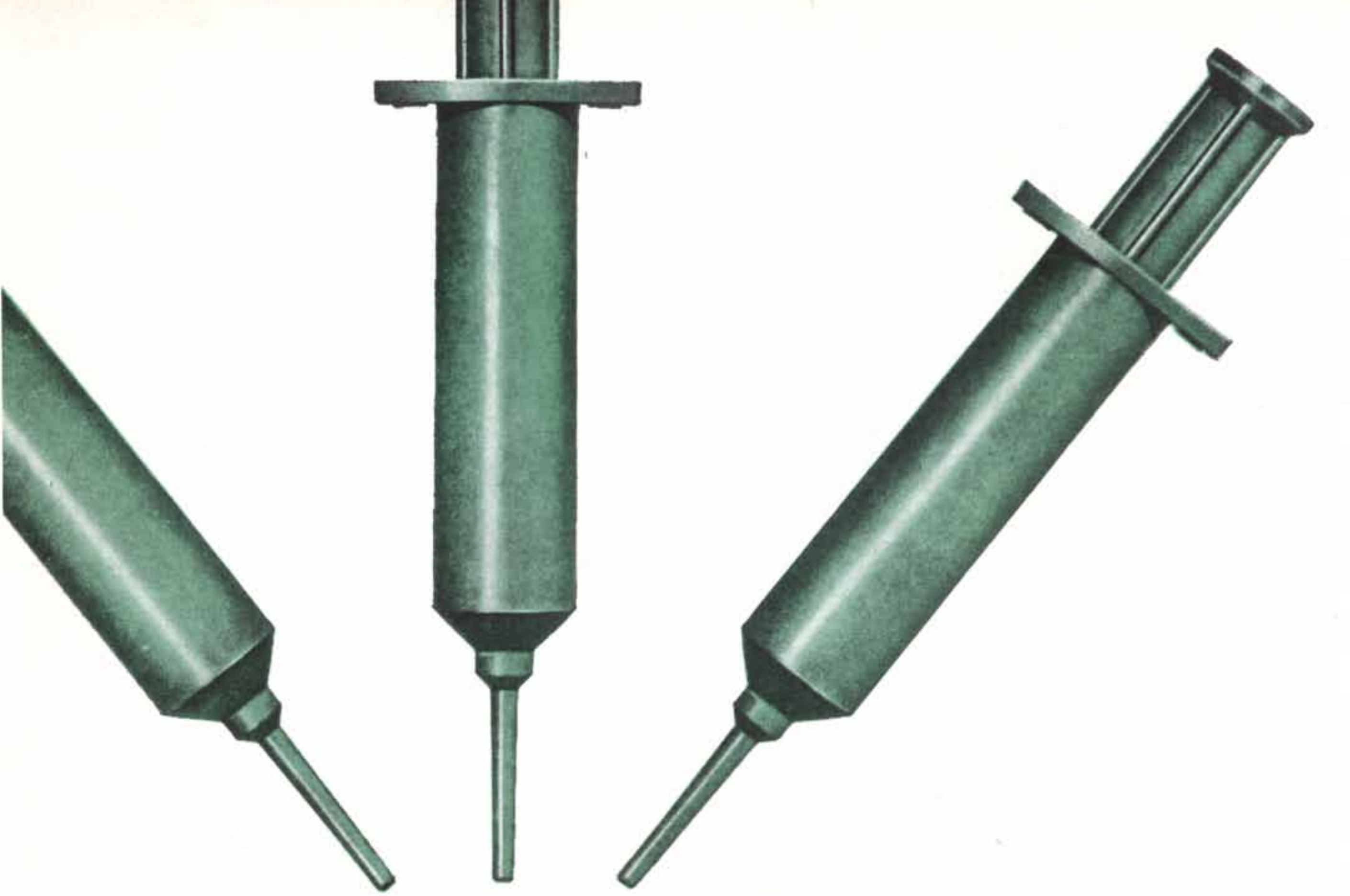


ANCIENT ETRURIA was based on the area between the Tiber and the Arno. Towns no longer inhabited are labeled with their historic names. At the height of their power the Etruscans colonized the Po Valley and the Adriatic shore and dominated the Tyrrhenian Sea.

who quarried the ore with crude tools and carried it out in leather or wicker panniers on their backs. The earliest miners used tools of wood and flint, and the mines were shallow, open pits. After iron implements were developed, the Etruscans dug the pits much deeper and reinforced them with stone props and pillars. The still later mines of Roman times had air shafts and a network of intercommunicating galleries.

The furnaces for treatment of the ores were built as near as possible to the mines themselves. A few of the ancient furnaces have been found in fairly good condition in the Val Fucinaia (Valley of the Forges), not far from Populonia. Completely covered with earth except for a front opening, the furnaces were built of sandstone, with a clay plaster over the interior and in all joints. They were conically shaped, about six feet across at the base and five and two thirds feet at the top. A horizontal partition made of small blocks of quartz porphyry divided the furnace into two chambers, with holes cut in the partition. The upper chamber was filled with ore, and the fuel—usually charcoal—was burned in the lower one.

The Val Fucinaia furnaces were evidently used for roasting copper ore; the slag piles near them contain a good deal of copper mineral. Roasting separated the copper from sulfur and from iron and other metals that were mixed in the minerals. Elsewhere in Etruria iron was extracted in much the same way. The iron ore was first roasted in the upper chamber to free it of sulfur and water; then the treated ore was laid in alternate layers with charcoal and smelted to pro-



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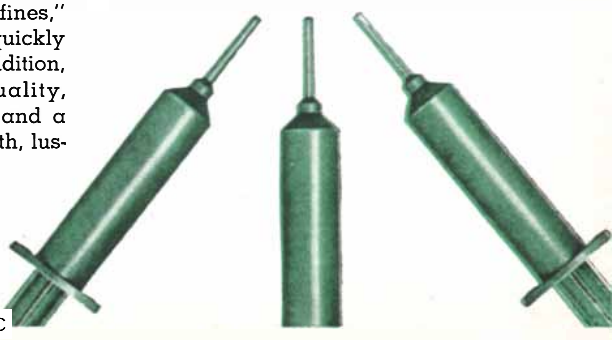

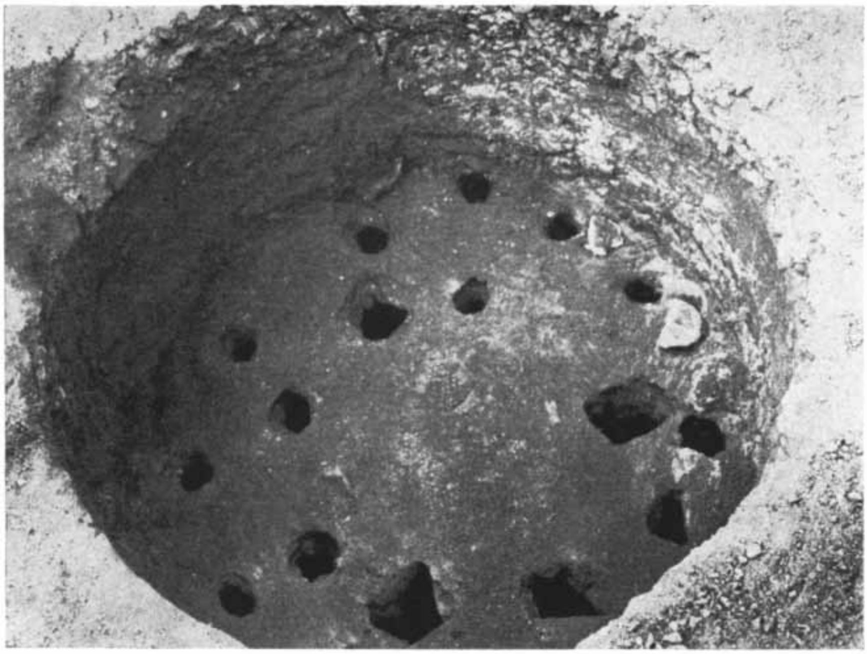

CONICAL FURNACE unearthed in the Valley of Forges is almost six feet in diameter. The perforated partition supported the ore, which was roasted by charcoal in a lower chamber.

duce a spongy iron. The sponge iron was either forged into tools and implements or molded into pig iron for export.

The Etruscans exported iron to all the countries of the ancient Mediterranean world, and particularly to Greece, whose terrain has always been poor in metals. This trade accounts for the outstanding importance of Populonia in the Etruscans' industry. The city not only had an excellent natural port but was also surrounded with supplies of minerals and of stone and clay for its furnaces. Moreover, thick forests nearby furnished an abundance of fuel. Thus Populonia was ideally placed to be a great center of industry and commerce in the ancient world. From this capital the Etruscans made treaties with other Mediterranean countries, established maritime laws and spread abroad to other lands their culture, art and mastery of metalcraft.

The Etruscans' skill in working metals was unsurpassed in the ancient world, and in some respects it is unequaled even today. They made marvelous ornaments of precious metals, with the finest embossing and filigree. But even more remarkable was their production of bronze, the secret of which has never been rediscovered. The Etruscan bronze was so beautiful and so perfectly fused that a research center has been established in Florence to investigate what can be learned from the Etruscans' metallurgy. Their bronze was created not by science but by artistic genius.

Bronze today is manufactured according to precise formulas. The Etruscans made theirs by some empirical method. Their metals were highly impure, but they evidently knew how to turn these very impurities to advantage. By a series of smeltings, in which they solved the problems at each stage in intuitive fashion, they produced an alloy of matchless beauty and resistance. Their method of fusing bronze enabled them to run the molten metal into molds in extremely thin layers, so that the minutest details have a perfect finish. Even after iron came into general use, the Etruscans continued to employ bronze, sometimes using both metals together: some of their objects had a decorative design in iron inlaid in bronze.

When the Romans conquered Etruria and absorbed the Etruscan civilization, its mining and metal industries swiftly declined. The Roman conquerors found more attractive mineral riches in Gaul, Britain, Spain and Sardinia. And after the fall of the Roman Empire, Etruria like the rest of Italy was overrun by barbaric tribes who obliterated the last traces of its industry.

Today, after centuries of oblivion, the ancient metallurgical industry of central Italy has been revived. The archaeologists' discovery opened an unexpected bonanza for economic exploitation. The slag heaps of the Etruscans contain a great deal of rich and usable mineral. Since their wood fuel could not heat the ore above about 800 degrees centigrade,

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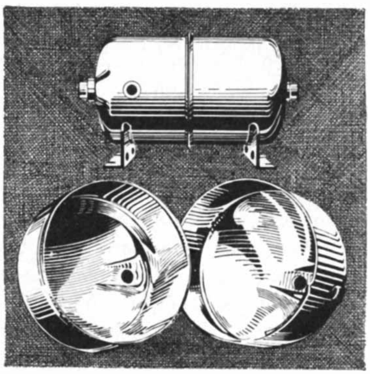
Last year a famous manufacturer of domestic refrigerators decided that an automatic juice dispenser would be a desirable feature for special models of its 1955 line. It was known that in many homes two kinds of concentrate are regularly stocked in the refrigerator. One is orange, the other may be lemon, lime, or some other juice. Two containers for concentrate were therefore required, size one pint each, plus a two-quart water tank, with appropriate connections with the household water system, and a metering mixing valve. Thus it would be possible for the housewife, or her children, to push a button or otherwise operate the valve, and obtain juice properly mixed with the correct amount of chilled water.



As is always the case with any good new idea, reducing it to practicality required a lot of hard work. The mixing valve was readily obtainable from a valve specialist. Unexpectedly, difficulties arose in connection with the water tank. This is made of red brass, 85/15. Two almost identical one-quart cups are drawn from soft strip, the seam brazed, the necessary water connections brazed in, and the outside tinned.

This would seem to be a simple operation, but Revere was told that there was too much breaking and tearing of the brass in drawing. Although at that time we were not supplying the brass, we were glad to work with the firm which had the tank contract. The Revere Research Department reported that the grain size of the unsatisfactory metal varied between .035 and .050 mm., and that holding the size closely to .050 mm. would cure the difficulty. In addition, suggestions were made as to die design, and die lubricants. Revere also was asked the reason for defects in brazing. This became another project for Revere Research, which sent a man to the plant to study the methods used. After some special work in the laboratory at Rome, N. Y., it was found possible to make a successful adjustment of conventional brazing methods to the ones the fabricator wished to use. Still further, Revere's Methods Department recommended changes in the beading operation, ending breaking there. A Call Report written at the end of all this work states that the customer "is very enthusiastic in his praise."

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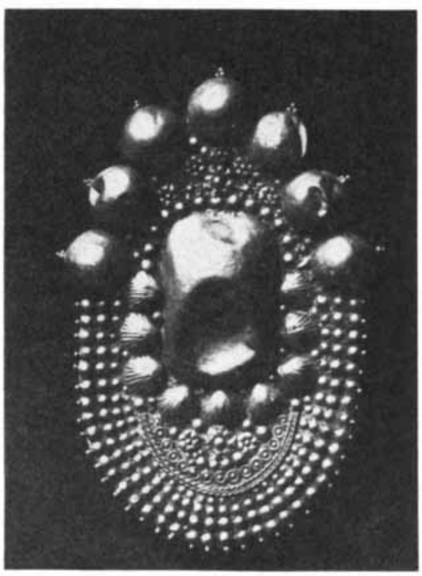
and since their furnaces were short-lived, the Etruscans were able to extract only a small fraction of the metals in their ores. The iron slag (easily separated from the soil deposits by electromagnetic means) contains up to 60 per cent iron, and the copper refuse is similarly rich in copper carbonate. Modern industry has found it worth while to salvage the ancient mounds of slag and establish metal foundries at the very sites where the Etruscans developed man's first great metallurgical industry 2,500 years ago.

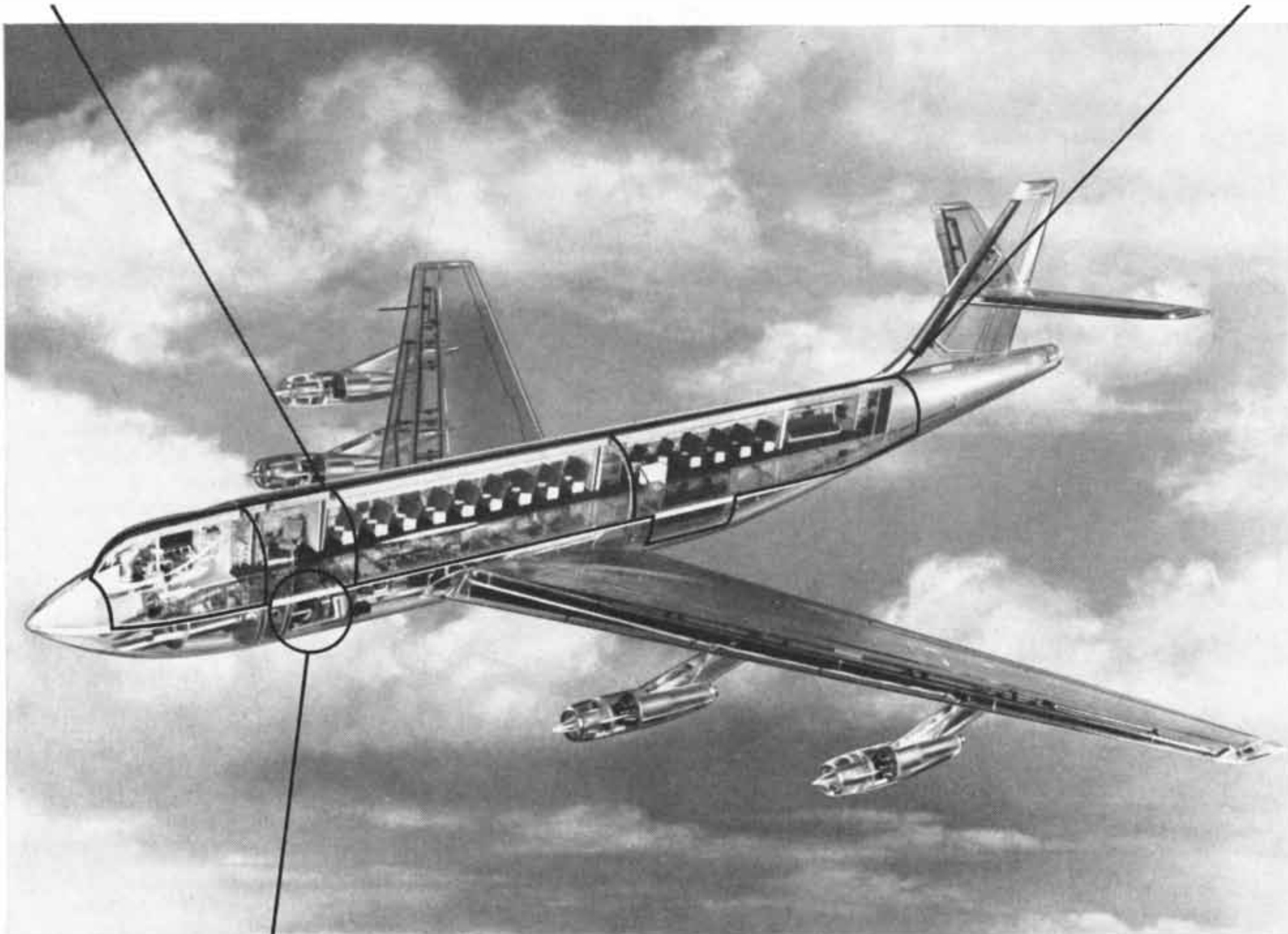
An amusing sidelight on this revival was an ownership dispute fought through the law courts. The landowners around Populonia maintained that the slag was part of the real estate. The concerns who wished to use the slag contended that it was a buried treasure, and as such movable property. The courts upheld the second contention, but they also ruled that according to Italian law all "mineral underground treasure" belongs to the state. Thus the mineral wealth of Populonia is now owned by the Italian government, which leases it to private concerns for exploitation.

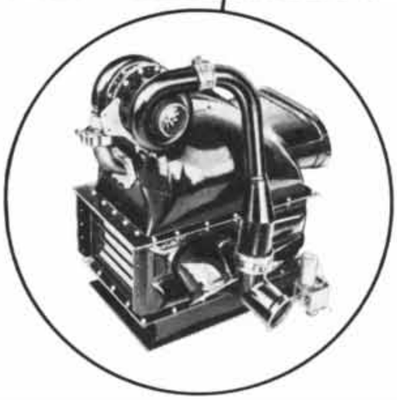
The chimney stacks of modern blast furnaces now rise at the same site where the ancient Etruscans wrought their craft, and modern machines drill for iron ore in the very same mines on Elba where the Etruscans once sank their pits. The long-desolate land is once again a center of industry. And side by side with the steam shovels digging into the ancient piles of slag, archaeologists also are excavating for more knowledge of the brilliant Etruscan civilization.



PERSONAL ORNAMENT is an example of detail executed in metal by the Etruscans.

Cabin air conditioning





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TOO MANY DEER

A biologist demonstrates that the number of deer is regulated not by predators, including man, but by their food supply. The moral: More hunting would result in healthier deer and less damage to crops

by A. Starker Leopold

The shy deer, drifting through forest shadows and bounding over brushy hills, is blissfully ignorant of the fact that for decades it has been a subject of fierce polemics. The point of contention has been: Should the deer population be curbed or be helped to multiply? Nature lovers want more deer to look at and hunters want more of them to shoot. On the other hand, gardeners, ranchers and foresters would like to see fewer of them because they eat up too much vegetation. Government conservationists have had a difficult time trying to find a formula which would satisfy these conflicting interests.

After much research in the field, biologists are coming to the regretful conclusion that in many parts of the U. S. we have too many deer. The charming animals have a tendency to outgrow their food supply and sink into a gaunt, enfeebled existence. The ecological evidence strongly suggests that it would be best for all concerned, including the deer population itself, if many more deer were shot.

Studies of the population dynamics of deer disclose some paradoxes. Most people probably associate deer with the

THREE WHITE-TAILED DEER lie dead of starvation in Pennsylvania's McKean County. That malnutrition, rather than disease, is the cause of death in deer is often determined by examining the condition of the marrow in the femur, the upper bone of the leg.

MULE DEER DOE was photographed in Yosemite National Park as it reached upward for twigs of chokecherry. The sprouts on the lower branches of the tree had already been eaten.

forest primeval, but actually they do best in lands that have been cleared and settled by man. Unlike other wild ungulates such as the bison, the caribou and the mountain goat, which tend to disappear as man disturbs their natural ranges, deer thrive on new or secondary vegetation. Their favorite foods are shrubs and young trees. In the western mountains, for example, the ranges that support the most deer are cut or burned timberlands which have grown up to wild lilac shrubs and mountain mahogany, scrub oak, willow and aspen trees. Similarly in the eastern U. S. deer favor the second-growth lands where palatable young trees grow in place of the original forest. This kind of vegetation is called "subclimax." A climax (mature) forest generally supports few deer.

It follows that a given range changes in deer-carrying capacity. After a forest has been logged or burned, the new young growth may support a large deer

YEARLING MULE DEER DOE, also photographed in Yosemite, had survived winter in poor shape. It nibbles manzanita, a food which is eaten only when better forage is gone.

population for a time. But as the canopy of trees closes over again, reducing the supply of shrubs and other young vegetation, the deer dwindle in numbers. By periodic logging or burning, we can produce the conditions that will maintain a high deer population. However, the deer themselves may create a Malthusian scarcity. Protected populations of deer often consume the food supply of their range long before it would have disappeared naturally.

Food is the all-important regulator of their numbers. Curiously, the presence of wild animals that prey on deer seems to have comparatively little effect on the size of their population. In parts of Mexico where lions and wolves are still numerous, the size of deer herds still seems to be a function of the deer's food supply. Poor ranges support few deer; good ranges support many deer, predators notwithstanding.

In recent years biologists have studied in considerable detail how food regulates deer numbers. They have learned a great deal about the ways in which nutrition influences the deer's birth and death rates.

A female deer in perfect health is capable of producing one offspring in her first breeding season and a litter of two each year thereafter. But because of seasonal shortages of the most nutritious foods, few herds in the wild approach this potential rate of increase. Studies in New York State of the white-tailed deer, which may ovulate and breed during the first year after birth, showed that only 20 to 40 per cent of the female fawns on the best wild ranges actually became pregnant. On poor ranges practically no fawns bred. Similar studies of the western mule deer, which can bear its first offspring when it is two years old, showed that on poor ranges or under crowded conditions most females do not bear young until they are at least three years old.

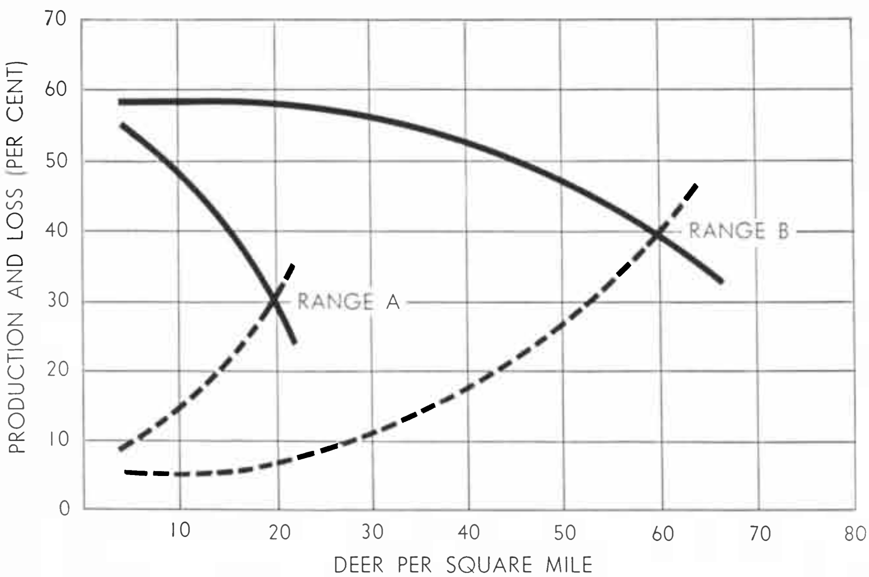
Thus poor diet clearly delays the age at which deer reach sexual maturity. It also reduces the number of young a doe may bear after she starts breeding. On a good range twins are common, and the average pregnancy rate may be 160 to 175 fetuses per 100 does. In contrast, on poor ranges the females rarely bear more than a single offspring. The pregnancy rate may be as low as 80 fetuses per 100 adult females. Moreover, many of these apparently are lost at birth or shortly afterward, for it is frequently observed that the number of fawns following their mothers in early summer is considerably below the number of pregnancies count-

GOOD DEER FORAGE often grows in forest areas that have been burned over. Here wild cherry and white thorn grow on the site of the Wright's Creek burn of 1952 in California.

ed in the same herd a few months earlier. Presumably poor nutrition of the breeding females, resulting in failure of the pregnancy or the birth of weak fawns, is responsible for these losses.

In short, shortages of nutritious food strike hard at the ability of deer to reproduce. In some cases this can be related directly to the amount of competition among the deer for the available food. For example, when a large part of a herd is killed off by hunters or by winter conditions, the productivity of the remaining females increases considerably, sometimes twofold, the following season.

As diet is the basic regulator of the deer's rate of reproduction, so also it controls their chances of survival. In cold climates winter is the critical season. A well-fed herd can easily endure cold and snow. But if food becomes scarce or poor in quality, the deer's vulnerability rises sharply. In the colder areas of North America hundreds of thousands of deer die during an average winter, and probably millions during a severe one. The herd usually eats up all the nutritious forage early in the winter and then has to subsist on second-choice foods of low digestibility. Most of those



TWO HYPOTHETICAL DEER RANGES yield these curves of production (*solid lines*) and mortality (*broken lines*). On the poor range (A) a dynamic balance is reached at a level of 20 deer per square mile, with an annual turnover of 30 per cent (30 deer per 100). On the good range (B) the density is 60 deer per square mile and the turnover 40 per cent.

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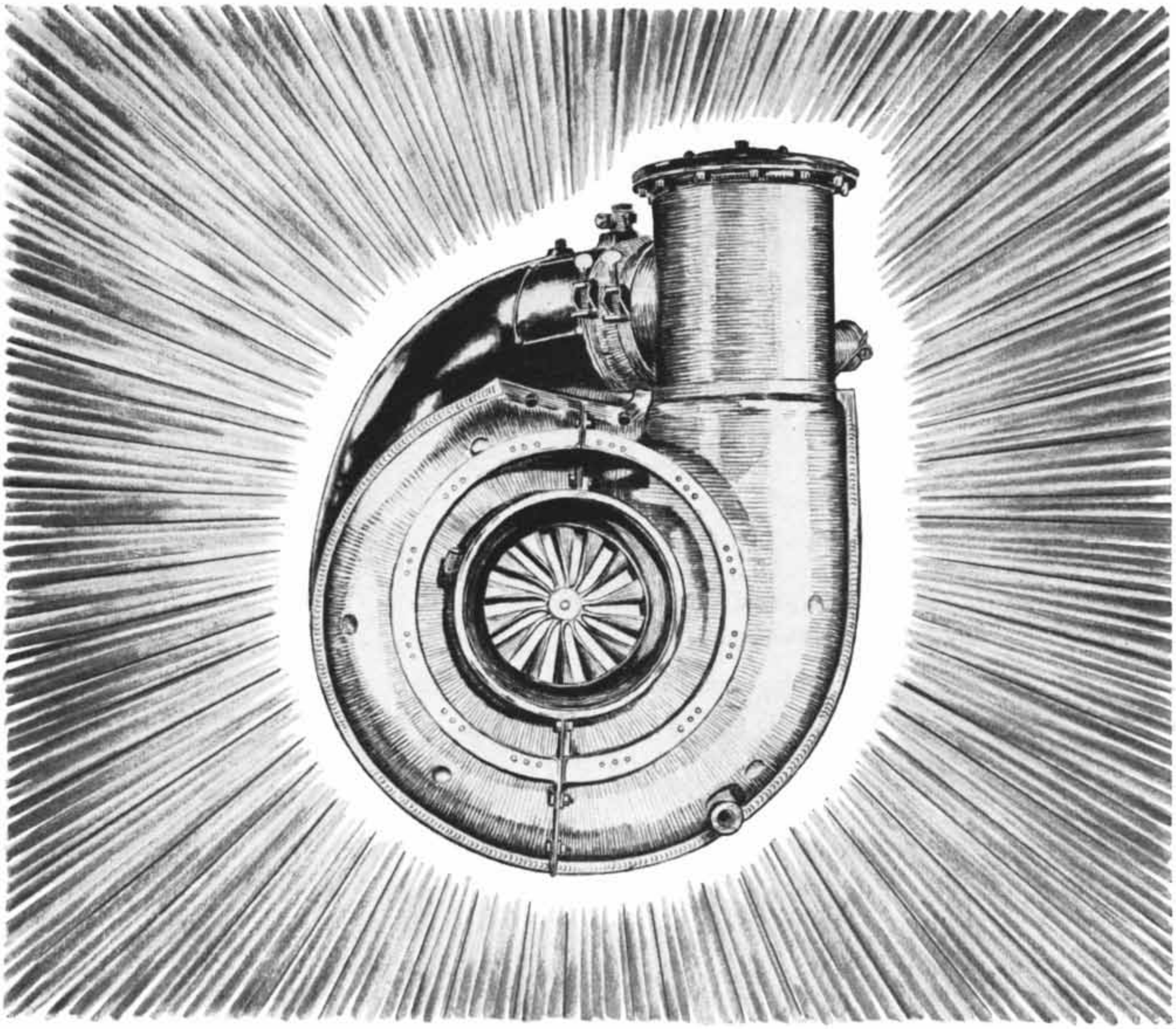

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TWO MULE DEER FAWNS were photographed with a doe in Yosemite National

that perish die directly of starvation. But the weakened deer also become prey to other causes of death. Even in a warm climate undernourished deer die on an epidemic scale—from parasites and diseases if not from starvation.

One way or another, the herd is balanced to its food supply. For example, in a certain range of natural chaparral growth on the coast of California, the deer population averages about 20 animals per square mile. It has been found that a range in the same region where the year-round food supply has been improved by controlled burning and seeding of grasses can support three times as large a population—an average of about 60 deer per square mile. However, the better range, paradoxically, has a higher death rate. This fact is not so mysterious if we remember that in a stable population deaths must balance births. The better range is stabilized at a higher density, but since more deer are born, more must die to keep the herd at the limit imposed by the supply of food. Thus on the poorer range the annual turnover rate (the number of deaths replaced by births) is about 30 per 100, while on the better range it is 40 per cent or more.

If we convert these statistics into a life-expectancy table, it becomes clear that the better the range and the higher the population, the shorter will be the

Park. Poorly fed deer tend to produce one fawn per gestation; well-fed deer, twins.

average life span of the individual deer. This paradox has implications which go beyond the competition for food. Apparently density *per se* has adverse effects upon a population. And indeed close studies not only of deer but also of elk and of laboratory rats have indicated that high population density produces considerable bickering which may cause nervous strain and physical weakening.

A good deal of study has been given to the dietary requirements of deer. It has been demonstrated that they need foods rich in protein and probably also in easily digestible carbohydrates. Like other ruminants, deer can convert woody material to food by breaking down cellulose to digestible compounds with the help of bacteria in their stomachs. But they seem to need sugar in their food to catalyze this bacterial action, and they require minerals and vitamins as well. The intensive chemical and physiological studies of deer diet should soon enable biologists to tell precisely what kind of browse is best for the animals.

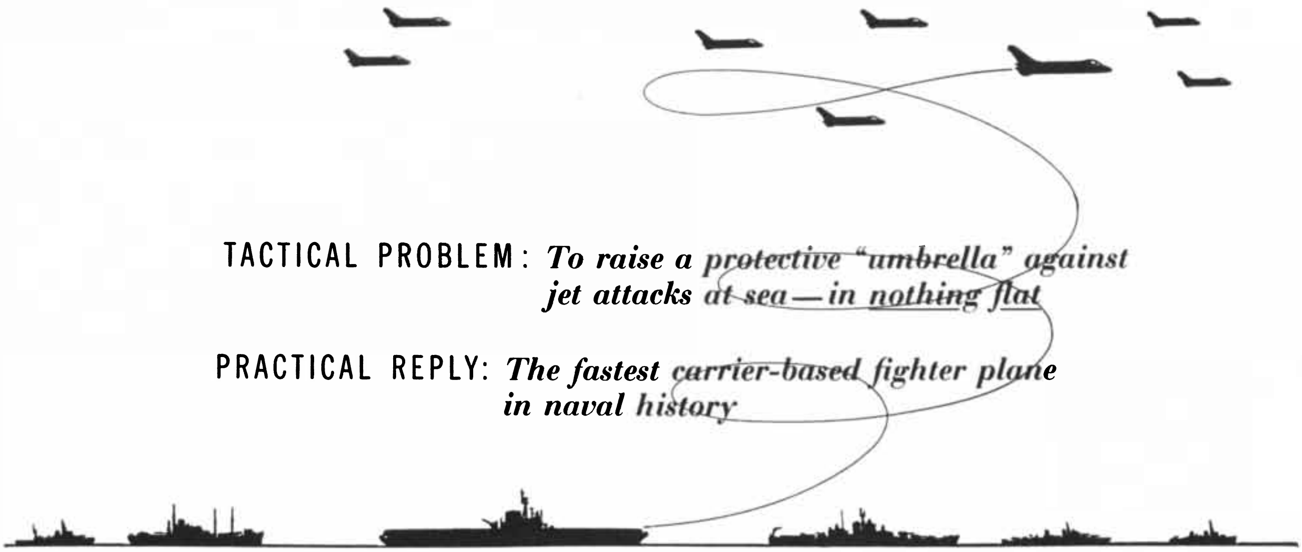
Yet it is obvious that the amount of good forage any range can produce is limited, and therefore the number of deer it will support cannot be increased beyond a certain maximum no matter how solicitously they are protected. Indeed, too much protection may allow them to overrun their food supply and thus actually reduce their numbers in the end. The best thing we can do for the deer is to permit a great deal more hunting. It would eliminate the excess of population each year and leave the remaining deer in a healthier and more thriving condition.

One serious present obstacle to such control is the "buck law," which prohibits the shooting of any deer but full-grown bucks. This measure, though not popular when first adopted, has come to be accepted as part of the sportsman's code. The buck-hunting tradition practically limits the maximum hunters' kill of any herd to about 4 to 9 per cent of the population. Yet a dense deer population could withstand a kill of at least 40 per cent per year, for this is no more than its natural turnover rate. It might be desirable to shoot an even higher proportion, in order to reduce the population density. Such a principle of limitation is applied by every livestock rancher who is managing his stock for the maximum yield of healthy animals.

To take 40 per cent of a deer herd each year would require shooting does and fawns as well as bucks. Consequently game biologists have been trying to convince state game commissions, legislatures and the interested public that the hunting of does and young deer would be in the interests of the deer as well as of the hunters. Considerable progress in this direction has been made: most deer states are now relaxing their rigid protective laws.

A second step in better management of the deer population should be to maintain their ranges in a condition of maximum productivity, consistent with other uses of the land. Forage conditions for the deer can be improved with only slight modifications in forestry practices and in cattle grazing. One of the effective measures is controlled burning of areas in some types of otherwise unproductive forests. The paramount need is to provide the deer with better food. A dollar spent on improving their food supply will often yield far more returns than the same dollar invested in some other form of protection.

As a result of biological research, deer management is evolving rapidly from a legal and quasi-political undertaking to an applied science, comparable to modern forestry or livestock management. A few decades hence the deer kill by hunters should be several times greater than it is today. The controlled and well-fed deer herds will then do much less damage to ranges and crops, and there will still be plenty of deer for the nonhunting public to see.



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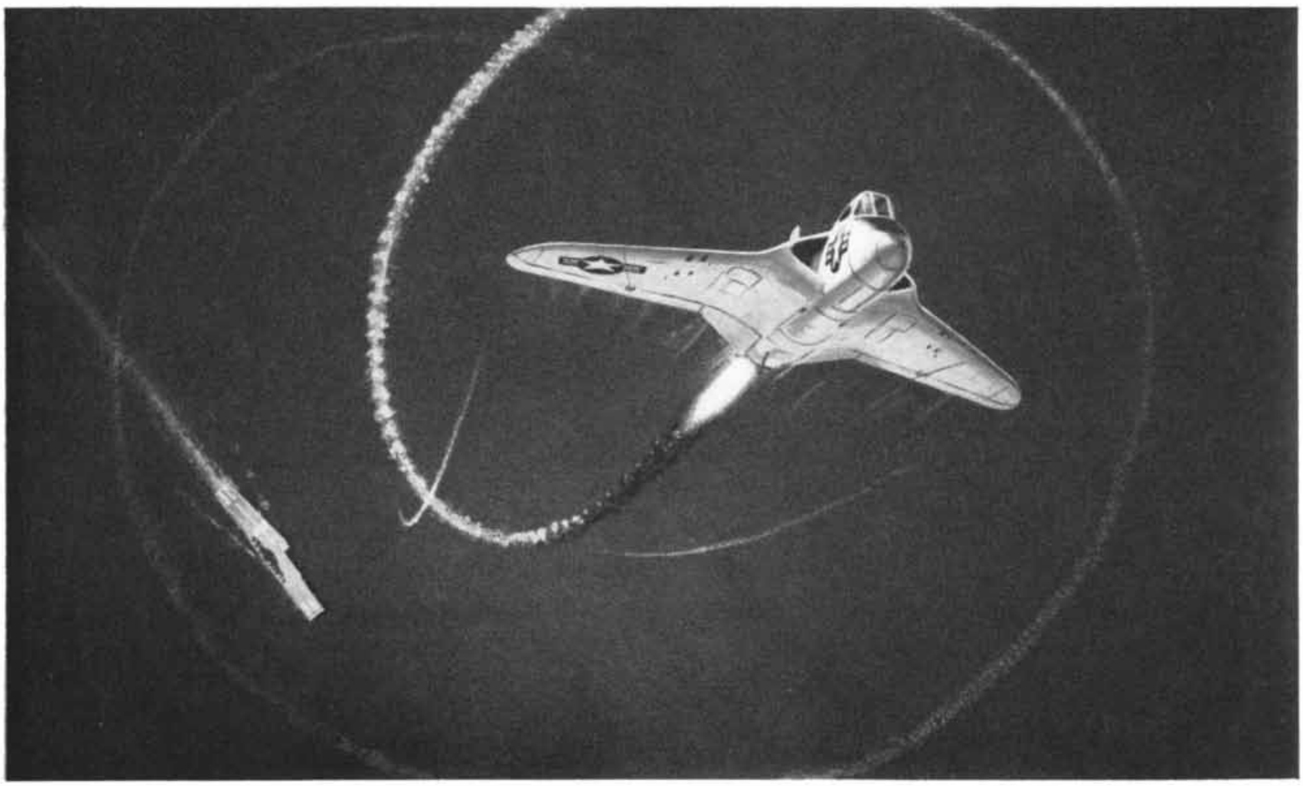

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BOOKS

A physicist's speculations about the evolution of technology during the next hundred years

by James R. Newman

The Foreseeable Future, by Sir George Thomson. Cambridge University Press ($2.50).

How foreseeable is the future? Sir Charles Galton Darwin once took a long look ahead: in a book reviewed here in 1952 he leaped over no less than a million years. Now another eminent British physicist, Sir George Thomson, making a shorter jump, peers into the middle of the next century. On Sir Charles' scale this is a modest prophecy, but it is not necessarily easier to make. In 10,000 centuries averages assert themselves and entropy does its dreary work. Darwin could count on the fact that even the best machines run down. A million years from now the earth, because of the voracious habits of its occupants, will be poorer and shabbier. Its resources will be depleted. Men may be wiser but not happier; plankton is no diet for joy. Maybe they will have to quit this planet for another.

Sir George's picture of 2050 is less doleful. He is chiefly concerned with the future of technology; in this direction, he says, predictions are possible. The scientific revolution has been churning for more than three centuries, during which enormous advances have been made in man's control over his environment. The rate of progress still seems to be accelerating. It is natural to ask how long this pace can continue. To be sure, a catastrophe may intervene—a man-made holocaust which would leave the future to rats or insects. We shall assume, however, that this will not happen: that either there will be no more big wars or the zeal for self-extermination will flag, once a war is on, before we are all dead. On this assumption we can look forward to continued material improvement. We cannot say exactly where science and technology will carry us in a hundred years, but something of the future of machines is discernible in outline. The trend of social circumstance is more shadowy. "Sociology," says Thomson, "has still to find its Newton, let alone its Planck, and prediction is guesswork." Still, it is hard to resist the temptation to speculate on people's responses to technical progress, and this book has something to say about the society of the 21st century as well as the machines.

Science limits technology at the same time it feeds it. This fact is not widely understood. We expect too much of mechanical ingenuity. Technology has been so successful that men are apt to suppose that everything can be solved, answered, cured, that there are no limits. We have a light in the refrigerator, therefore we will fly to the moon; our theaters are air conditioned, therefore we can change the world's climate. Let us grant that inventors are fertile and may make us immortal. But there are things they cannot do, things prohibited by the nature of nature as we understand it.

Sir Edmund Whittaker, I believe, coined the phrase "principles of impotence" to describe the scientific rules of what cannot be done. Since these are Thomson's guidelines, they are worth listing. Perhaps the most familiar is Einstein's principle "that no material object and no signal can go faster than the velocity of light." This should not unduly distress either aeronauts or astronauts; nevertheless it sets bounds. The conservation of mass-energy is another limiting principle. Of course the fact that this principle is a combination of two others, conservation of mass and conservation of energy, which 50 years ago were thought to be distinct and immutable, is disquieting and suggests that there are no permanent principles of impotence. But we shall have to do with the science we have, at least until another Einstein appears. Sir George covers his tracks by saying that while it would be rash to suppose the principles will remain for all time, it would be "still more rash to suppose that they can be modified in any particular way."

That one cannot make an electric charge or a magnetic pole "without making an equal one of opposite sign somewhere else," that a particle of atomic size cannot be pinned down exactly both as to velocity and position, that no two electrons can be close to each other both in position and in velocity (Pauli's "exclusion principle")—these represent four more principles to be added to the list. Finally there is the second law of thermodynamics, which says that "order always tends to disappear till complete chaos is reached."

The foreseeable future of science and of its offspring technology is thus bounded by the principles of impotence. Moreover it is reasonable to suppose that other such principles may be discovered, valid not only in physics and chemistry but in biology also. As Sir George points out: "Animals and plants have to be able to reproduce and grow as individuals from a relatively very small seed or egg, which yet contains the pattern of the whole. There must be limitations introduced here. Not every arrangement of bones and nerves and muscles, even though it might make a viable animal, could, one would suppose, grow from an egg—still less be developed by evolution. Perhaps this is why nature never has produced a workable wheel or even a 'caterpillar' track."

Besides principles of impotence, there are other fundamentals which must be taken into account. These define the scope of technology as a whole just as an individual craftsman's materials and tools define what he can do. There is not an infinite number of different materials in nature, nor of forms, nor of building blocks. The marvelous profusion of the world is achieved with comparatively simple means. The universe is formed from less than 100 different kinds of atoms (which themselves are made of only a few basic constituents). A peach tree differs from a grain of sand which in turn differs from a star; yet at bottom the three are alike and differ only as do mosaics. The fixed properties of the fundamental atomic particles impose limitations not only upon the particles themselves but upon the larger bodies built of them. Man, for example, cannot grow beyond a certain size without altering shape. Beyond a critical point his bones will not support him; if he were as big as the moon he would have to be spherical, because "no material could make a neck capable of supporting such a head without being crushed." One thing is in man's favor in seeking to control nature. While it is true that he is "despicably weak" compared with elemental forces, the disposition of energy frequently enables him to take advantage of what are called "trigger" actions, "where a small cause produces a disproportionate effect." A boulder perched on a ledge may be pushed off easily and produce an avalanche. A handful of silver iodide may produce rainfall over a big area. There is a large class of such "metastable" systems, organic and inorganic, requiring only a small key to unlock their energy. The right key is, of course, not always easy to find, nor are the consequences always easy to reckon. "A very high degree of understanding," Thomson warns, "is needed by those who would interfere with nature in this way."

Having set forth briefly some of the limitations on technology and having told us what will not happen in the next century, Sir George undertakes to predict what can be expected. He discusses the future of energy and power, of materials, of transport and communications, of meteorology, of food, of applied biology, of social studies, of mechanical devices for solving problems far more complex than any we are able to tackle at present. What he offers is a brilliantly succinct review of the main questions of contemporary science and technology, together with clues and conjectures as to how they will be answered.

Many books and articles have appeared in recent years on future needs and sources of power. Until nuclear energy was discovered, the outlook was bleak. Even now there are experts who are skeptical about atomic power. Sir George puts matters into perspective and resolves many doubts. He makes several things clear: first, that supplies of fossil fuels, coal in particular, are still very large; second, that we are so wasteful and incompetent in generating power that some of our processes might properly be regarded as no better than "burning the house down to roast the pig"; third, that the potentialities of solar energy and of combustible materials raised in agriculture (such as peat) require much more serious consideration than has been given them; fourth, and most important, that electricity derived from nuclear reactions, both fission and fusion, will be available in almost any quantities that we want for a very long time. This is not to say nuclear power will necessarily be cheap. Technical improvements will bring costs down, but large-scale projects will still be expensive in terms of capital investment, depreciation and the like. Efficiency will therefore be at a premium.

Shipping will "go nuclear" about the time that natural oil gives out. The internal combustion engine is already an anachronism and only waits upon the invention of a satisfactory electrical accumulator to become wholly obsolete. The heat pump, says Sir George, is a device of much promise, especially for the heating of homes. It is "really a refrigerator in which instead of creating cold inside the refrigerator by taking the heat away and then discarding the heat, you have the refrigerator out of doors and introduce the heat into the house." With cheap electricity as the power source it is "the obvious way" of keeping houses warm.

In sum, whatever shortages may arise during the next century, power will not be among them. This is less obviously true of materials. Our civilization would be quite different if it were deprived of the new materials introduced in the last 50 years: light metals, plastics, steel alloys. Thus far we have been fortunate in finding great concentrations of valuable metals, but even the richest lodes are not inexhaustible, and it will soon be necessary to search for and exploit the leaner deposits. This demands improved methods of prospecting, of mining at great depths where it is very hot and of handling "enormous masses of material in order to extract very little." Sir George suggests the possibility of deep mining by techniques like those in oil drilling. Under the crust of the earth lies molten magma, a pasty primordial mixture of minerals or organic matter. No one knows the extent of such veins of liquid, but if they could be located it is conceivable they could be tapped and brought to the surface.

A more promising source of minerals, perhaps, is the "fluid ore" composing the ocean. Concentrations are very low, but quantities are immense and the fluid ore is easily handled. Certain sea animals extract from the water metals forming an essential constituent of their blood. There are fish that are able to concentrate copper and vanadium, which occur in sea water only to the extent of about two parts in 10,000 million. It may be possible, Sir George believes, to breed plants or other organisms which will perform for us the first stage of extraction; then we can take over with our clumsier methods.

Much can be done to increase the strength of materials. Metals, for example, fail by slippage of one layer over another due to "dislocations"—faults within the crystal structure [see "Dislocations in Metals," by Frank B. Cuff, Jr., and L. McD. Schetky; SCIENTIFIC AMERICAN, July]. There is no reason to believe, Thomson says, that these elements of weakness cannot ultimately be eliminated.

Once materials can be manufactured with much higher breaking stresses, a drastic change in structures will result. Buildings, airplanes and suspension bridges will be transformed. The buildings of the 21st century "may be a little like the masts and rigging of a sailing ship, with the spaces between the structural members enclosed with a light 'cladding' of which a considerable fraction will be transparent." Sir George predicts that "the world of the future may be expected to look more aetherial, more like fairyland, than the world of the present or of the past."

Communication has come a long way in the last 50 years, and further improvements are foreseeable. The walkie-talkie will undoubtedly proliferate as transistors are improved. Television will be much extended. We can anticipate face-to-face "meetings" of groups of people while each person remains in his own home or office. Business, political and even scientific gatherings could be arranged in this way. Yet one dares to hope that the need and desire for actual human contacts will not have vanished in a century, and it is reassuring to know that for various technical reasons there are limitations upon remote communication and upon the possibilities for invasion of privacy. Perhaps we should recall Thoreau's famous question on learning that Maine and Texas were to be joined by telegraph: "Who knows whether Maine and Texas have anything to communicate?"

How fast will our descendants travel? Faster than now but not so fast as some undoubtedly would like. The famous drag factor bedevils every effort to increase air speed; resistance due to the waves at the bow and the turbulence in the wake cuts into a ship's speed. Crossing of the Atlantic in an hour and a half is foreseeable, and routine train speeds of 100 to 150 miles per hour. While these by no means represent upper limits, it must be recognized that much higher speeds, especially for short distances, are simply not worth while. Increased speed means increased cost; the question is whether it is worth assuming the larger cost when there are end delays (at the start and finish of the journey) which are apt to account for half or more of the total elapsed time. Sir George does not foresee everyone hopping around in helicopters. At best they will not be as easy to operate as automobiles, and air space is not unlimited.

An interesting point arises in connection with ocean travel. A fast-moving ship produces waves which offer high resistance. This resistance increases rapidly and can be overcome only by lengthening the ship or by redesigning it so that it lifts itself out of the water and is partly an airplane. A better alternative is "to copy the fishes." They create practically no waves. With nuclear power available, and with the elimination of surface "excrescences" that produce "skin friction," it should be possible to drive submarines at 70 or 80 knots "with considerably less horsepower per ton than an Atlantic liner of the present day."

Sir George is pleasantly calm in discussing the prospects of space travel. In due time we shall get to the moon. The problems of getting there, landing and returning are difficult but can be overcome. A very pretty idea is the possibility of making a rocket propelled by particles emitted in nuclear fission. Fast electrons escaping from radioactive fission products, while themselves too light to form the material for an efficient rocket jet, might be used to generate an electric field; this, in turn, could be used "to accelerate heavier charged bodies, either atoms or clusters of atoms, which provide the actual material of the jet." The peacefully inclined will be interested to read that Thomson characterizes as "absurd" the idea of the satellite station as an instrument of war. "I cannot see the least prospect of establishing a station that would not be destroyed almost at once by guided missiles from below, which would be far easier to construct than the station itself," says Sir George.

Travel into interstellar space "is not imminent but we may well be nearer to it in time than we are to Peking man." The nearest star, Proxima Centauri, is 4.3 light-years away. If velocities could be attained equal to half that of light, the journey would become feasible. Because of the relativistic contraction of time, the trip would be shorter from the point of view of the travelers than as measured on the earth. Roughly 2.6 years might be saved. This shrinking of time for the participants, observes Sir George, "seems a small prize for all the discomfort and risk" of the voyage.

There is promise at last of doing something about the weather. In fact we may

be able to change it before we can predict it. As one illustration of the horrendous difficulties of forecasting, Sir George estimates that an electronic computer must perform 30 million individual operations to digest the data needed to calculate an hour stage of upper winds over a small section of the Atlantic. Meteorology is not only complex but filled with paradoxes. For example, it appears that an increase in heat radiation from the sun would not make the earth warmer but instead would lead to an ice age. The argument is that the earth's atmosphere is driven by solar radiation, that an increase of the latter would speed up the winds and so lead to more precipitation which, at the poles, would appear as snow.

Weather is "like a pencil balanced on its point." A slight tremor may make it fall; the problem is to get it to fall in the direction you want. One can approach the problem with brute force or delicately. With large amounts of nuclear energy one might attempt to break up the Arctic ice or Greenland barrier and so change the climate over large areas. On the other hand, an atom-thick layer of material laid on the earth would absorb enough solar radiation to affect the weather, perhaps profoundly. To spread such a thin blanket over the whole earth might not be impossible (about a million tons of material would be required). It is far from certain, however, that the results would be desirable. The attempts to produce artificial rainfall by seeding are impressive, but it is still too early, according to Sir George, to be confident of the usefulness of this method. The growing of plants in desert areas, thereby altering the absorption of radiation by the ground, has a high chance of modifying climate for the better. It is important to realize, however, that changes in the vegetation of one area may adversely affect the climate of an adjoining area, so that the method has political implications, international as well as domestic. In the world of today, and even more of tomorrow, nobody's backyard, it appears, is really his own.

There will be enough food to go around for quite a while, says Sir George. Chlorella has possibilities, so have yeasts. He also has much to say on other absorbing topics, such as artificial mutations, domestication of animals (it is suggested that we train monkeys to pick our crops), control of population, and the prevention of old age. (Immortality, in his opinion, is not impossible.)

On the social consequences of another century of technological progress, Thomson's comments are much less interesting than the rest of his book. His views on "the future of the stupid" (he seems to favor a return to "domestic service" for those who cannot master the ways of the bright new world), on education and on the uses of leisure are at worst not very creditable and at best unoriginal. He does, however, make a few shrewd observations that can bear repeating, among them that there is "far less real evidence on the best method [of teaching reading] than there is on the best sort of potato to grow."

The last chapter of the book, in which Sir George speculates on various aspects of the theory of communication, is fascinating. Very little is known about the working of the brain, but in time we shall know more. The big computers will help us, as will developments in electrophysiology, information theory and so on. Already enough is known to make one realize that the small, intricate, fleshy lump in our skulls, "with its ten thousand million working parts and its countless possible interconnections, vastly exceeds anything we are ever likely to be able to make and is [utterly] unlike the unorganized masses we physicists study, which show at best the rather banal wallpaper patterns that crystals display."

Suppose we attain a much deeper understanding of brain processes than at present; suppose we glimpse what is involved in the formation of ideas, habits, prejudices, desires and the like. Philosophers and even plain men have long esteemed self-knowledge as one of the greatest goods. Will they continue to esteem it if it should reveal the origins of altruism, tolerance, kindliness and other human virtues in terms of electrical circuits? Many things that men value may not survive such analysis. It is dangerous enough to understand the secrets of the atom, but suppose we understood, as we understand the operation of an electric washing machine, why we laugh or are patriotic or admire Matisse or embrace religion. How long could these values be maintained once their genesis and nature were expressed as a circuit diagram? Sir George suggests that the possibility of reducing human responses to electromagnetic patterns need not necessarily impoverish life. We may learn new scales of values, learn to appreciate the intrinsic profundity of what seemed to us trivial at the same time we perceive the trivial in what seemed to us profound. "Consider the relation of Jove's thunderbolt to the fluttering of chaff round a piece of rubbed amber; consider how relatively easy we now find the movement of the planets, and

how hard it still is to understand the workings of a worm."

It cannot be said that we are remotely within sight of the relation between brain and what we call mind. That there is a simple one-to-one correlation between states of the brain and of consciousness has been assumed but never proved. Now doubt has been cast on this assumption by research on extrasensory perception, yielding evidence which Sir George regards as uncomfortably impressive. It may be necessary, if the evidence accumulates and stands up, drastically to revise our general scheme of thought. "The importance of the subject," says Sir George, "is enormous and much too little work is being done on it." Clearly the frontiers of the mind lie much beyond us; not only is it possible that we use unsuspected modes of communication but there are plain indications that "we are far from using our full mental potentialities." There is no permanent reason why only a few men should be bright and the rest mediocre, or worse. Why should the calculating wizard or the musical prodigy so often be an idiot in other respects? Is there no way to train special mental powers so that many will be able to do what can now be done only by a few? It is difficult to prophesy how men's brains will be improved, whether by drugs, by "feeding in electrical impulses of the right kind," by new methods of education, by psychiatric stratagems employed in earliest youth, by selected mutations. But it will be done, Sir George believes, and since we have come a long way from being mollusks, in the head as well as in the body, we have proof that it can be done. That the brain which can foresee has a future that is not foreseeable is the greatest of the promises that lie ahead.

Short Reviews

THE LIFE AND WORK OF SIGMUND FREUD: VOL. II, by Ernest Jones. Basic Books, Inc. ($6.75). In this second volume of his definitive biography of Freud (the first volume was reviewed in the November, 1953, SCIENTIFIC AMERICAN), Dr. Jones covers Freud's "years of maturity," from 1901 to 1919. In 1901 Sigmund Freud was in his 45th year, and his greatest creative labor, *The Interpretation of Dreams*, in which he built the foundations of psychoanalysis, lay behind him. The rest of his life he was to devote to elaborating and extending the theories put forward in that work and to applying his concepts of the role of the unconscious and infantile sexuality to the understanding not only of mental disorders but also of other aspects of human life, such as myths, legends, folklore and custom. Freud's exertions on behalf of his science took many forms and required an all but incredible expenditure of energy. During 10 months of the year Freud toiled from 15 to 16 hours a day. He saw his first patient at eight in the morning, his last at eight in the evening. He took time out for meals and for brisk walks, but by 10:30 or 11 he was back at his desk for another two-to-three-hour stint answering correspondence, reading, correcting proofs, working on one of his books or papers. Yet somehow time had to be found for still other essential activities. For years Freud had lived in "splendid isolation," as he described it. But with the turn of the century, as his reputation spread, as he gained adherents and enemies, new tasks and responsibilities were thrust upon him. He had to participate in the affairs of psychoanalytical groups and societies that were being formed. He had to write for and even to keep alive journals and yearbooks he had started. He had to encourage and make peace among his disciples—a brilliant, wayward, ill-assorted and neurotic collection of mavericks. He had to fend off critics for whom his "obsession with sex" was as outrageous, as much a basis for moral loathing, as a belief in communism is in the U. S. today. He had to struggle to propagate his theories, and to gain wider acceptance for them in the face of the defections and outright repudiations by persuasive and influential disciples such as Jung and Adler. All that needed to be done he did. His professional duties were never neglected; his writings poured forth in prodigious quantity; he kept the key societies and publications going; he soothed and scolded and polemicized as occasion demanded; he met the opposition with courage, pertinacity and superb self-confidence. There were, of course, moments of doubt and periods of despair. He was deeply grieved when followers deserted him. His health was basically sound but he suffered from a chronic intestinal disorder. That he won out in the end, as Jones convincingly shows, was as much a tribute to his simplicity and faith, to his sheer will, as to the validity and profundity of many of his insights. From the average reader's standpoint, this second volume of Jones's cannot be said to come up to the interest of the first volume. Inevitably a good deal more space has to be devoted to the dissensions, to the character of the disciples, to somewhat technical analyses of Freud's voluminous writings. Yet there is much in these pages that will stir and fascinate almost everyone: brilliant vignettes of personalities, intimate glimpses of Freud at work and at leisure, lucid explanations of difficult psychoanalytical concepts, descriptions of major and trivial sequences in Freud's life. One emerges from this massive and meticulous book with a sense of grasping the dimensions and lineaments of its subject, with renewed admiration for the biographer's skill, and with a feeling of gratitude and relief that the work itself is not yet finished, that more good things are still to come.

The Interpretation of Dreams, by Sigmund Freud. Basic Books, Inc. ($7.50). *Die Traumdeutung* made its first appearance in 1899. Thereafter seven other German editions were published during its author's life, as well as three editions of English translations, the first two by A. A. Brill. This new volume is an entirely new translation by the distinguished British student James Strachey, who has labored for many years to render into English other of Freud's writings. Freud himself tinkered repeatedly with his masterpiece, adding material, modifying various passages, reorganizing entire sections. In this way he tried to keep the book more or less up to date. But it was not a systematic effort and the result was something of a hodgepodge, the despair of the faithful. Strachey has now produced what will probably be accepted as the definitive English version of *The Interpretation of Dreams.* All the material Freud added is here: "An effort has been made to indicate, with dates, every alteration of substance introduced into the book since its first issue." There is a formidable critical apparatus of references and explanatory notes. The translation itself is exemplary; where it is hard going, the difficulties are imposed by the material, not by any shortcomings of the translator. For any student who is interested in Freud's thought processes this admirable edition, executed with so much devotion and skill, is indispensable.

Man Above Humanity, by Walter Bromberg. J. B. Lippincott Company ($5.75). This book is a history of psychotherapy by a psychiatrist of broad experience and a capable student of his subject. Dr. Bromberg offers a detailed account of man's striving to control mental disease, at first by exorcising spirits, by treating the sick as if they were unclean or evil and by cruel restraint and sheer brutality, later by pseudo science and faith healing, finally, in our own time, by kindness, understanding, hygiene and rational therapy. It is a fascinating drama of many acts, persons, devices and theories: incubi and succubi, Lydia Pinkham and Sigmund Freud, Benjamin Rush and his "tranquilizing chair," Mesmer and his magnet, "Dr. Diet and Dr. Quiet," Phineas Quimby, Harry Stack Sullivan, sodium pentothal, Paracelsus, libido, the malleus maleficarum, malicious animal magnetism, Mary Baker Eddy, mescaline and bedlam. Despite a weakness for jargon, and an inclination to pile up quotations and footnotes which make it difficult at times for the plain reader to see where the main road is heading, Bromberg succeeds pretty well in conveying the richness and variety of a momentous struggle for light.

ANXIETY AND STRESS, by Harold Basowitz, Harold Persky, Sheldon J. Korchin and Roy R. Grinker. McGraw-Hill Book Company, Inc. ($8.00). An understanding of anxiety is of central importance to all psychiatric theory. These authors studied several groups of soldiers undergoing paratroop training, reasoning that the intense social pressure to succeed, as well as the constant physical dangers to which the airborne trainees were exposed, would make them ideal subjects for an investigation of anxiety states. As their training progressed, the soldiers were repeatedly subjected to biochemical and psychological tests. The chief merit of the work lies in demonstrating clearly the many problems involved in this sort of investigation. Despite a worthy effort, the research yield was poor. This is due in part to the inherent methodological difficulties of multidisciplinary studies. There was also the disconcerting finding that paratroop training does not create the expected amounts of free anxiety in trainees. The thought of jumping from an airplane may make research workers more anxious than it does the soldier volunteers.

THE OCEAN FLOOR, by Hans Pettersson. Yale University Press ($3.00). Oceanographers have their own special methods for reconstructing the past. They study ocean currents and probe great marine trenches and deeps; by analyzing cores from the sedimentary carpet on the ocean floor they are able to make remarkable conjectures as to the history of the earth. This book by a distinguished Swedish oceanographer is based on the Silliman Lectures given at Yale University in 1952. It reports fully on findings of recent years, especially those made by the Swedish Deep-Sea

Expedition of 1947-1948, in which Pettersson participated ["Exploring the Ocean Floor," by Hans Pettersson; SCIENTIFIC AMERICAN, August, 1950]. The evolution of the oceans is described, and the author considers the remote, but not impossible, prospect of our planet ultimately becoming desiccated. Pettersson's well-written book enables the reader to gain a vivid appreciation of scientific method and reasoning.

AIRBORNE CONTAGION AND AIR HYGIENE, by William Firth Wells. Harvard University Press ($6.00). Support for the airborne theory of disease has fluctuated over the centuries. Among the ancients the source of epidemics was thought to be the "winds." The plagues of the Middle Ages shifted attention to the dangers of actual contact with the sick. In the 19th century, with the rise of chemistry and the newer knowledge of gases, medicine turned again to "miasmic concepts." For a time it was believed that "expiratory droplets" carrying infectious microbes did not travel more than arm's length from the sick person before falling to the ground. Then in 1933 research, mainly by the author of this book, disclosed that most droplets "atomized into air evaporate almost immediately, leaving disease germs drifting like cigarette smoke in droplet nuclei." Thus for the first time there is scientific evidence for the belief that contagion is truly airborne; indeed droplet infections are now held to be "the most prevalent and the most damaging of the infections to which flesh is heir." Wells's book is so constructed that both laymen and specialists will find it useful.

THE ANCIENT NEAR EAST IN PICTURES RELATING TO THE OLD TESTAMENT, by James B. Pritchard. Princeton University Press ($20.00). Few books are more cogent proof than Pritchard's of the truth of the cliché that a single picture is better than a thousand words. The author has collected some 700 photographs constituting a superb pictorial record of the history, daily life and religion of Palestine and adjacent and related cultures during the span of biblical times. The peoples and their dress are shown, the jewelry, cosmetic aids, agricultural implements, methods of husbandry, boating, shipping, fishing, buildings and fortifications, arts and crafts, hunting, warfare, games and dances, writing practices and tools, historical records and monuments, habits of kings and commoners, the Gods and their emblems, religious practices. Each photograph is accompanied by a full descriptive note and by other details. In Pritchard's book ancient cultures are revived in all their richness, and ancient peoples again live and breathe.

One Million Delinquents, by Benjamin Fine. The World Publishing Company ($4.00). Among our pressing social problems juvenile delinquency has been pre-eminent in its capacity to evoke lopsided statements about its causes, dramatic and titillating caricatures of its subjects, and apathy or credulity concerning its management. Benjamin Fine, education editor of the New York *Times*, stimulated by Attorney General Brownell's observation that one million children would be in some kind of trouble with the police during 1954, spent that year surveying the problem. His book is a mature and balanced report of current thinking and practice in the field. Delinquency, as any sensible person would suspect, is a complex social phenomenon whose roots are nourished much more by poverty and neglect than by comic books, poolrooms and pornography. The serious delinquent emerges as a child who is trapped in life by overwhelming circumstances. As to treatment, Fine points out how tragically little we use of the limited understanding we have. The author's writing is pedestrian, but fortunately he often allows the children to speak for themselves.

Foundations of Quantum Theory, by Alfred Landé. Yale University Press ($4.00). Despite its brilliant success in mathematical physics, quantum mechanics continues to stick in the craw. Not a few scientists are dissatisfied with the picture of nature which it implies: a world of discontinuous jumps between discrete states. It is not a comfortable nor an intuitive notion: many an investigator accepts it for the time being because it is useful, but hopes something cozier and more deterministic will turn up to take its place before long. It may be that Dr. Landé has come to the rescue. This uncommonly interesting essay attempts to save the method while reinstating continuity. The argument points out that the principles of classical thermodynamics themselves lead to a discontinuity of entropy known as the Gibbs paradox. If now a postulate is introduced which removes this discontinuity from the classical scheme, one can straightway deduce the general structure of the quantum theory. Landé's work is not a book for beginners. But they can at least catch a glimpse of the challenging ideas of a most inventive theoretical physicist.

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	Electrical Engineers			Mechanical Engineers			Physical Science			Chemistry Ceramics Glass Technology Metallurgy		
	1-2	2-3	4+	1-2	2-3	4+	1-2	2-3	4+	1-2	2-3	4+
SYSTEMS (Integration of theory, equipments and environment to create and optimize major electronic concepts.)												
AIRBORNE FIRE CONTROL			W M			M			W M			
DIGITAL DATA HANDLING DEVICES			C			C			C			
MISSILE AND RADAR			M X			M			M			
INERTIAL NAVIGATION			M			M			M			
COMMUNICATIONS			C I						C I			
DESIGN • DEVELOPMENT												
KINESCOPES (B & W and COLOR), OSCILLOSCOPES—Electron Optics—Instrumental Analysis—Solid States (Phosphors, High Temperature Phenomena, Photosensitive Materials and Glass to Metal Sealing)	L	L	L	L	L	L	L	L	L	L	L	L
RECEIVING TUBES—Tube Design—Test and Application Engineering—Chemical and Physical Development—Methods and Process Engineering—Advanced Development	H	H	H		H	H		H	H		H	H
SEMI-CONDUCTORS—Transistors—Semi-Conductor Devices—Materials	H	H	H				H	H	H			
MICROWAVE TUBES—Tube Development and Manufacture (Traveling Wave—Backward Wave)		H	H		H	H		H	H		H	H
GAS, POWER AND PHOTO TUBES—Photosensitive Devices—Glass to Metal Sealing	L	L	L	L	L	L	L	L	L	L	L	L
AVIATION ELECTRONICS—Radar—Computers—Servo Mechanisms—Shock and Vibration—Circuitry—Remote Control—Heat Transfer—Sub-Miniaturization—Automatic Flight—Design for Automation—Transistorization	M C X	M C X	M C X	M C	M C X	M C X	M C X	M C X	M C X			
COMPUTERS—Systems—Advanced Development—Circuitry—Assembly Design—Mechanisms—Programming	C	C X	M C X	C	C X	M C X	C	C	M C			
RADAR—Circuitry—Antenna Design—Servo Systems—Gear Trains—Intricate Mechanisms—Fire Control	M C X	M C X	M C X	M C X	M C X	M C X	M C X	M C X	M C X			
COMMUNICATIONS — Microwave — Aviation — Specialized Military Systems	C	C	C		C	C		C	C			
RADIO SYSTEMS—HF-VHF—Microwave—Propagation Analysis—Telephone, Telegraph Terminal Equipment		I	I		I	I		I	I			
MISSILE GUIDANCE—Systems Planning and Design—Radar—Fire Control—Shock Problems—Servo Mechanisms	M	M	M	M	M	M	M	M	M			
COMPONENTS—Transformers—Coils—TV Deflection Yokes (Color or Monochrome)—Resistors	C	Z C	Z C	C	Z C	Z C	C	C	C		Z	Z
MACHINE DESIGN Mechanical and Electrical—Automatic or Semi-Automatic Machines		L	L		L H	C L H		L	L			

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THE AMATEUR SCIENTIST

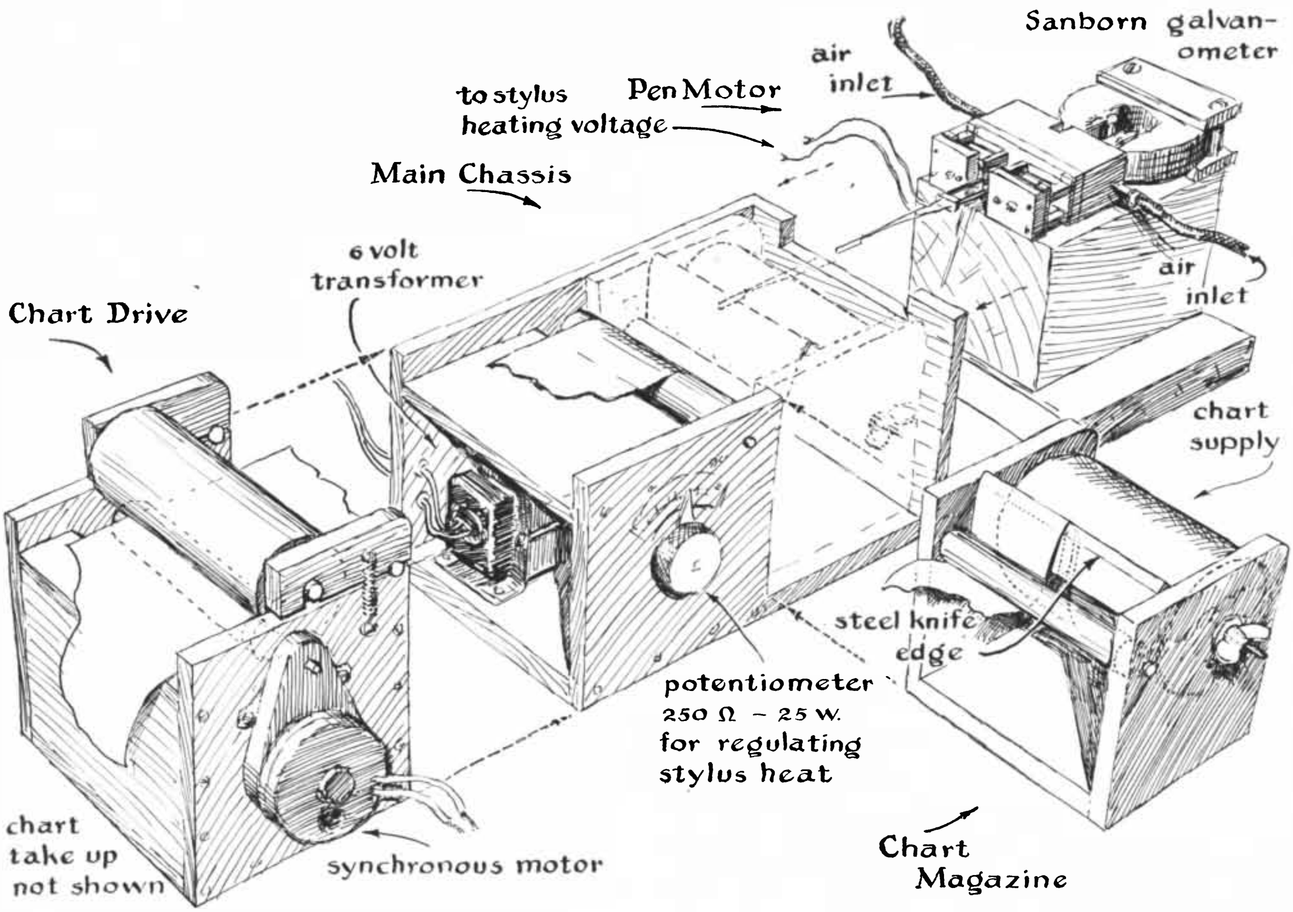
On the making of recording instruments and a moving model of the solar system

Henry Marrows, an instrument designer of New York City, quarrels with the cliché that the primary tools for scientific research ultimately boil down to just a pencil and a sheet of paper. "A brain limited to this method of recording data," he writes, "would certainly arrive at a narrow concept of the universe!" Over most of the spectrum of natural phenomena it is impossible to record observations without the assistance of more rapid, more sensitive, more tireless or more accurate recording instruments. Marrows explains:

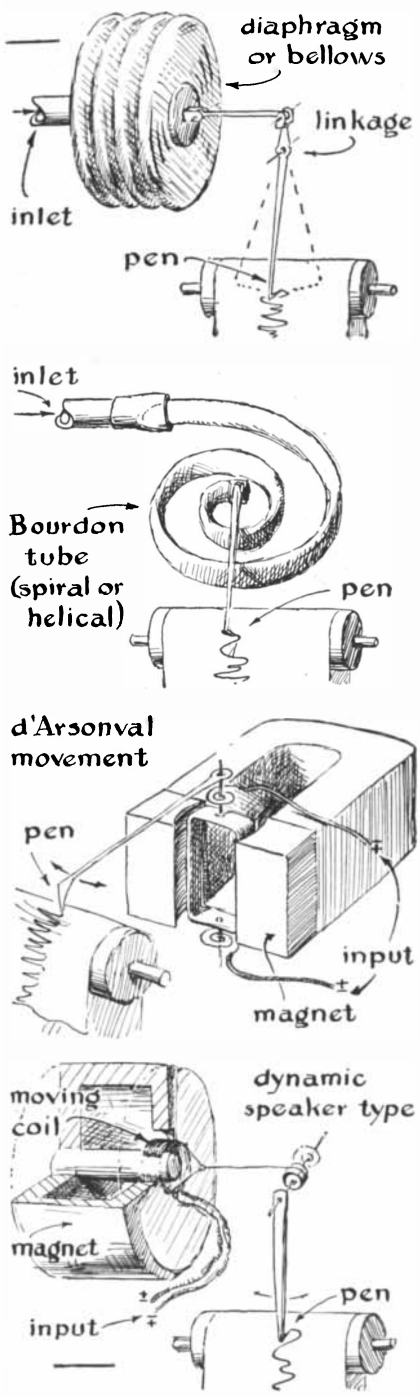
"A pencil propelled by human muscle can keep up with only about five events per second, and a human being cannot stay awake long enough to make a continuous record of events lasting more than about 24 hours. In the parlance of instrument designers, the muscle-driven pencil has a sharply limited frequency response. The frequencies of nature stretch across a spectrum paced at one extreme to the slow evolution of galaxies, covering billions of years, and at the other extreme to the spin of an electron, taking place within a millionth of a microsecond.

"At the low-frequency end, nature provides some ready-made recorders. The age of galaxies is recorded in their slowly changing form. The eras of the earth's evolution have been registered as strata in the rocks. The cycles of climate and other annual events can be read in tree rings and varves (lake-bottom mud deposits). And for recorders of more rapid events we have the deposits left by flash floods, the craters left by meteorites and the fused substances marking points where lightning has struck.

"There are certain important gaps in the spectrum where nature fails to furnish a record. Most of the interesting ones lie in the frequency band between a few hours and an infinitesimal fraction



A pneumatic recorder which may be built by an amateur of a second. To bridge these gaps modern instrument makers have devised various types of recorders. All of them consist essentially of a pen which automatically traces a record of the observed event on a chart of some kind. The pen may be linked to any kind of detecting or observing instrument—a barometer, a thermometer, a seismometer, a telescope or whatever. The sensing instrument translates what it observes into a signal—mechanical or electrical—which drives the recording pen. A recording instrument has two paramount advantages over a pencil-using human recorder: it can operate tirelessly around the clock and it is capable of responding to much higher frequencies.



Four basic pen motors

"The chart on which the instrument's pen writes may be a fixed sheet, a moving ribbon, a cylinder or a disk. The pen may be powered directly by the energy of the event itself (as in an old-fashioned seismograph) or may be driven by a motor actuated by an amplified signal from the event (as in a starlight photometer).

"The varieties of events to which a recorder may be applied are legion. Albert G. Ingalls, formerly editor of this department, spent his first summer in retirement recording the tidelike seiches (vibrations) of Seneca Lake in New York by means of a mechanically-actuated pen recorder which he constructed during the winter months. Studying his graph, 90 feet long, he found that the 35-mile lake had a long-period vibration of 56 minutes. He is now analyzing higher-frequency modes which appear as tiny peaks on the graph. The study promises to disclose interesting information about the shape of the lake bottom as well as clues to the forces responsible for the seiches. Another amateur, John Ruiz of Dannemora, N. Y., recently constructed a seismograph of the velocity type and is recording movements of the earth's crust through the range of 30 seconds per vibration to half a second. His home-built recorder employs electronic amplification. John Wilke of Chicago has fitted his eight-inch reflecting telescope with a photoelectric cell photometer and an electronic recorder which enable him to plot the decay of starlight during occultations in increments of two hundredths of a second. Radio hams and high-fidelity addicts study vibrations in the range from about 20 per second to billions per second. You find these amateurs investigating everything from the characteristics of transistors and homemade loudspeakers to the electromagnetic resonance of chemical compounds.

"Amateurs frequently ask for advice about the best kind of recorder to buy or build. Usually they have in mind a universal recorder—one that will accept signals from many types of sensing instruments. The criterion of selection is frequency response. The pen of the ideal recorder should be capable of full-scale deflection for frequencies 10 times higher than those anticipated in the variable under measurement. Thus if it takes a tenth of a second for the moon to occult a star, the photometric recorder should have a minimum response time of a hun-

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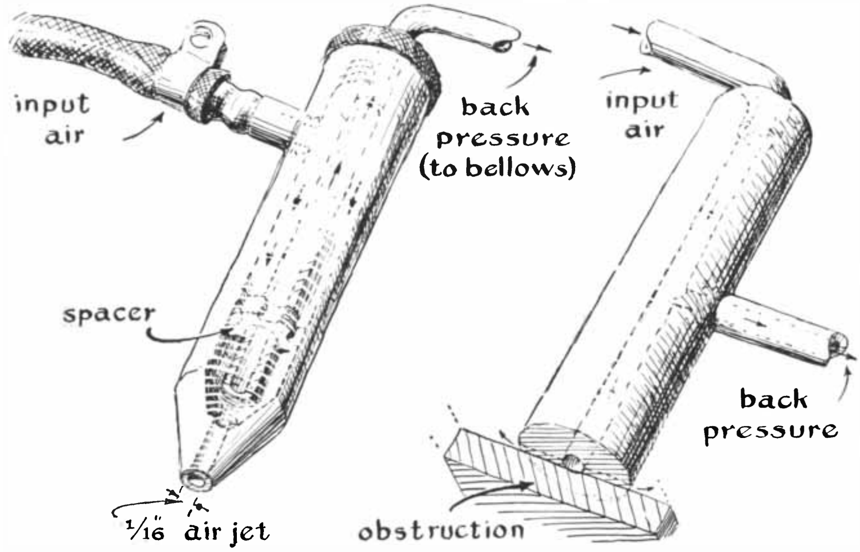


Details of the pneumatic pen motor

dredth of a second. Such a recorder will give a 'flat' response: that is, at every frequency the signal will deflect the pen by the same amount, thus tracing a straight line. Instruments of poor response, in contrast, will not respond uniformly to all frequencies, and therefore the graph will be a curve.

"A flat response is not necessary for all purposes. Sometimes a less than ideal instrument will do. One amateur biologist now investigating the circulatory system of the frog wanted to make recordings of the electrical impulses liberated by the beat of the animal's heart. He was interested in frequencies up to 200 cycles per second. He built an instrument around a war-surplus oscillograph but found that the pen covered only 7 per cent of its full-scale swing at 200 cycles and 50 per cent at 60 cycles. By taking this limited response into account, however, he could interpret the records as faithful measurements of the frog's heart action.

"The high cost of direct-writing recorders has discouraged many amateurs from taking up such hobbies as variable-star observing, seismology, micrometeorology and other avocations in which precise records are essential. A good chart drive and pen motor sells for about $300. A companion amplifier and power supply adds another $500. Equipment for dividing or multiplying the incoming frequencies and thus extending the range of the basic combination, plus equalizing amplifiers to compensate for distortion, can shoot the investment into the stratosphere. But if you have access to a drill press and a small lathe, you can make a good wide-range recorder at a cost of less than $250.

"You start with the pen motor, the heart of any recorder. A number of basic types are shown in the drawings on page 126. Most commercial instruments utilize the d'Arsonval movement in one form or another. Its construction, however, is strictly a job for the experienced instrument maker. In contrast, the pneumatic pen drive is relatively easy and inexpensive to make. It consists of a simple bellows linked to a pivoted lever which carries the pen on its outer end. The pneumatic motor may appear crude, particularly to devotees of electronic technology. Yet when coupled to a nozzle of the type shown above, the pneumatic motor is capable of astonishing sensitivity.

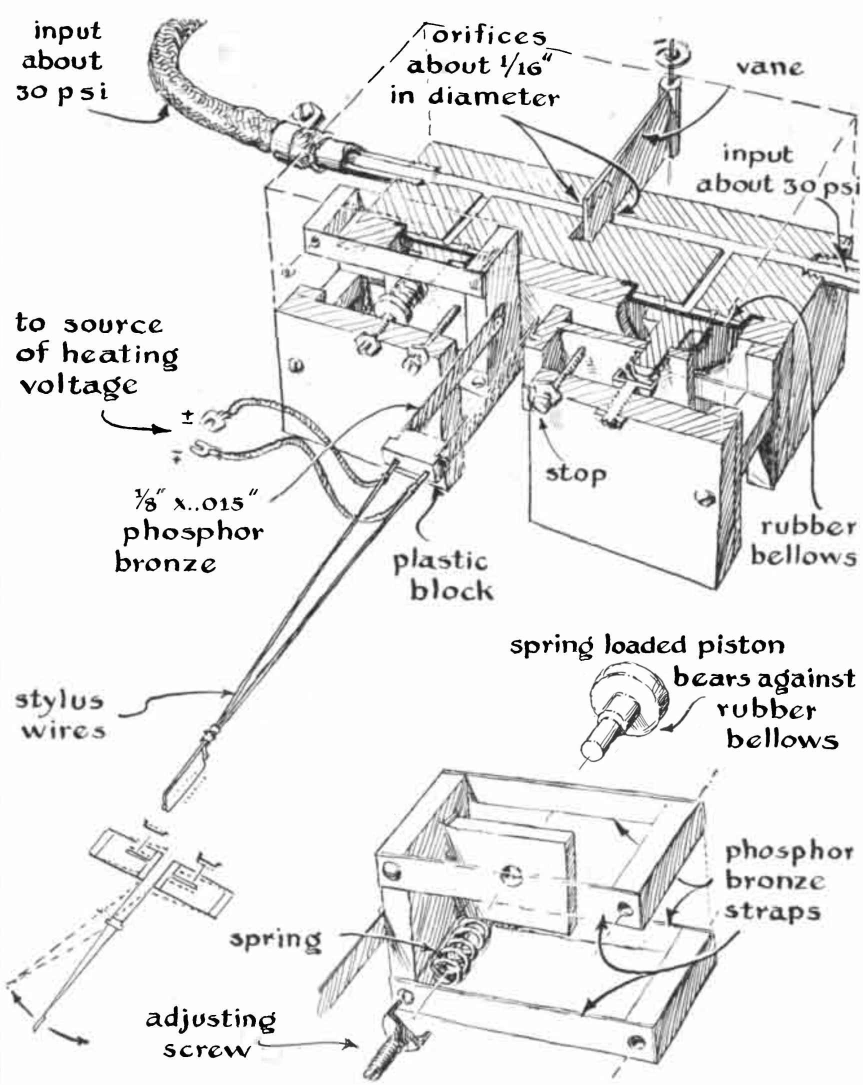
"The nozzle consists of a pair of coaxial tubes. Its outer tube ends as a small orifice from which a minute jet of air escapes. As an example of how it works, suppose we use it with a seismometer. To the pendulum of the seismometer is linked a vane, which is placed close to the orifice and moves toward it and away from it with motions of the pendulum. When the vane comes within a few thousandths of an inch of the jet, back pressure builds up inside. As the vane moves toward or away from the orifice the back pressure varies in direct proportion. The pressure is communicated through the small central tube to a bellows, which in turn moves the pen. The pen therefore swings in direct proportion to the movement of the pendulum. With air under a pressure of 30 pounds per square inch flowing from a sixteenth-inch orifice, the device is sensitive to a change of two millionths of an inch in the distance between the orifice and the vane. It gives a directly proportional response for dis-

tances up to 15 thousandths of an inch. The obstruction need not be a vane, of course. The pen will indicate changes in distance between the orifice and any smooth object.

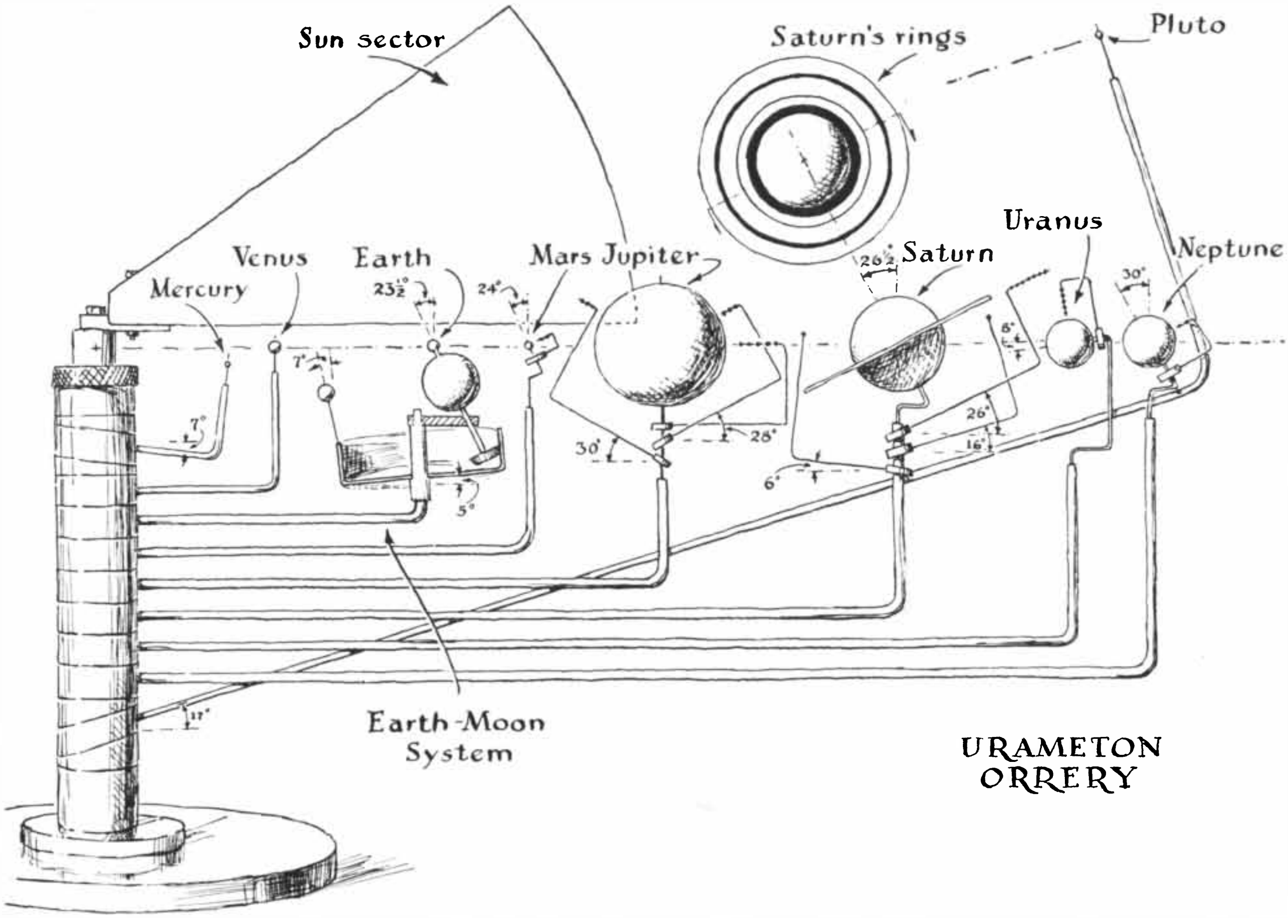
"A single tube with a 'T' near the center works as well as the coaxial jet over distances up to four thousandths of an inch. One end of the tube is connected to the air supply and the other becomes the jet. Back pressure is taken from the 'T' connection.

"It is interesting to arrange a pair of 'T' jets and companion bellows mechanisms for operation as a push-pull pen motor [*see drawing on this page*]. The obstruction can be a vane of light metal supported between the jets by a pivoted arm. Mechanical signals from the observing instrument are coupled to the vane through a conventional linkage. A regulated supply of compressed air enters the sensing nozzles at 30 pounds per square inch and impinges on opposite sides of the vane. The spacing between the surface of the centered vane and each orifice should not be more than two thousandths of an inch. As the vane is moved back and forth by incoming signals, back pressure is communicated to the bellows alternately, causing the spring-loaded pistons to swing the pen. The pen is centered by adjusting the spring tension. The vane floats free between the opposing jets, hence little energy is required to move it. The result is a combination pen motor and pneumatic amplifier capable of power gains of 10,000 to one and higher.

"Electrical signals also can be fed into the device, but they must first be converted into mechanical movement by a device such as the d'Arsonval motor. (This unit is sold by the Sanborn Company, the Brush Electronics Company, the Edin Company Inc., and others.) Alternating-current signals of five hundredths of a volt fed into the d'Arsonval



Details of a push-pull pneumatic pen motor



An orrery, or model of the solar system, built by a British amateur

unit will deflect the pneumatic pen to the limit of its travel. Moreover, the response is uniform for all frequencies from one to 60 cycles per second.

"What is perhaps more appealing than the sensitivity of the unit is its remarkable stability and reproducibility. It requires no controls for keeping the pen centered on the chart or for adjusting its sensitivity to various frequencies. In many applications extremely small mechanical signals can be fed directly into the vane. Because of the push-pull arrangement, small variations in the pressure of input air do not perceptibly affect either accuracy or stability. A small compressor of the type used for a paint sprayer will supply all the pressure needed, and the only electrical power required is 110-volt alternating current for working the compressor, heating the stylus and driving the chart motor.

"For the chart a direct-writing recorder may employ writing paper, wax paper or paper that changes color when an electrical current is passed through it. Each has characteristic advantages and limitations. The pneumatic pen motor develops enough power to drive any conventional writing tip, even pencil lead. Unless the chart movement is slow (a few inches per hour) pencils are inconvenient because they require frequent sharpening. An inking pen, preferably in the form of a glass tube pulled to a point and rounded against a fine carborundum stone, is convenient in low-frequency applications at any chart speed. But a pen is messy, clogs easily and at high frequencies tends to throw ink. On some tracings it may be accelerated at the rate of 16,000 feet per second.

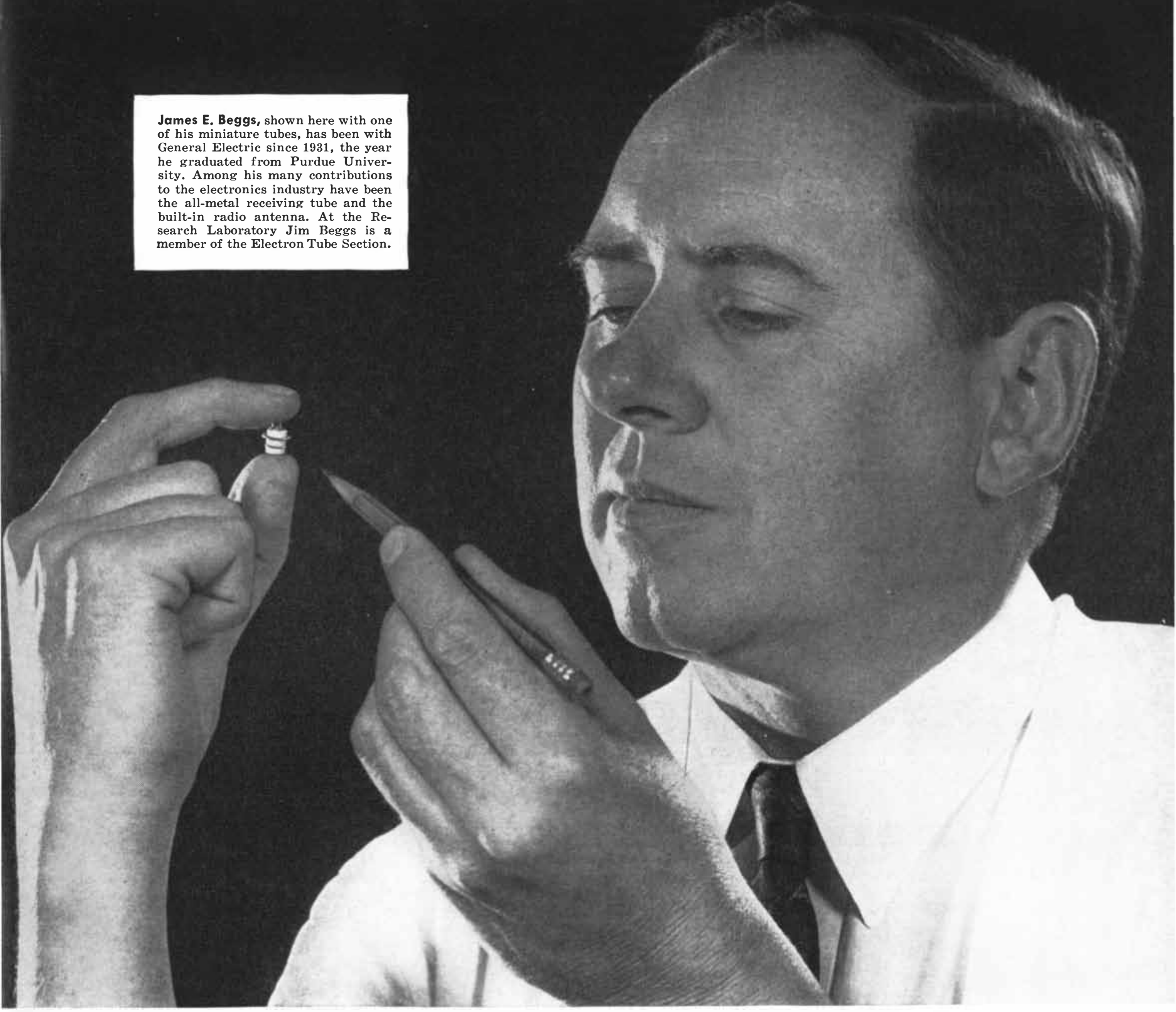
"Waxed paper (inscribed by a heated stylus) behaves nicely at high acceleration, but it costs more than untreated paper and the thickness of the trace varies somewhat with frequency.

"The heated stylus is more difficult to construct than an inking pen. It also requires a transformer for stylus voltage and a rheostat for controlling the heat. However, the heated stylus has the important advantage of making a trace that moves across the chart in substantially a straight line, instead of in an arc as conventional recording pens do. The impression is made at the point where the stylus crosses a knife edge that supports the chart. During lateral excursions the radius of the stylus arm is increased.

"An electrical stylus writing on paper sensitive to current also works well at high frequencies, but it is plagued by its own set of disadvantages. Its resolution is not as good; it requires special transformers, voltage-regulating devices and sensitized paper, and it is subject to arcing and pitting.

"For propelling the chart the available mechanisms range from weight-driven cylinders such as are employed in the old Wiechert seismograph to perforated tapes moved by high-speed sprockets geared to synchronous motors. Seismograms have even been made on the smoked surface of a paint bucket turned by the hour shaft of an alarm clock. The problem of the drive has been simplified by the recent development of inexpensive synchronous motors of the fractional horsepower type.

"It is now common practice to record events at frequencies between 200 and 100,000 cycles per second on magnetic tape. Several basic tape-pulling mechanisms, together with recording, reproducing and erasing heads, are now available for less than $100. They must be appropriately housed and modified for the frequency range in which they are



James E. Beggs, shown here with one of his miniature tubes, has been with General Electric since 1931, the year he graduated from Purdue University. Among his many contributions to the electronics industry have been the all-metal receiving tube and the built-in radio antenna. At the Research Laboratory Jim Beggs is a member of the Electron Tube Section.

Revolutionary vacuum tubes

James E. Beggs of the G-E Research Laboratory combines new knowledge with new materials and new processes

Jim Beggs has a unique talent for employing research results from many scientific fields to produce ingenious new vacuum-tube concepts and designs. Most recently, the man who 23 years ago demonstrated the first practical all-metal tube has pioneered what will certainly become a long line of microminiature ceramic vacuum tubes. The G-E Tube Department's first production version is the 6BY4 triode, which promises to bring UHF television within the range of many heretofore "televisionless" homes.

Beggs' tubes are no bigger than a shirt stud, but they will be invaluable to both industry and defense because of their low-noise and high-gain characteristics, usefulness at microwave frequencies, ability to operate while red hot, and unusual ruggedness. To achieve this revolution in the vacuum-tube art, Beggs coupled his own ingenuity in designing tubes with the work of other G-E scientists — new fundamental knowledge about titanium, new insulating ceramic materials with special expansion characteristics, and new processes for sealing metals to ceramics.

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to work. With this type of recorder high-frequency events can be replayed in 'slow motion.' The low-frequency signal of the reproduction is fed into the electropneumatic pen motor and transcribed as a chart. Frequencies up to 100 cycles per second are recorded by means of frequency modulation, and those above this band by the conventional amplitude techniques. When driven at 60 inches per second, magnetic tape registers signals from 200 to 80,000 cycles uniformly with an error of not more than about three decibels. At high frequencies speed regulation of the tape-propulsion mechanism becomes critical. The speed is sometimes regulated by generating a 60-cycle signal from a tuning fork and amplifying it for power to drive the motor of the tape puller. The frequency stability of commercial electric power is generally adequate for recordings up to 10,000 cycles.

"Construction details of an experimental pneumatic recorder equipped with a heated stylus and a Sanborn transducer are shown on page 125. The specifications are not rigid: an ingenious experimenter doubtless will find ways to modify this plan. Aluminum stock is specified for the chassis because it is easy to cut with hand tools. For sufficient strength the aluminum should be a quarter of an inch thick. Amateurs with limited shop facilities may adapt war-surplus apparatus for some of the parts.

"One such item available as a starting point is a McElroy telegraph tape puller. It is equipped with a 110-volt motor drive and sells for about $20. Its aluminum casting will serve for constructing the chassis of a two-inch chart. Another basic unit is a magnetic wire-recorder magazine which sells for about $18. Another piece of surplus gear, designed as an element of a photographic processing machine, looks promising as a part for a recorder equipped with a pair of two-inch charts and companion pen motors—a so-called two-channel recorder. It consists of a magnesium casting with a side compartment housing gears on detachable shafts. These could be moved around to form almost any type of gearing arrangement. It is fitted with rollers which could be modified for the chart drive. This unit is priced by my instrument maker at $8.

"The most difficult part of the pneumatic recorder to make is the pen motor. If the recorder's frequency response is not critical, a pressure transmitter made by the General Electric Company can be used when modified. It will work on a back pressure in the neighborhood of 10 pounds per square inch. My instru-

ment maker has a limited number of these in stock priced at $10."

This department will forward the address of Marrows' instrument maker to any reader who sends a stamped, self-addressed envelope.

The imminent attempt to launch the first man-made satellite into space undoubtedly will heighten interest in the planets and satellites of the solar system and their motions. One of the most interesting refresher courses you can take on these matters is to construct an orrery. This classic model of the solar system, long a fixture of physics classrooms and planetaria, was named by its inventor, George Graham, after his patron, Charles Boyle, Fourth Earl of Orrery. An English engineer, Frank W. Cousins, submits the design for a simple orrery pictured here [*see page 132*].

"The orrery," writes Cousins, "shows all known planets—except the minor ones—from Mercury to Pluto, with their satellites. You will find an imitation pearl necklace with beads of various sizes a splendid source of spheres to represent the planets. The scale of sizes here is based on a bead one eighth of an inch in diameter for the earth. The satellites are too small to be scaled to this standard and therefore are represented by small beads of uniform size.

"A circular scale mounted on the base gives the zodiac, the months and the right ascension from zero to 24 hours. The sun sector, attached to the tip of the central spindle, is made to scale and gives some idea of the great size of the sun when compared with that of the planets.

"The planets are mounted on arms with devices for showing their inclination to the plane of the ecliptic. In the cases of Mercury and Pluto, this is managed by means of tilted washers on the central spindle. For the earth, Mars, Saturn, Uranus and Neptune we use Z-shaped axis rods turning in deep sockets at the ends of the orbit arms.

"The central spindle and washers are of brass and the orbit arms are of silvered steel.

"As you doubtless know, we English have a custom of naming the things we make. I call this instrument the 'Urameton Orrery.' I have had a lifelong interest in the physics of astronomy, and when uranium 235 came into prominence I chanced to remember the Metonic cycle (235 lunations equals 19 years). My address is 235 Bilton Road, Greenford. I was so impressed by the coincidence that I immediately christened my observatory *Urameton!*"

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NOVEMBER, 1955

BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful.

OPINIONS AND SOCIAL PRESSURE

EFFECTS OF GROUP PRESSURE UPON THE MODIFICATION AND DISTORTION OF JUDGMENTS. S. E. Asch in *Groups, Leadership and Men*, edited by Harold Guetzkow. Carnegie Press, 1951.

SOCIAL LEARNING AND IMITATION. N. E. Miller and J. Dollard. Yale University Press, 1941.

SOCIAL PSYCHOLOGY. Solomon E. Asch. Prentice-Hall, Inc., 1952.

THE TRENCHES OF THE PACIFIC

FURTHER NOTES ON THE GREATEST OCEANIC SOUNDING AND THE TOPOGRAPHY OF THE MARIANAS TRENCH. T. F. Gaskell, J. C. Swallow and G. S. Ritchie in *Deep-Sea Research*, Vol. 1, No. 1, pages 60-63; October, 1953.

GRAVITY ANOMALIES AND THE STRUCTURE OF THE WEST INDIES, PART I. Maurice Ewing and J. Lamar Worzel in *Bulletin of the Geological Society of America*, Vol. 65, No. 2, pages 165-173; February, 1954.

THE PHILIPPINE TRENCH AND ITS BOTTOM FAUNA. Anton Fr. Bruun in *Nature*, Vol. 168, No. 4277, pages 692-693; October 20, 1951.

SEISMICITY OF THE EARTH AND ASSOCIATED PHENOMENA. B. Gutenberg and C. F. Richter. Princeton University Press, 1954.

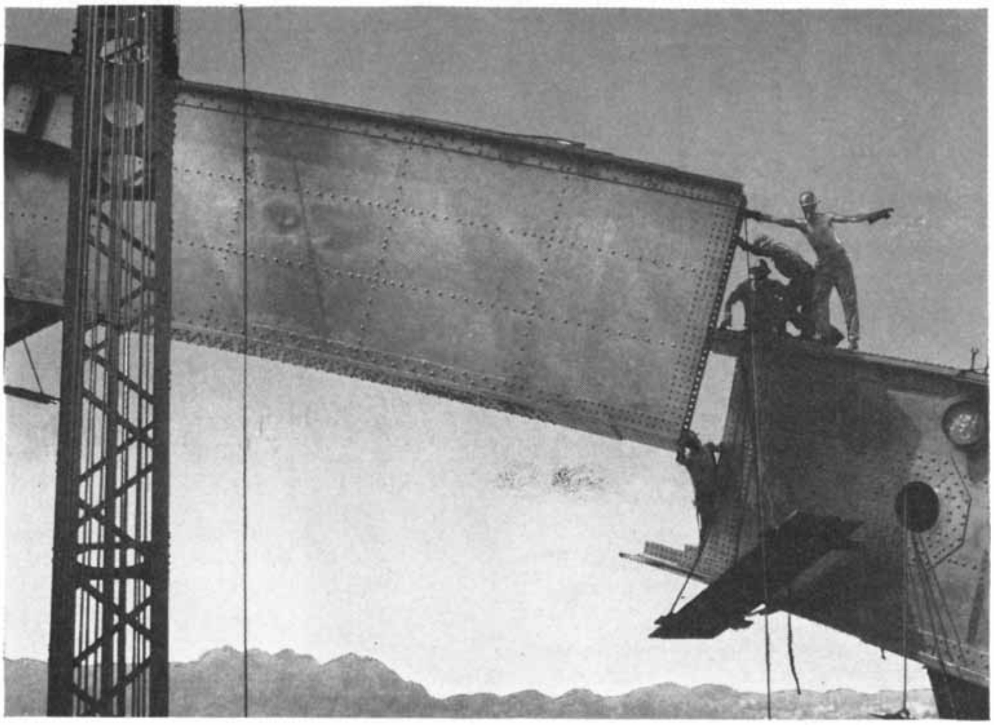
SYNTHETIC DIAMONDS

AN EXPERIMENTAL CONTRIBUTION TO THE PROBLEM OF DIAMOND SYNTHESIS. P. W. Bridgman in *Journal of Chemical Physics*, Vol. 15, No. 2, pages 92-98; February, 1947.

THE PROBLEM OF ARTIFICIAL PRODUCTION OF DIAMONDS. C. H. D[esch] in *Nature*, Vol. 121, No. 3055, pages 799-800; May 19, 1928.

RADIATION AND HUMAN MUTATION

NATIONAL SURVEY OF CONGENITAL MALFORMATIONS RESULTING FROM EXPOSURE TO ROENTGEN RADIATION. Stanley H. Macht and Phillip S. Lawrence in *American Journal of Roent-*



A better steel for better bridges

● We are in an era of bridge building. You don't have to drive very far through the countryside to be made well aware of this fact. On almost any trip you take, one or more detours marked "Bridge under Construction" have become an accepted part of today's motoring.

That's because an estimated 170,000 highway bridges, considered inadequate for modern traffic, are gradually being replaced, or strengthened or widened to meet present-day needs. In 1954 this country spent almost $500 million for highway bridges. And that's only the beginning; to date the backlog of proposed bridge construction amounts to more than $2 billion.

Steel is playing an important role in this tremendous program. For whether it is a small bridge on an obscure rural route or one of the large bridges forming part of a super highway system, steel almost without exception is a basic part of the structure.

To reduce the dead weight of bridges, designers and engineers needed a *high strength* steel. For many years, for long spans in riveted bridges, where weight saving was an important consideration, they have used structural silicon steel (ASTM A-94) which has a minimum yield point of 45,000 pounds per square inch.

About two years ago, United States Steel metallurgists set to work to develop a new steel for this purpose, that would be even better than structural silicon steel.

Now, in USS MAN-TEN (A-242) Steel, bridge engineers have available a steel that, in thicknesses up to and including 1½ inches, has a higher yield point than structural silicon steel—that has twice the resistance to atmospheric corrosion—that punches, drills and gas cuts as well, and, because of its greater ductility, forms more easily. All this at lower cost.

USS MAN-TEN (A-242) Steel is available in plates, wide flange beams, standard structural shapes, in bars and bar shapes. It is intended primarily for use in members of riveted and bolted structures requiring high strength, good fatigue resistance and atmospheric corrosion resistance equal to that of copper steel.

A number of bridges, both large and small, have already been built, or are under construction, with this superior steel. Among them are the West Virginia State Highway bridge at Wheeling, W. Va., in which 2,500 tons of USS MAN-TEN (A-242) were used; the Maumee River bridge near Toledo, Ohio, (1,913 tons); the Red River bridge at Shreveport, La., (2,000 tons); the Delaware River Turnpike bridge connecting the Pennsylvania and New Jersey Turnpikes, (11,070 tons) and others.

We tell this story because it so well illustrates how United States Steel is constantly working to give America ever finer and more efficient steels—steels of infinite variety that can be confidently counted on to meet every demand that Industry can make on this most versatile of metals. United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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genology and Radiation Therapy, Vol. 73, No. 3, pages 442-446; March, 1955.

OUR LOAD OF MUTATIONS. H. J. Muller in *American Journal of Human Genetics*, Vol. 2, No. 2, pages 111-176; June, 1950.

X-RAY-INDUCED MUTATIONS IN MICE. W. L. Russell in *Cold Spring Harbor Symposia on Quantitative Biology*, Vol. 16, pages 327-336; 1951.

"EMPTY" SPACE

GAS DYNAMICS OF COSMIC CLOUDS. Edited by Johannes Martinus Burgers and H. C. van de Hulst. Interscience Publishers, Inc., 1955.

WHAT MAKES LEAVES FALL?

AUXINS AND PLANT GROWTH. A. C. Leopold. University of California Press, 1955.

STUDIES ON ABSCISSION. R. H. Wetmore, William P. Jacobs and F. N. Rossetter in *American Journal of Botany*, Vol. 40, No. 4, pages 272-280; April, 1953. Vol. 42, No. 7, pages 594-604; July, 1955.

ETRUSCAN METALLURGY

ETRURIA PAST AND PRESENT. Mary Anderson Johnstone. Methuen and Company, Ltd., 1930.

THE ETRUSCANS. Massimo Pallottino. Penguin Books, 1955.

TOO MANY DEER

THE JAWBONE DEER HERD. A. Starker Leopold, Thane Riney, Randal McCain and Lloyd Tevis, Jr. State of California, 1951.

PENNSYLVANIA'S DEER PROBLEM. Roger M. Latham. Pennsylvania Game Commission, 1950.

A SURVEY OF CALIFORNIA DEER HERDS: THEIR RANGES AND MANAGEMENT PROBLEMS. William M. Longhurst, A. Starker Leopold and Raymond F. Dasmann. State of California, 1952.

THE AMATEUR SCIENTIST

DIRECT-INDICATING RECORDING INSTRUMENTS. S. R. Gilord in *Electrical Manufacturing*, Vol. 52, No. 5, pages 114-121; November, 1953. Vol. 52, No. 6, pages 120-128; December, 1953.

MECHANICAL MEASUREMENTS BY ELECTRICAL METHODS. Howard C. Roberts. The Instruments Publishing Company, 1951.

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