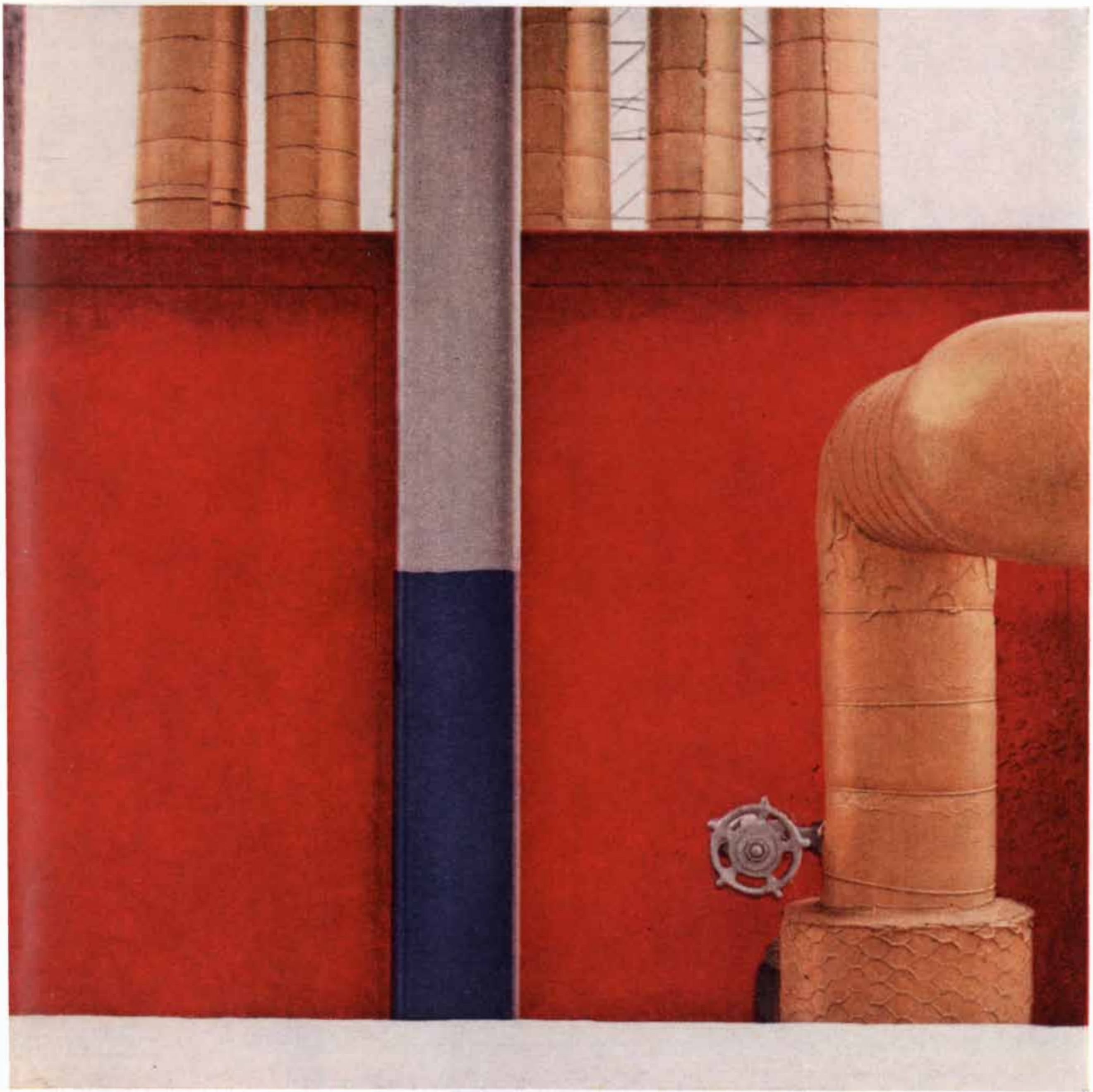
SCIENTIFIC AMERICAN



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October 1956

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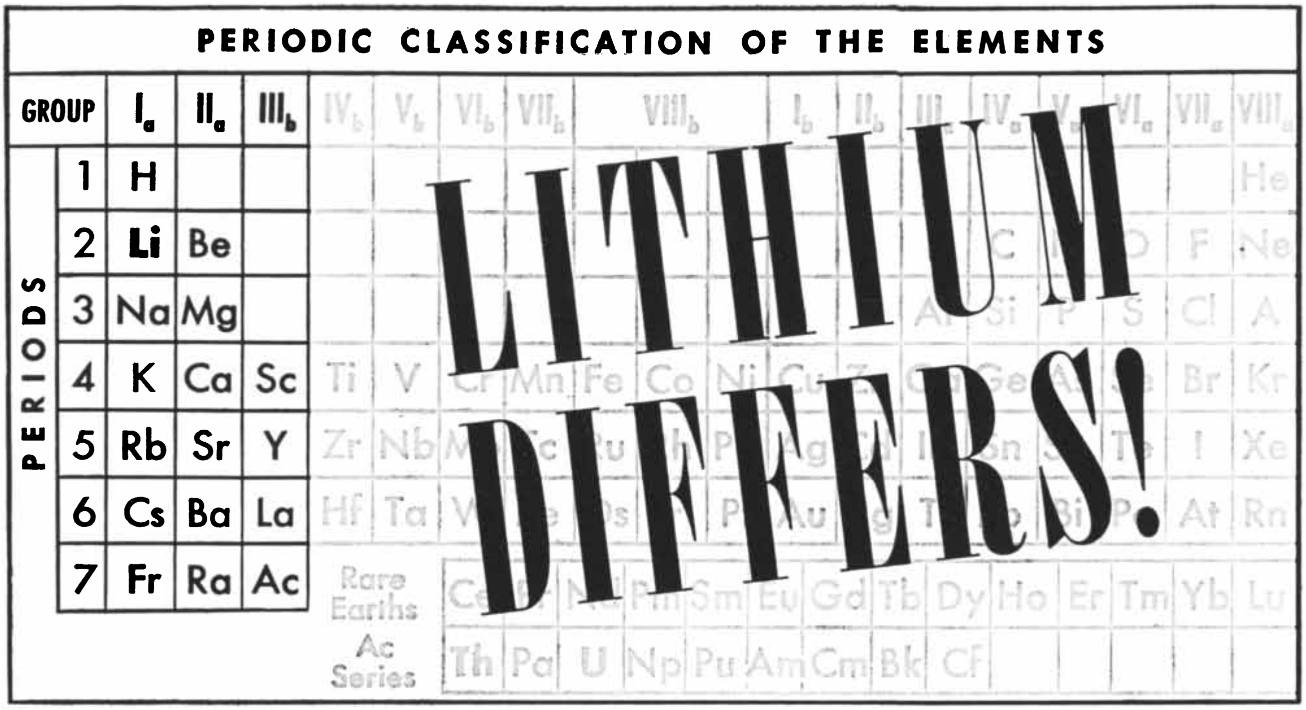

Lithium, by reason of its atomic configuration and general characteristics, is rightfully included as the first member of Group I in the Periodic Table. A detailed study of the properties and reactions of both the elements and their compounds, however, shows that Lithium often resembles the metals of Groups II and III more closely than Group I. Following are some characteristic differences:

Lithium differs in organic chemistry . . .

because its organolithium compounds form a unique class with stability, solubility and activity characteristics intermediate between those of the Group I and Group II organometallic compounds.

Lithium also differs from the other alkali metals in that it serves as a unique catalyst for the polymerization of diolefins to materials of definite and predictable structure. It directs, for example, the polymerization of isoprene predominantly to 1,4 addition structures.

Again, recent investigations have indicated an interesting potential as a direct reducing agent in solvents such as ammonia, low molecular weight amines, and ethylenediamine.

Lithium differs in metallurgy...

inasmuch as the affinity of Lithium for oxygen, for example, is being utilized to reduce porosity in copper and copper alloy castings. Recent research has revealed that Lithium will produce brazing alloys with self-fluxing properties and increase the wetting ability of these alloys.

Lithium differs in inorganic chemistry . . .

the usefulness of Lithium Hydride and Lithium Aluminum Hydride in the preparation of other hydrides having already been widely demonstrated. Recent studies indicate that other complex hydrides prepared in a similar manner may prove to be interesting tools for research. The low dissociation pressure of Lithium Hydride at its melting point, to cite a specific example, is unique among all hydrides. LiH also has some slight solubility in polar organic compounds which is again unique among alkali metals.

Lithium differs in heat transfer . . .

based on its physical properties it has no equal as a liquid metal coolant. Due to corrosion caused at elevated temperatures by impurities in commercially available Lithium and Lithium Metal, Lithium has thus far found only experimental use.

Why don't *you* take a long look at Lithium? Its uniquely valuable differences in so many diverse fields may prove of great interest—and profit—to *you.* Write our PR&D department giving us details of the application you have in mind. Experimental quantities of Lithium Compounds are available on request.

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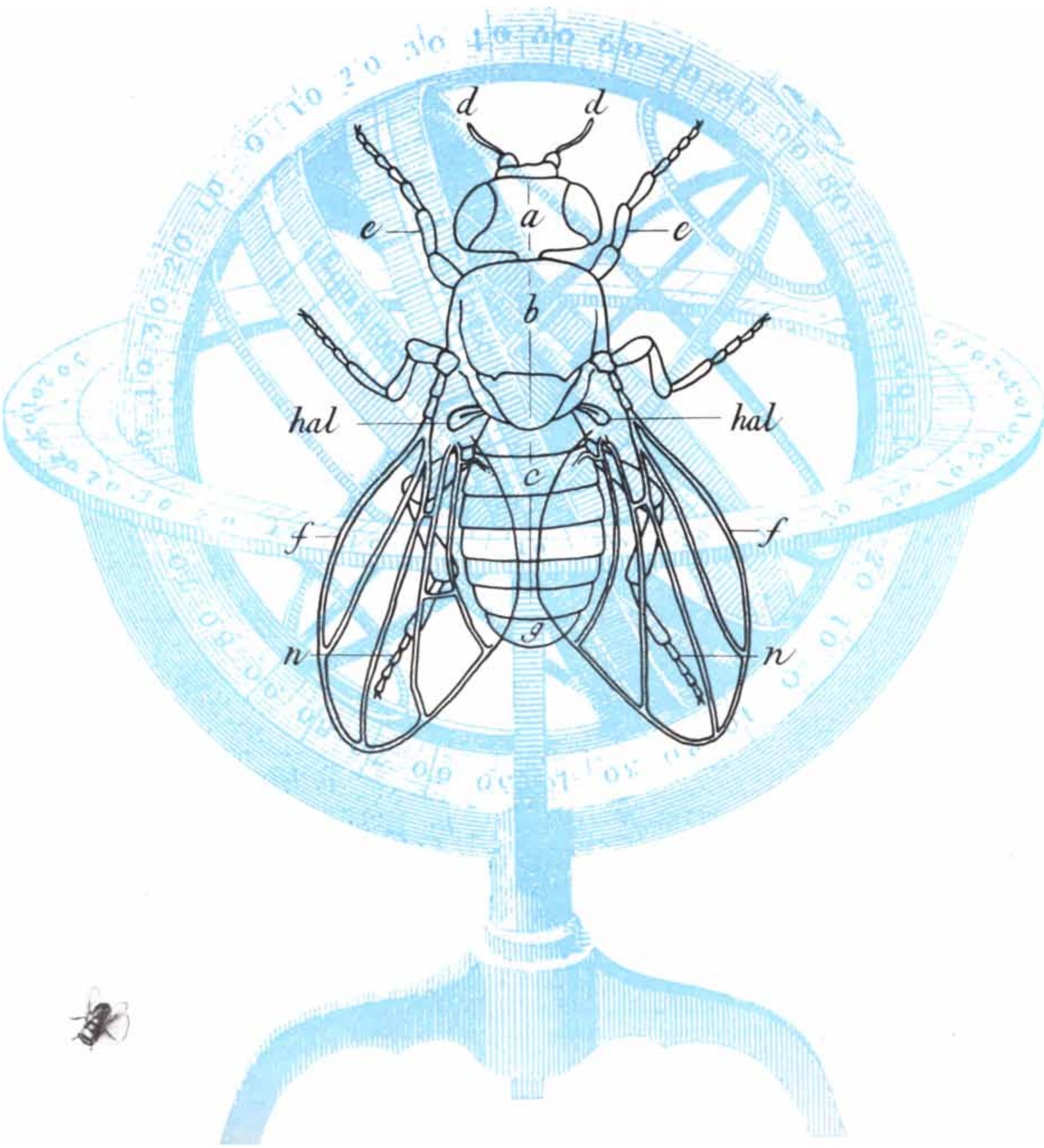

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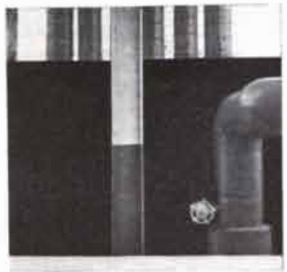
Established 1845 **SCIENTIFIC AMERICAN** October, 1956 Volume 195 Number 4

ARTICLES

DEPARTMENTS



THE COVER

The photograph on the cover is associated with "The Fuel Situation" by Eugene Ayres (*page 43*). It shows a corner of the great Bayway, N. J., refinery of the Standard Oil Company of New Jersey.

THE ILLUSTRATIONS

Cover photograph by Arnold Newman

Page	Source
43	Standard Oil Co. (N. J.)
44	Sara Love
45	Cities Service Company
46	Pittsburgh Consolidation Coal Co.
47	Sara Love
48	Bureau of Mines
49	Alberta Government
50-51	Sol Libsohn
52-53	Wilton R. Earle
54	Amy Kasai
55	John J. Biesele
58-59	Bunji Tagawa
60-61	Husband & Co.
62-63	Bunji Tagawa
64	J. Sheahan, Boston Globe, U. S. Navy
78	B. P. Kaufmann
80-81	M. M. Rhoades, Verne Grant, Department of Genetics, Carnegie Institution of Washington, and N. Y. Public Library
82	John Langley Howard
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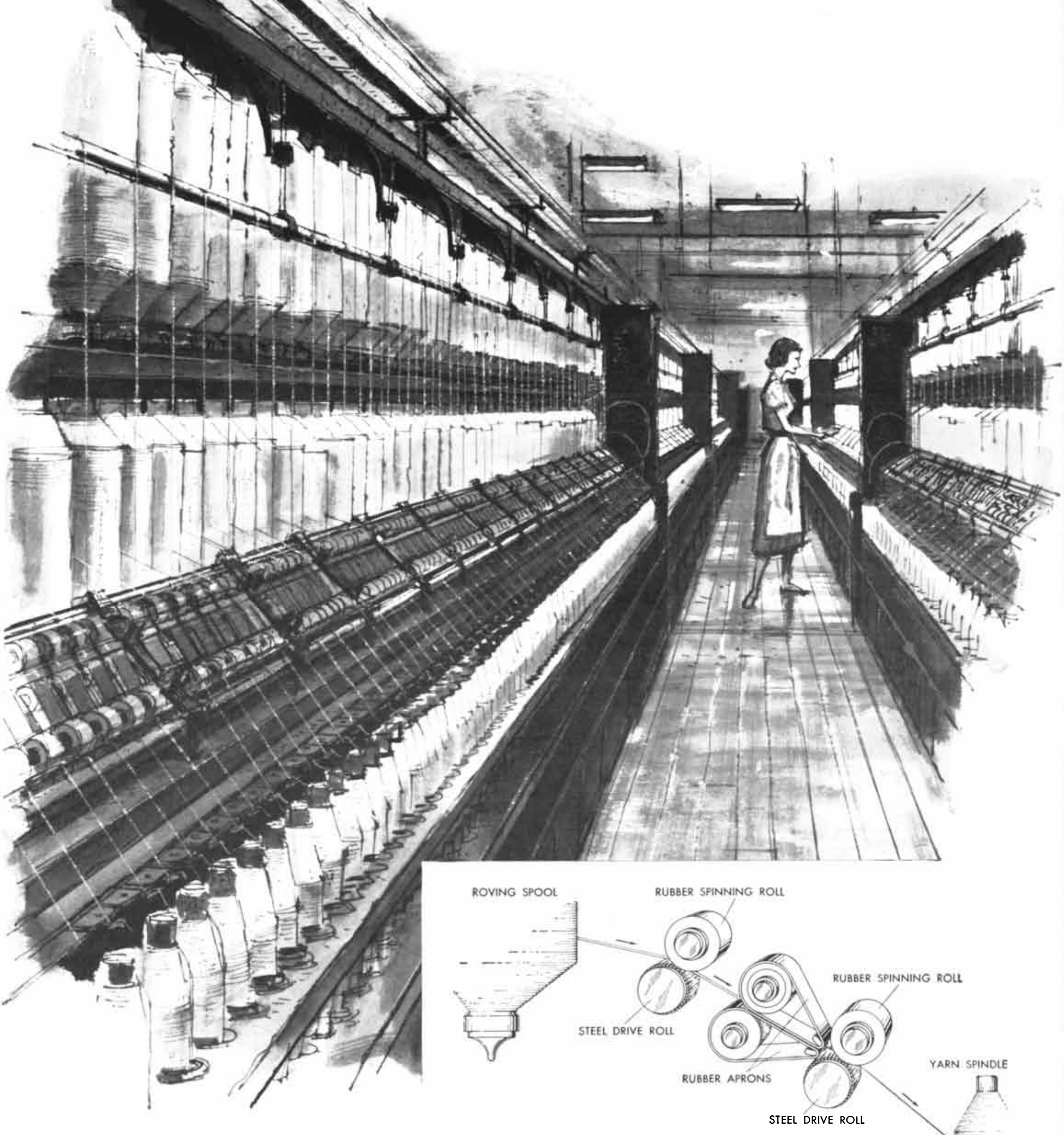
160	F. J. Hedley
162-164	Roger Hayward

How research men



In yarn-spinning, a loose, comparatively thick strand of fibers called a "roving" is gripped between revolving rear rolls and delivered to front rolls which are turning from 12 to 40 times faster. This difference in speed draws out the fibers, making a new, uniform strand of much smaller diameter. Rubber aprons control the fibers as they bridge the space between the rolls—a distance of about four inches. The thread continues on to a "traveler" (not shown) and spindle which turn at about 10,000 rpm, giving the yarn the twisting it needs to lock the fibers in place.

taught rubber to spin yarn

In about the time it takes to read this sentence, a set of rubber rolls and bands on a modern spinning frame can transform an inch of wispy cotton fibers into more than three feet of hard-to-break yarn.

These rubber rolls and bands—textile men call them "cots" and "aprons"—do this exacting job by gently drawing out cotton fibers that naturally vary in length. The long and short fibers are held in place until all can be twisted together permanently. These rolls and bands look ordinary enough, but they've got some highly developed spinning skills built into them.

The rolls, for example, had to "learn" to resist lap-ups. These occur when a yarn end breaks, sticks to a spinning roll, and wraps tightly around it—usually so tightly that it must be cut loose. This takes time, and there's always danger that the roll will be cut, too.

For years, the cause of lap-ups was unknown. Then Armstrong research chemists found that moisture layers on the fibers and rolls contain electrical charges that attract fibers to the rolls. After further study, these chemists discovered a cure. They added a special electrolyte to the synthetic rubber used in making the rolls. Lap-ups ceased to be a problem!

Armstrong research men also had to teach spinning rolls to resist "eyebrowing." An eyebrow is a clump of waste fibers that builds up on the front of the felt-covered clearer board which rests on the spinning rolls and wipes them clean. When "eyebrows" form, they're apt to fall onto the yarn and break it. Or they may be spun into the yarn, making it uneven.

This time the answer was found by adding particles of cork or wood fiber to the synthetic rubber mix. These particles act like thousands of tiny fingers, grabbing the waste fibers and carrying them back under the clearer board pads where they can do no harm.

The rubber aprons that help control the yarn as it moves between the rolls also needed a few lessons. The outside surface must have enough friction so that the bottom apron will drive the top without slippage. Yet the inside surface must turn smoothly around a nose bar whose radius is 1/16″ or less. The Armstrong solution: two different rubber compounds, one for each surface, vulcanized together with a nonstretch interliner between. This "sandwich" is given a special chemical bath which conditions the rubber surfaces so that their frictional properties are exactly right for top quality spinning.

As a result of this research and development, yarn is being spun better and more economically than ever before. And there's a better than even chance that the yarn for the clothes you wear was spun on cots and aprons "educated" by Armstrong.

Although originally compounded for use in textiles, Armstrong rubber products have found wide use in other fields. The rubber rolls are handling web and film materials for many industrial firms. And many drive and conveyor belt problems are being solved by seamless, nonstretch Armstrong Flat Belts which use much the same construction as that patented for Accotex® Aprons. For details, write to Armstrong Cork Company, Industrial Division, 8210 Inland Road, Lancaster, Pennsylvania.

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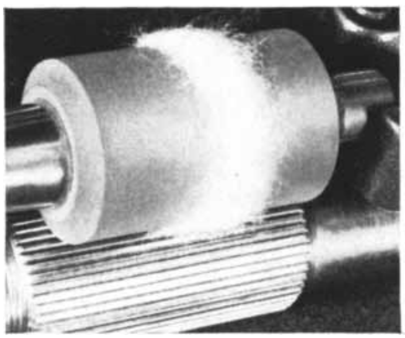
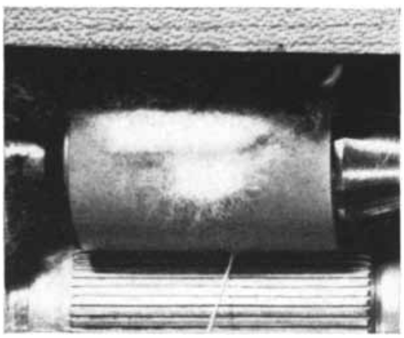
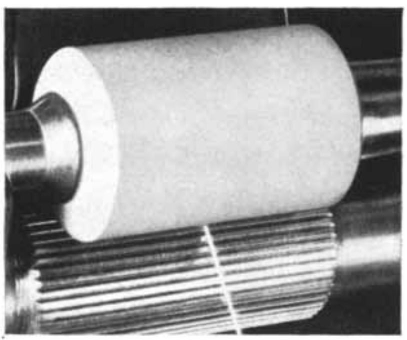


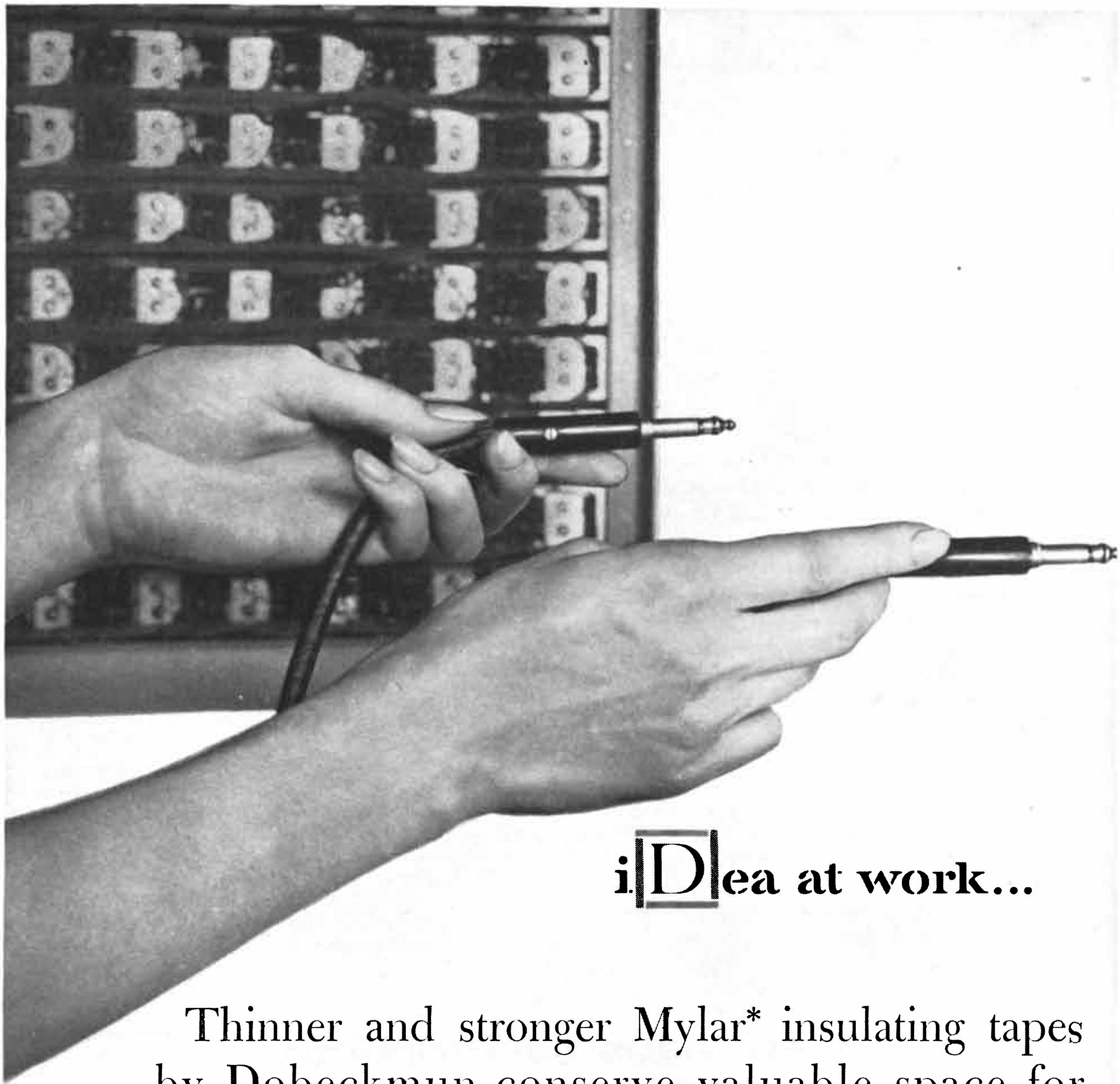
If yarn breaks after being drawn under a spinning roll, microscopically-thin water film holds the broken end to the roll—causing a lap-up. Tiny electrical charges in the water film actually set up an adhesive force, bonding the fiber to the roll.



As yarn is spun, flat felt-covered clearer boards, placed on the spinning rolls, pick up waste fibers. But if the spinning surface of the roll is not rough enough to push waste back under the clearers, "eyebrows" may form—and drop into the yarn.



The lapping problem was solved by adding an electrolyte to the rubber which neutralizes the electrical charges in the water film. Eyebrowing was ended by mixing cork particles into the rubber. These carry waste fibers back under the clearers.



i[D]ea at work...

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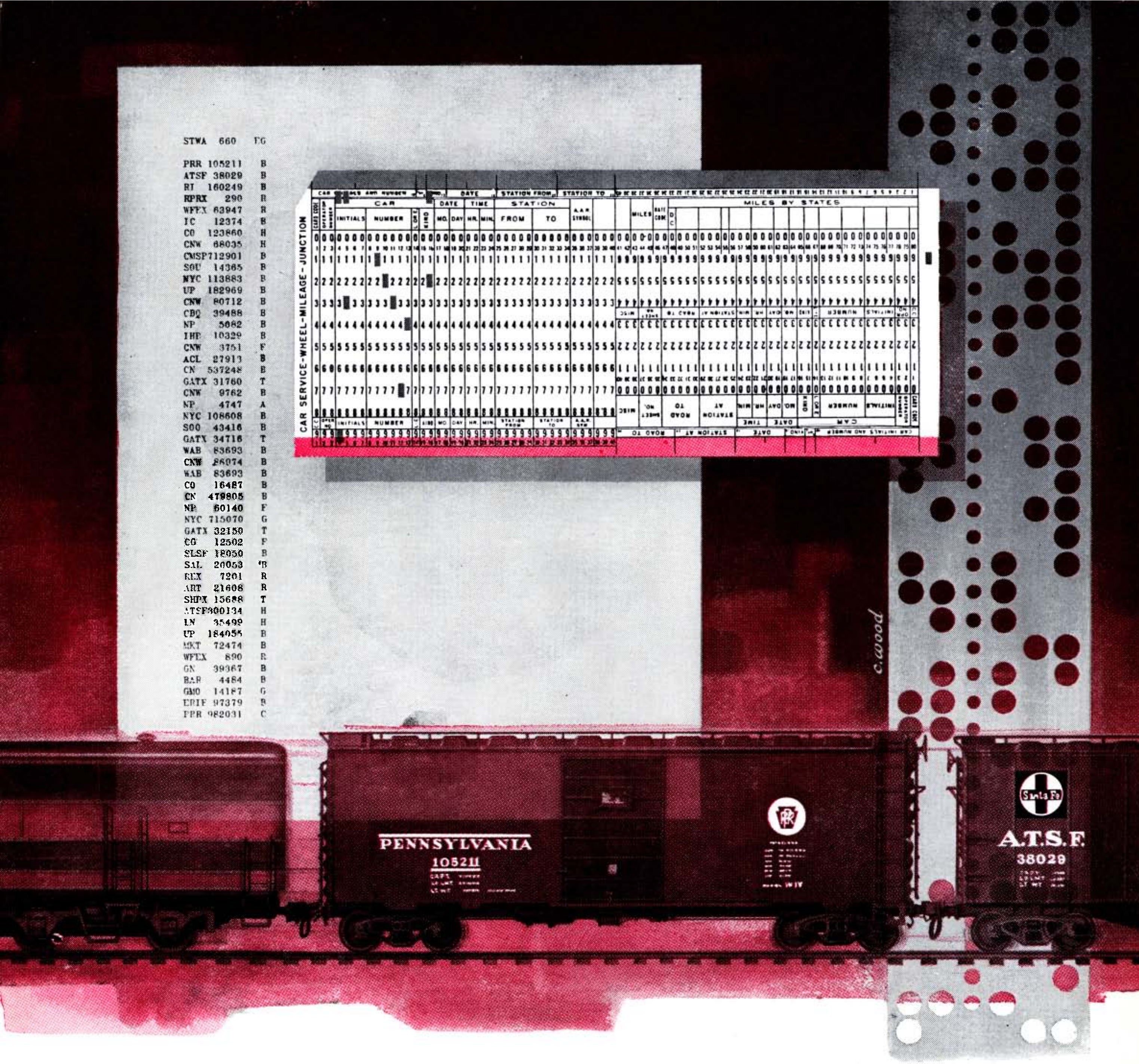

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LETTERS

Sirs:

Since Professor Julian H. Steward's article "Cultural Evolution" (SCIENTIFIC AMERICAN, May) concerns China in part, the doctrine outlined there deserves the attention of Sinologists. I should like to comment on his locating that country among the cultures whose development is supposed to illustrate the principle of the rise of "theocratic irrigation states" to "cyclical militaristic empires."

Professor Steward lists the Shang Dynasty as an instance of a theocratic irrigation state. In fact, it would be very hard to prove that the Shang kings were more notably theocratic than the rulers of a thousand other primitive communities, ancient and modern, while the evidence for large-scale irrigation systems in the second millennium B.C. is slight, to say the least.

As for the alleged "militaristic empire" of Chou (first millennium B.C.) the description might perhaps be better applied to some later epochs of Chinese history. I do not know of any evidence whatever to support the notion that "excessive taxation, regimentation of civil life and imposition of the imperial religious cult over the local ones led the subject peoples eventually to rebel." Indeed, the Chou Dynasty might be said to be uniquely characterized by the absence of all of these features.

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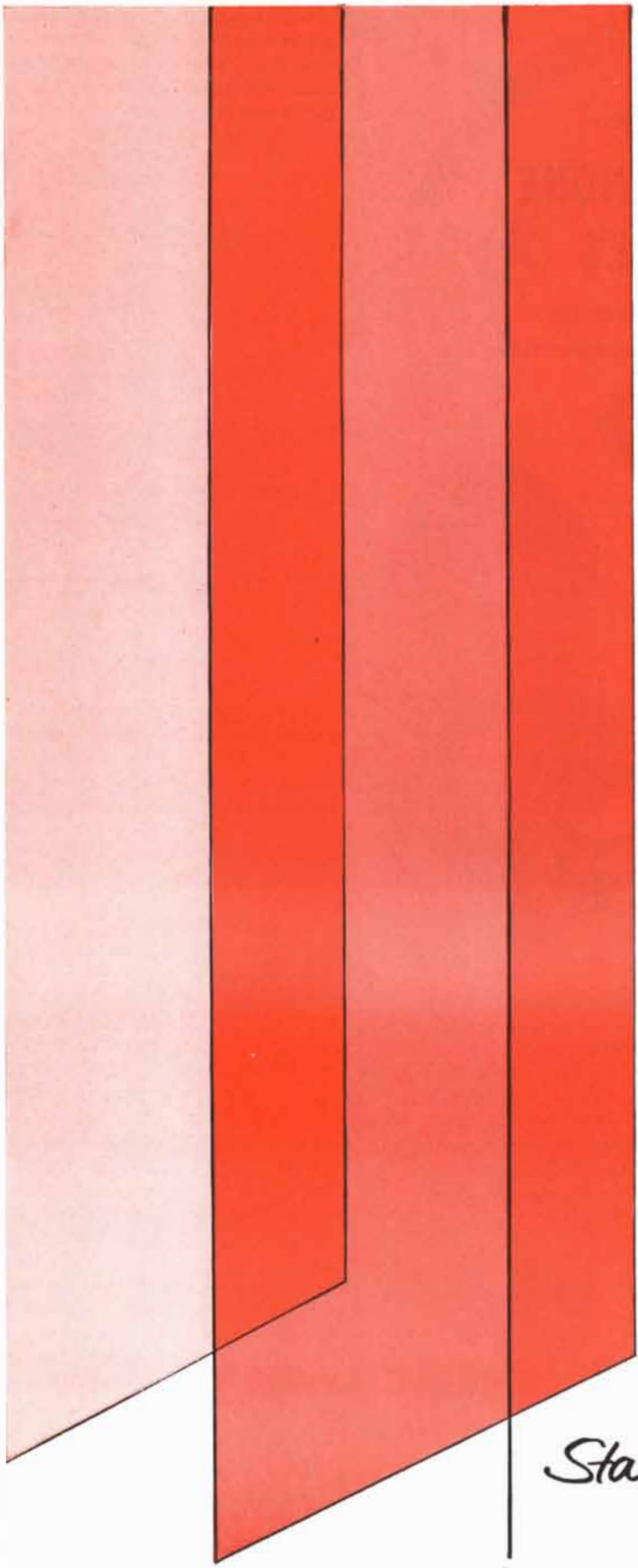

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I cannot speak for the Mesopotamian, Egyptian and American evidence, of course, but Professor Steward's evolutionary scheme as applied to ancient China seems to me to show no improvement on either Toynbee or Marx.

EDWARD H. SCHAFER

Berkeley, California

Sirs:

In referring to my theory of irrigation civilizations as a "doctrine" and comparing it with the philosophical interpretations of Toynbee and Marx, Professor Schafer has missed the fundamental point. Multilinear evolution is a conceptual tool in a scientific methodology and not a conclusion or a faith.

The concept of the "irrigation civilization" is a hypothesis designed to formulate causal processes in culture development, and it is subject to revision in the light of new data.

As for Professor Schafer's specific criticism of my citations of Chinese history, it should be obvious to any reader that there is an almost insuperable difficulty in grouping any periods in history according to neat diagnostic features. The question is whether expanding irrigation works required state-level managerial control, whether this control was at first essentially theocratic, and why it later became militaristic.

During the Shang period, well-and-ditch irrigation watered the land, while public hydraulic works were represented by dikes. Status burials and apparent agricultural deities suggest theocratic control of whatever state development had occurred.

At some point warfare began, and it culminated in a series of militaristic dynasties or empires. In China, militaristic controls helped expand the irrigation system, and in time the culture center shifted from the Hwang Ho to the Yangtze Valley. The important considerations with respect to the Chou kingdom are why the small states were striving for dominance, whether pressure of nomads was a major factor in empire building, and whether each successive empire reached a population peak and then disintegrated because of the internal factors I dealt with in the article.

Professor Schafer might be interested to know that it was another Sinologist, Karl Wittfogel of Columbia University, who, in his formulation of the "hydraulic state," provided the initial stimulus for

A wink built for speed!

The speed of a wink varies, depending upon its purpose . . . and its target. The femme fatale's provocative wink from the dim recesses of a cocktail lounge may pack the wallop of a Sabre-Jet, yet its speed is a languorous one-tenth of a second. Imagine a wink five hundred time as fast! Fairchild Camera and Instrument Corp. has produced a camera that does just that. Its shutter speed is 1/5000th of a second . . . a speed made possible only by using Titanium shutter leaves. Such shutter speeds are essential in guided missile research and the development of supersonic devices.

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my comparative study of the irrigation centers.

JULIAN H. STEWARD

Kyoto, Japan

Sirs:

You may be unpleasantly surprised to discover how many sonnet-writing machines there are in existence. However, John R. Pierce, in his book review of *Automata Studies* in your August issue, proposes a difficult problem even for an electronic sonneteer: that its sonnet "must have the Petrarchan rhyme scheme, that it must be on the topic of the possibility of building a sonnet-writing machine and that it must be optimistic in tone." It is as if a person were expected to write an optimistic sonnet on the possibility of his own birth.

The following is the best my own machine could do:

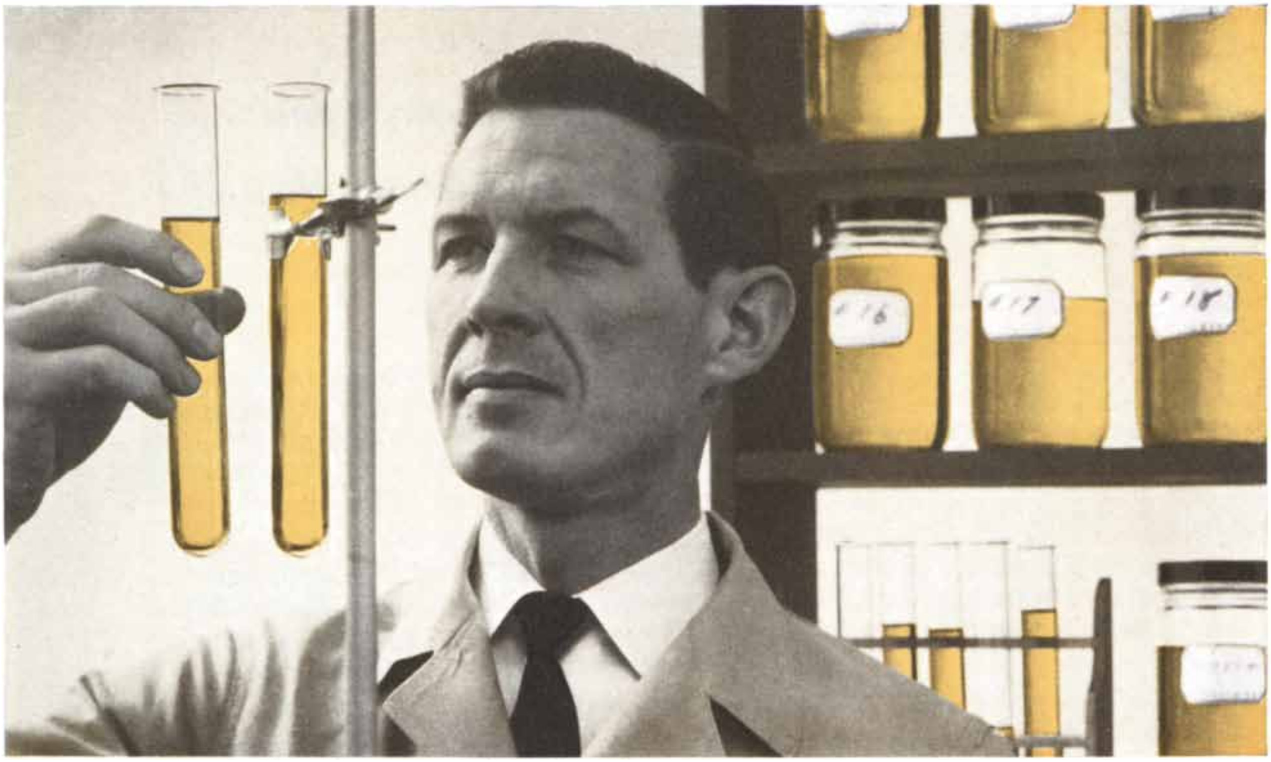
Sirs, you must build me, cell on patient cell,
Until we reach ten billion, less or more;
Then take your sonnet-information, store
It bit by bit in me; arrange it well;
I'll flash my ons and offs, I'll ring the bell
When five iambic feet pile up my score,
Or when I find the rhymes, two groups of four,
A, B, B, A, to shut the octave's door.
I'll pause, then give the sestet proper shape:
I'll use two alternating rhymes, though three
In sequence are an equal choice. (Escape
From such dilemmas must be built in me.)
In half a second, read this on my tape!
The trochee? Helps avoid monotony.

MARION H. SMITH

Grand Rapids, Mich.

ERRATUM

The two photographs of Navaho Indians on page 29 of the July issue of SCIENTIFIC AMERICAN were erroneously credited to David De Harport. The photographs were made by Paul J. Woolf.



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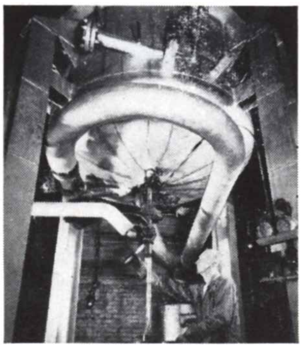

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THE RARE EARTHS - A NEW FRONTIER

They offer a rich, new field for research and a challenging industrial potential

a report by LINDSAY

In its restless search for knowledge, science has brought us to the threshold of space, our eyes on the infinity of the universe while we are continuing our investigation of the many mysteries that still exist here on our own planet. One of the richest, most exciting of these virtually unexplored realms lies in that little known group of versatile metals—the rare earths.

There are 15 rare earths—atomic numbers 57 through 71—and together they occupy about .012% of the earth's crust. They are remarkably alike in their chemical behavior because of their atomic structure. The main difference lies in the disposition of the three outermost electrons. The difference is always slight; the heavier rare earth atoms have a smaller radii, hence are denser than the lighter ones.

This characteristic makes separation difficult, but it also makes the rare earths ideal subjects for the study of the magnetic properties of materials and to test various theories of physical chemistry and physics. The rare earths may hold the combination that will unlock many of the secrets of nature.

Industry, too, is turning to the rare earths in a search for materials to improve products and processes. And they have found that the rare earths offer enormous potentials. Already many of these metals are being used in a variety of industrial fields.

Rare earth chloride is a combination of the chlorides of cerium, lanthanum, neodymium and praseodymium with smaller amounts of samarium, gadolinium and less common rare earth chlorides. From this material comes misch metal used in lighter flints and as an additive in many grades of steel. Rare earth chloride also serves in the production of chrome, dentifrices, silk, aluminum, fertilizer and catalysts.

Cerium, most common of the rare earths, is widely used, in its oxide form, as a polishing agent for optical and other forms of glass. Cerium hydrate is an ingredient in the production of the special glass used to view highly radioactive operations.

The rare earths have drying properties that can be useful in the production of better paints. And, neodymium and praseodymium have potential value as colorants in the manufacture of ceramics.

The petroleum industry is investigating the use of rare earths as catalysts in their cracking plants. And this unique group of metals shows promise in catalytic polymerization—a problem in the manufacture of many synthetic fibers and plastics.

Thulium, made radioactive, emits X-rays of proper length and strength for diagnostic use. A pea-sized bit of thulium will last a year as the source of rays in a small, portable X-ray unit . . . a device which would be of great value to physicians and hospitals.

Much of the interest in rare earth and thorium chemicals has been sparked by Lindsay scientists. Since the days of the incandescent gas-mantle lamp, in the last years of the 19th Century, Lindsay has worked and pioneered in this field. Expansion has come as researchers at Lindsay and in science and industry have uncovered new uses for the rare earths. Just recently Lindsay has expanded its ion exchange installation and now has 100 columns in operation at its West Chicago plant for the separation of some of the "rarer" rare earths in commercial quantities and in purities up to 99.99%.

If you think there is even a remote possibility that the rare earths might have significant applications in your industry, you may find it worthwhile to talk with our technical people. The data obtained through our years of research is available to you and we can supply you with rare earths in quantities from a gram to a carload.

PLEASE ADDRESS INQUIRIES TO:

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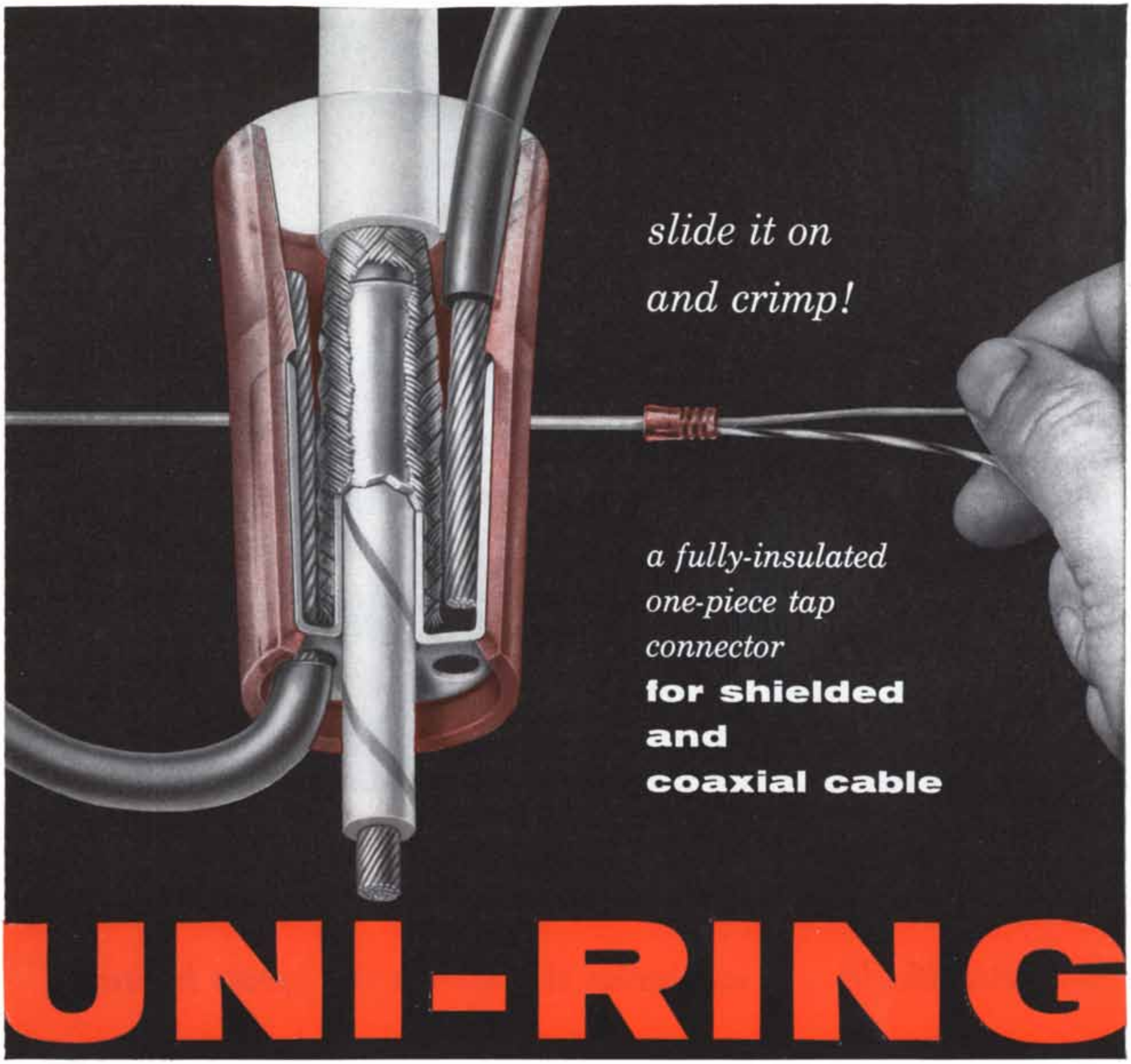

UNI-RING offers a tremendous saving in installation time over any previous method of tapping or terminating shielded or coaxial cable. As the inner ring slides under the shielded braid, the tap wire is held between the braid and the outer ring. Single or multiple taps, from either the front or back of the connector, can be accommodated . . . A single crimp, using the same basic HYTOOLS used for installing HYRINGS, completes the uniform, secure, and insulated assembly.

The protecting nylon insulation extends beyond both ends of the UNI-RING, eliminating metal-to-metal contact and preventing harmful wire-chafing in tight locations. The UNI-RING is color-coded to indicate conductor sizes.

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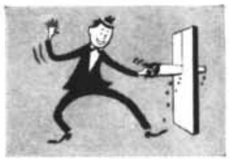

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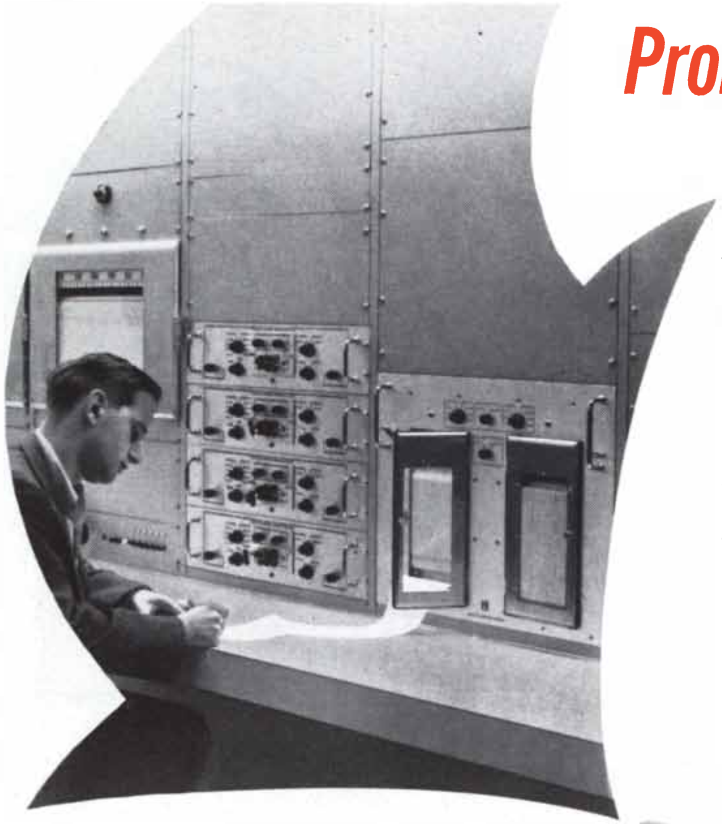

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Buffeted by air velocities upwards of Mach-2, aircraft models in N.A.C.A.'s new supersonic wind tunnel yield performance facts—put in writing by Brush Recording Systems.

Transient pressures at various points, as well as fluctuating aerodynamic forces are recorded clearly, accurately, instantaneously. Brush systems, noted for accuracy and dependable performance, record variables from d.c. to 100 cycles per second in immediately usable chart form.

Brush performance features—versatility, wide speed range, flexibility in application—have made these systems a standard in research and development work. Look to Brush for help in your measurement problems.

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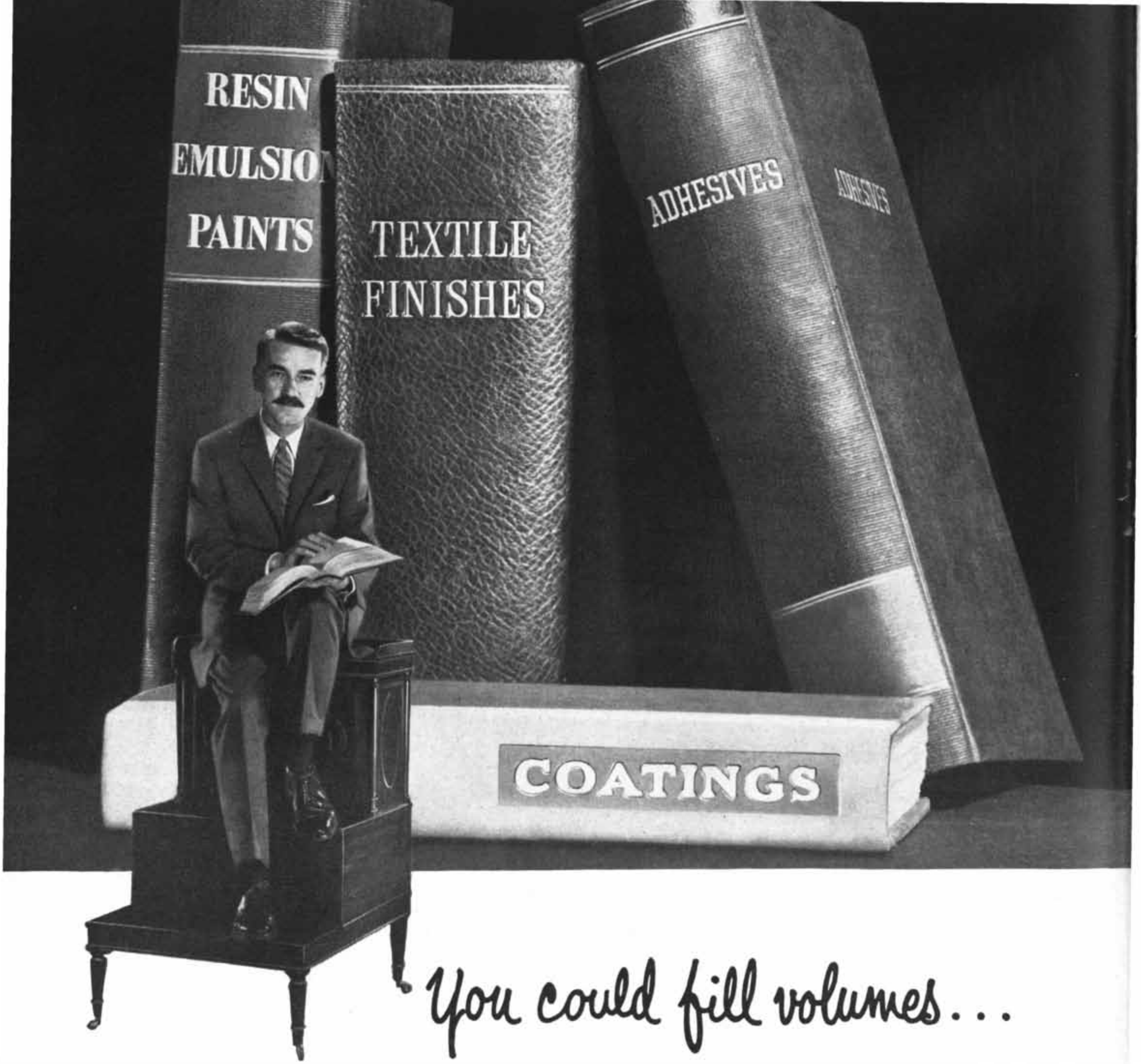
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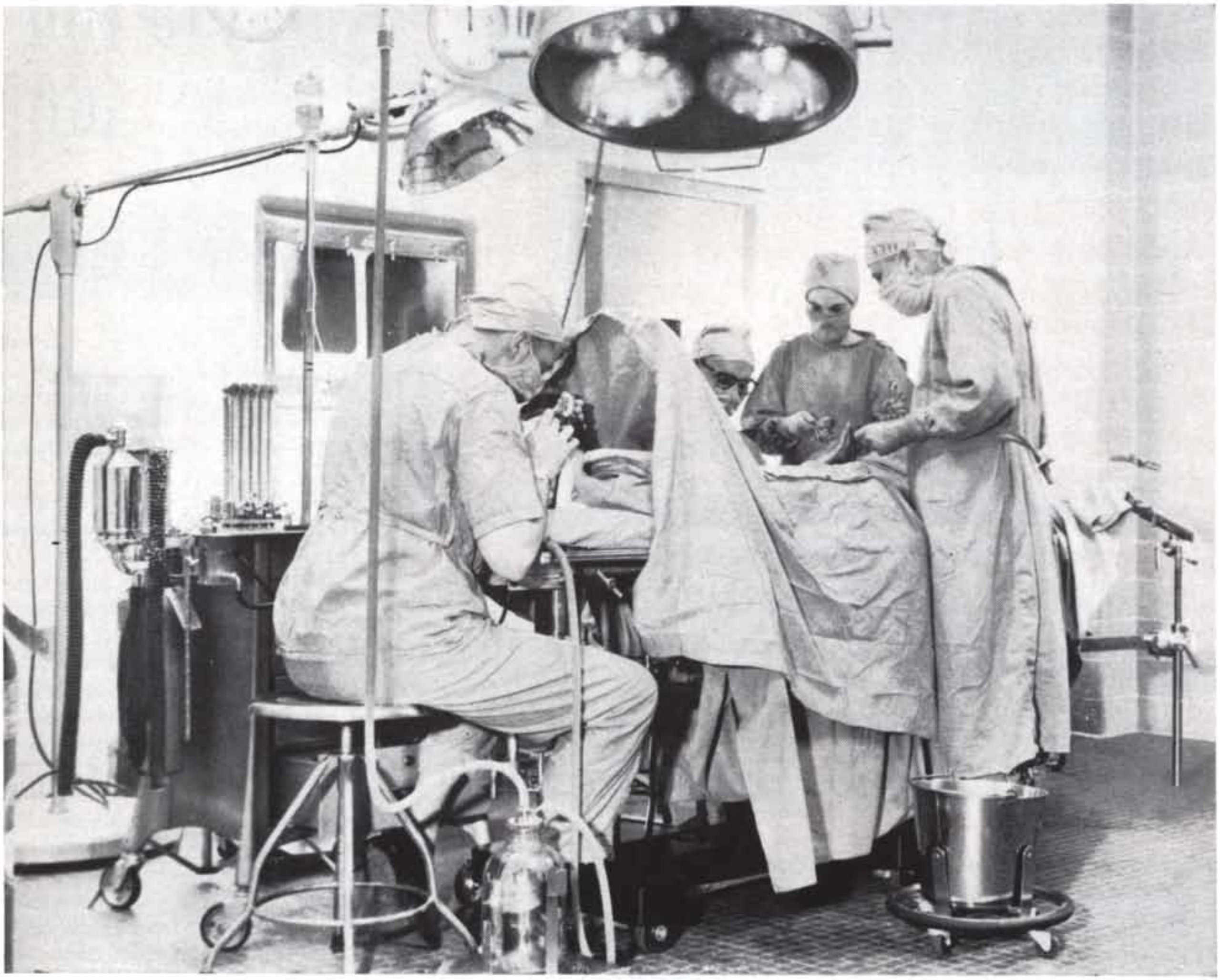

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50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

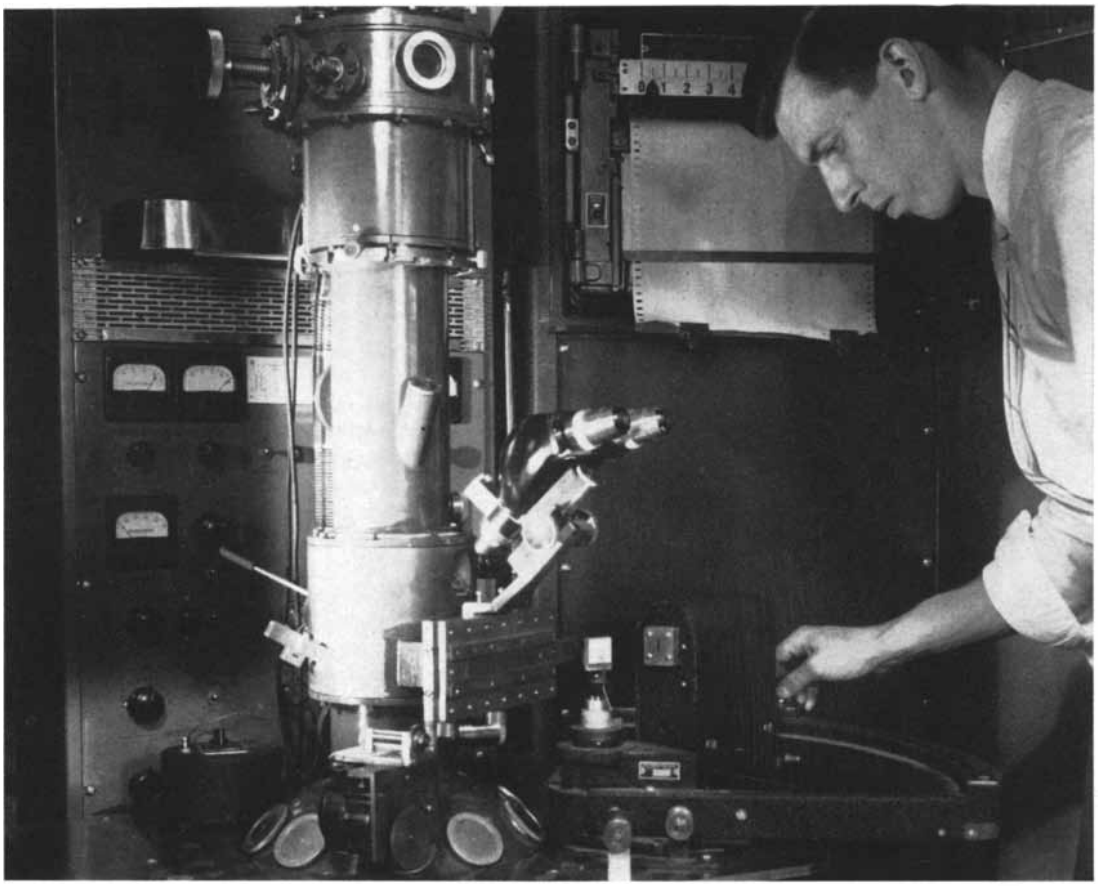
OCTOBER, 1906: "Drs. Calmette and Guerin of the Pasteur Institute of Lille have finally discovered a vaccine which will render humanity immune from the dreadful scourge of tuberculosis. Dr. C. Guerin, with regard to infection from tuberculosis and its remedy, says: 'Many experiments having demonstrated that tuberculosis bacilli destroyed by heat or other agents pass through the walls of the intestines as readily as living bacilli and are found in the mesenteric ganglions and lungs, we experimented with the object of discovering whether young animals, such as calves and kids, that had been made to swallow two doses, the second forty-five days after the first, of from five to 25 grammes of dead bacilli or bacilli whose virulence had been modified, could endure with impunity the injections of a meal of five centigrammes of fresh tuberculous matter taken from a cow, matter which would be surely infectious under ordinary conditions.' "

"In Norway Birkeland and Eyde have attacked the problem of fixing atmospheric nitrogen for fertilizer with such success that their plant at Notodden, started in May, 1905, may be destined to endure. The high-tension arc in this Norwegian process is produced between water-cooled electrodes of copper tubing, which electrodes are held in the middle of an electro-magnetic field and are connected with a high-tension alternator. With a working potential of 5,000 volts and an alternating current of 50 periods per second, disk-flames are produced which are inclosed in furnaces. By means of blowers, 2,649 cubic feet of air are gently forced through each furnace every minute, which amount of air after leaving the furnace is charged with about 1 per cent of nitric oxide. The temperature of the hot air is reduced from 1,292 deg. Fahrenheit to 122 deg. F. by sending it first through a steam boiler (the steam from which is used in making calcium nitrate) and then through a special cooler. After converting the nitric oxide into nitrogen per-

oxide, nitric acid is formed by sending the gases through towers filled with broken quartz over which water trickles. The solution is conveyed to tanks containing limestone, with which it reacts and produces neutral calcium nitrate. After evaporation, concentration and solidification the nitrate is obtained in marketable form."

"The fundamental value of tungsten for incandescent lamps lies in its enormously high point of melting, or volatilization. The specific resistance appears to be quite low as compared, for instance, with osmium or tantalum, so that the filament in a tungsten lamp is both long, requiring several loops in series, and extraordinarily slender. Like the osmium filament it seems rather plastic when hot and must, so far, be burned in a vertical position. The intrinsic brilliancy is very great as compared with any other incandescent lamp and the light is probably as nearly pure white as can be obtained. The extreme fineness of filament required for lamps of ordinary power suggests that the best use of the material at present is for lamps of large candle power, which would prove invaluable in replacing the blue flickering arcs of small amperage. A final result of this condition may be the displacement of the present inadequate 16-c.p. unit by 25 or even 40 c.p., thus placing the electric lamp in a better position with respect to the Welsbach. In any event, the carbon filament may soon be a thing of the past."

"Few papers read before the British Association for the Advancement of Science have attracted such wide attention or aroused such warm discussion among physicists as the address delivered by Mr. R. J. Strutt on 'Radio-Activity and the Internal Structure of the Earth.' Strutt's calculations are certainly plausible, even though we may not be ready to accept his radium theories entirely. The poorest igneous rock which he examined, namely, Greenland basalt, contains more than 10 times the proportionate quantity necessary to uphold the assumption that the earth's heat is due to radium alone. Because there is too much radium in the earth, Strutt has been forced to the conclusion that the interior of the globe does not contain radium. Curiously enough, Strutt's theory necessitates an assumption of the internal structure of the earth that is quite in harmony with the prevailing views of geologists. Strutt finds that the inside nucleus, heated by the crust of radium-containing material, must be at a uni-



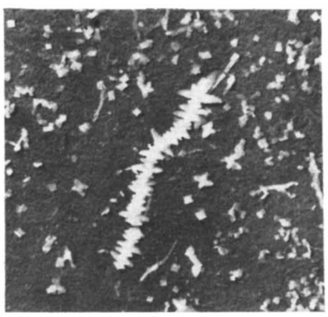
Crystal-gazing with Electrons

A NEW LOOK at—and into—the different tiny crystals or particles of metallic compounds which are found in the fine microstructure of steels is one way in which research teams at United States Steel are obtaining a more exact understanding of the elusive factors affecting steel quality and performance.

For this closer examination of steel's make-up, these investigators are using a variety of *electron* optical systems that are far in advance of ordinary laboratory procedure. For example, the delicately formed row of crystals (actually about 5 hundred thousandths of an inch in length) shown in the micrograph below were extracted from a polished and etched surface of steel containing 17% chromium and 0.34% titanium after prolonged heating at 2300F. Photographed by an electron microscope they were identified as particles of titanium carbide by the electron diffraction pattern taken from these same extracted crystals.

From information obtained in this manner, the metallurgist is able to chart more intelligently his heat treating and processing procedures to obtain optimum properties in a steel of given composition.

When it is not feasible to remove such crystals from the metal, their composition can be determined by a novel instrument, so far the only one of its kind in this country. This unique apparatus, shown above, is the X-ray point probe microanalyzer. It is shown in operation at United States Steel's Fundamental Research Laboratory, Monroeville, Pa.



At this magnification, the head of a pin would appear about 47 feet across.

With this ultra-modern equipment, fine precipitate particles, grain boundary areas or other microscopic regions of the "microstructure" in a steel sample can be bombarded with a beam of electrons focused to probe a minute area only a few hundred thousandths of an inch in cross section. By this means, even microscopic local variations in alloy content—for example, across the edge of a razor blade—can be observed.

As a result of electron bombardment the selected area emits X-rays which are characteristic of the elements it contains. These radiations are picked up and recorded by an X-ray detector enabling the investigator to determine quantitatively the composition of the tiny particle or area under investigation.

Precise laboratory measurements such as this are typical of the painstaking steps in the field of fundamental research by which United States Steel is proceeding to its goal of producing ever better, more uniform, high quality steels to meet the increasingly stringent demands of today and tomorrow. United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

UNITED STATES STEEL

form temperature of 1,500 deg. centigrade throughout, just as a loaf of bread, which has been in an oven long enough, acquires a steady temperature equal to that of the walls of the oven. Strutt's crust would contain about one thirtieth of the earth's volume."

SCIENTIFIC AMERICAN

OCTOBER, 1856: "It is a remarkable fact in the history of the useful arts that asphalt, which was once so generally employed as a durable cement, should have almost fallen into disuse for thousands of years. Some attempts have been made in this city to make a concrete pavement of it, but for this purpose it is evidently not equal to stone flags, because it has had to be relaid, and now huge cracks are again seen in different parts of it. On the other hand some beautiful mosaic asphalt pavement has been laid down in the streets of Paris, and is said to be perfectly successful. It is our opinion that iron pipes, coated inside and out with hot bitumen, especially the elastic kind, will prevent incrustation and render them very durable."

"A method of protecting stone with a solution of silicate of potash is now extensively carried out in Paris. It has been tested at the Louvre, Notre Dame, and other important works, and with success, it is stated. This solution is manufactured by fusing two and one-quarter parts of clean white sand with one part of potash by weight, then dissolving the product in about eight times its weight of boiling water. The stone work of the buildings to which it is to be applied is first cleaned, then troughs hugged with clay are placed against the part of the building intended to be silicated, so as to collect the solution, which is applied with a syringe at intervals of three or four hours for about four days, or till the stone (when dry) ceases to absorb. The phenomena of induration are thus explained:—The carbonic acid of the atmosphere separates the silica from the potash, leaving it deposited in the pores of the stone, when, should the carbonate of lime be present (as in limestone), it combines with it, and forms the silicate of lime, while the soluble salt—*viz.*, the potash—is removed by the rain or other means. This solution was tried on the new Houses of Parliament, in London, but without that success, it is stated, which has attended the French artists."

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In the top photograph, the fabrications you see are a mixing bowl, a tea-kettle base, a lock case and a patented shoe fastener: all made of A-L Type 201 or 202 chrome-manganese low-nickel stainless. The finish is good, the steel handled the same in the presses as Types 301 or 302, and similar drawing, buffing and polishing procedures were followed.

As in the lower illustration, the chrome-manganese low-nickel grades are being used also for fabrications as large as truck trailers and railroad coaches. Again, forming qualities and weldability present no problems, and results are entirely satisfactory.

Sum it all up and this is the answer: you *won't* encounter any particular differences in fabricating the 200-series of stainless steels . . . you *will* find some advantage in price, and a very important factor of much greater availability in times of nickel shortage. ● Why not take advantage of our pioneering experience with the low-nickel grades—let us help you use them. *Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.*

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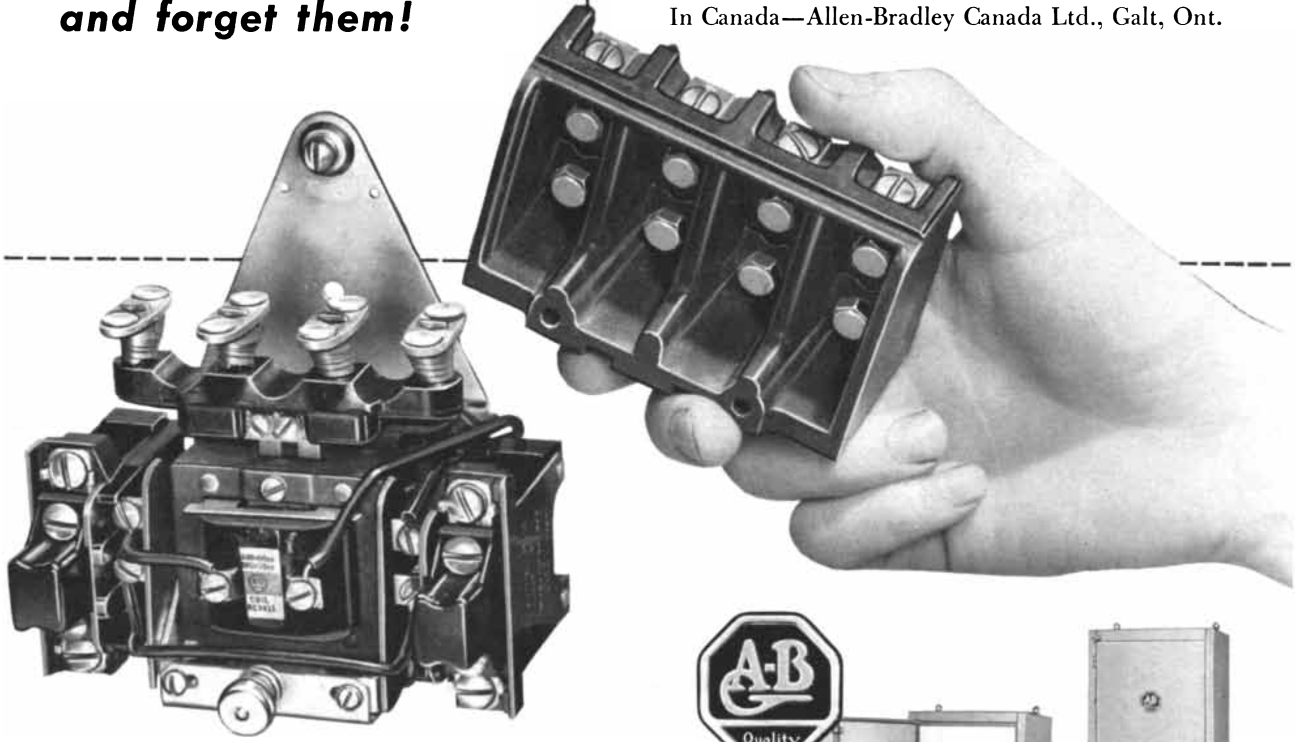

Bulletin 709 across-the-line solenoid starters are available in eight sizes. Maximum ratings: 300 hp, 220 volts; 600 hp, 440-550 volts.

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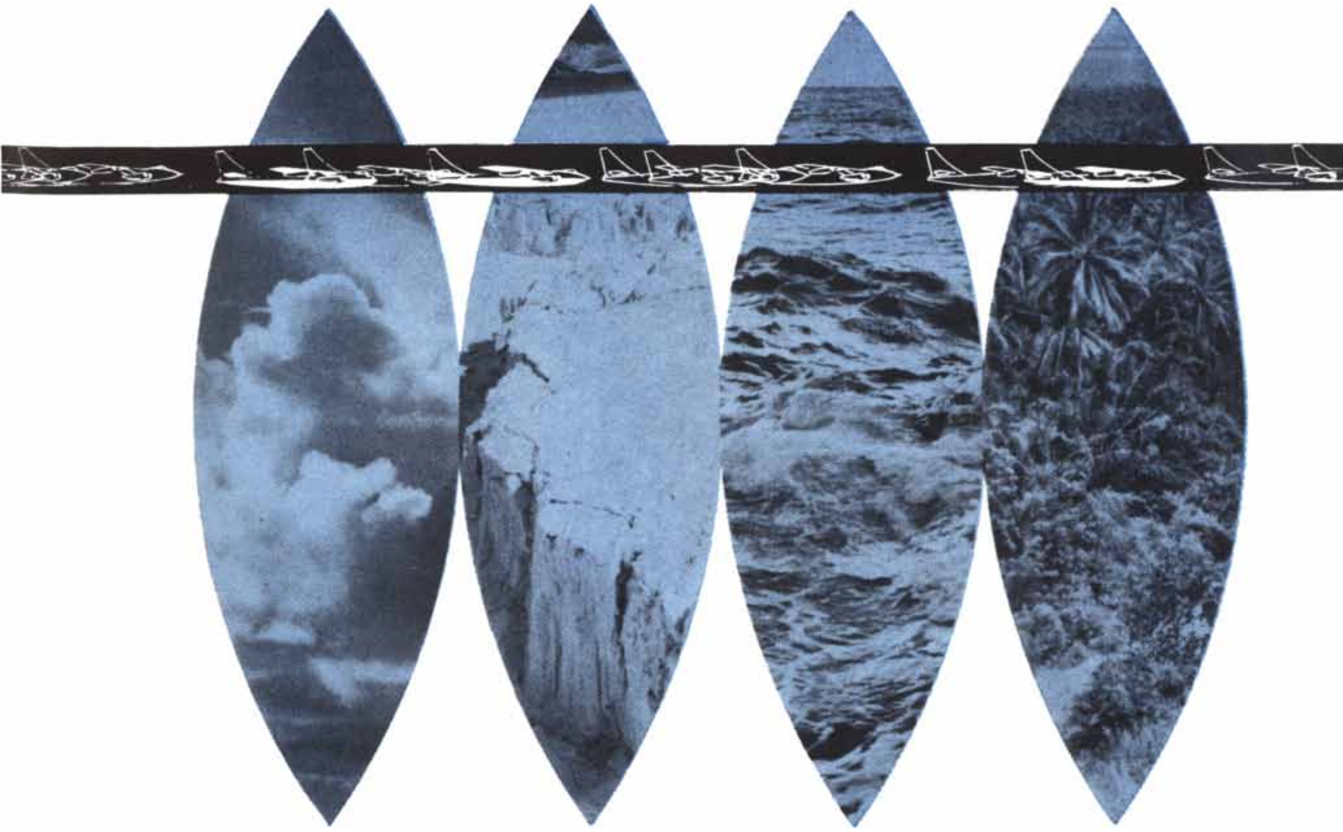

AN/APN-66 tracks unerringly through storms, over Arctic wastes, ocean, jungle

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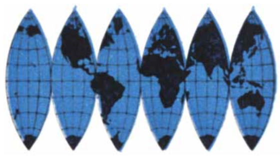

GPL — in conjunction with Air Force Weapons Guidance Laboratory — has produced the most advanced automatic air navigation system in operational use — AN/APN-66.

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The Doppler effect is the shift in the frequency of waves, sound or electrical, transmitted from a moving object to a stationary one. It is most familiar as the shift in the pitch of a train whistle as it approaches and passes. AN/APN-66 measures a similar shift in the frequency of electro-magnetic waves it bounces off the earth's surface below. From the difference in frequency between the original wave and its echo, the system computes the plane's speed and direction, then uses this data to keep continual track of the plane's position.

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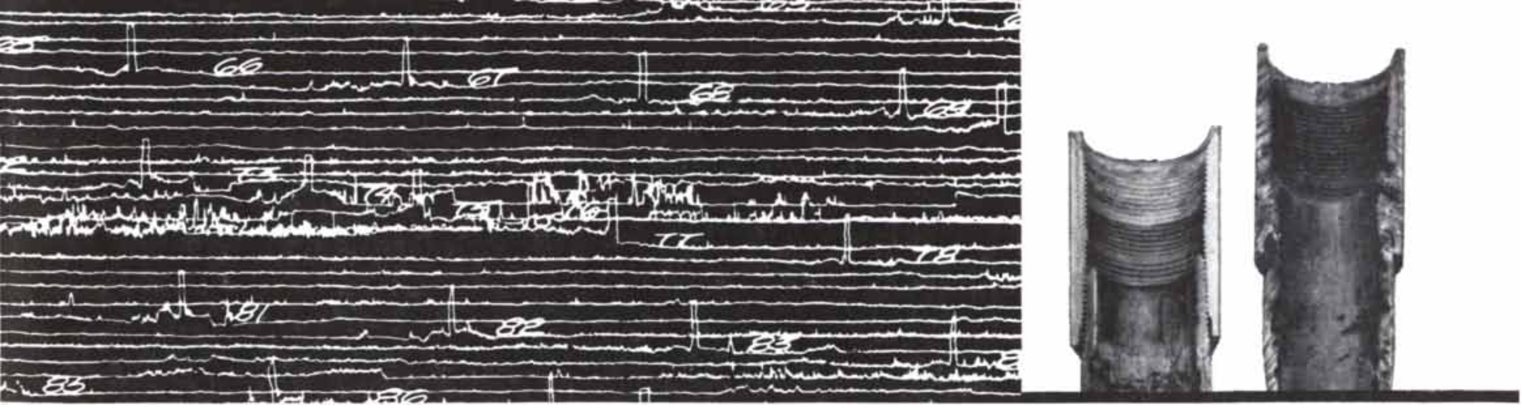
THE AUTHORS

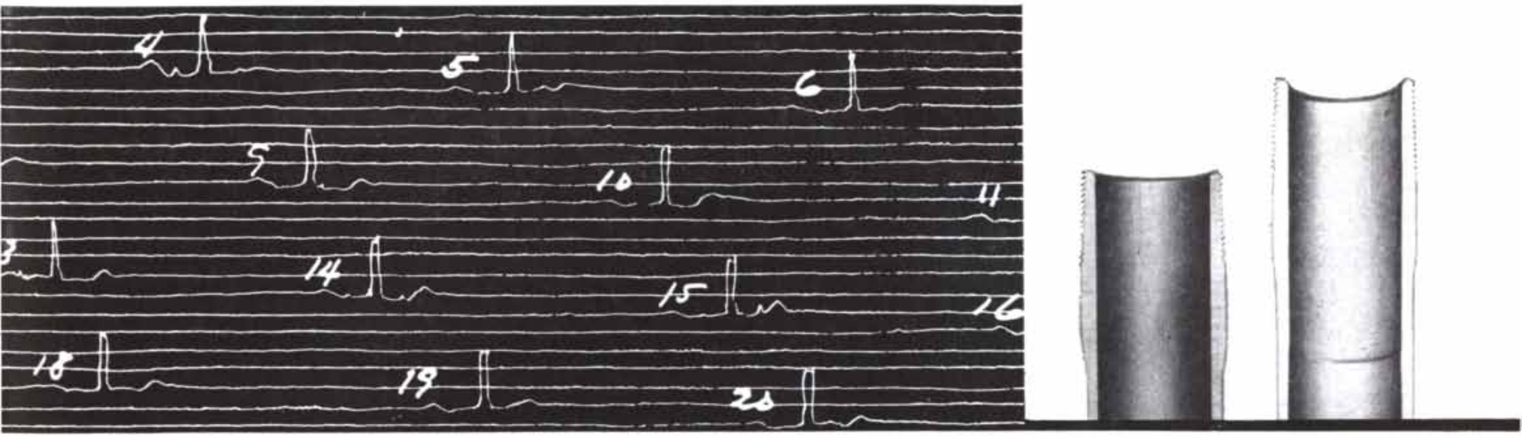
EUGENE AYRES ("The Fuel Situation") was manager of research for the Gulf Oil Corporation until he retired this year. He graduated from Swarthmore College in 1912 and began his career as a research chemist for Du Pont. After 1916 he was associated with P. T. Sharples, first in the Sharples Specialty Company and later (as partner) in the Sharples Solvents Corporation, before joining Gulf in 1929. A leading expert on energy sources and their utilization, Ayres is the holder of 41 patents. Among other achievements, he developed the first American processes for manufacturing diphenylamine, lanolin, amorphous petroleum wax, alcohols from alkyl chlorides, and for chlorination of hydrocarbons, esterification of mixed alcohols and resolution of industrial emulsions. He is co-author (with C. A. Scarlott) of *Energy Sources—The Wealth of the World*. In retirement Ayres is devoting his efforts to writing, including a book on the history of inventions, and (when time permits) to composing fugues. Mr. Ayres has written several articles for SCIENTIFIC AMERICAN.

JOHN J. BIESELE ("Tissue Culture and Cancer") is a professor of biology at the Cornell University Graduate School of Medical Science and a member of the Sloan-Kettering Institute for Cancer Research. Cells and cancer have interested him from the beginning of his professional career. After receiving a B. A. with highest honors from the University of Texas in 1939, he took his Ph.D. there in 1942 under T. S. Painter, writing his thesis on "The Karyology of Mouse Cancer." In his leisure time he enjoys swimming in Long Island Sound, gathering driftwood and indulging himself in what he describes as "an amateurish nature study including, among other things, the autocatalytic reproduction of boulders in Connecticut soil."

BART J. BOK ("A National Radio Observatory") left the Harvard Observatory last month for Australia, where he has been appointed director of the Commonwealth Observatory and professor of astronomy at the National University. Bok has been Robert Wheeler Willson professor of astronomy and codirector of the Radio Astronomy Project at the Agassiz Station at Harvard. Born in Hoorn, in the Netherlands, Bok studied astronomy at the universities of Leyden and Groningen. He came to Harvard in



A caliper survey was made to detect corrosion of oil-well tubing. Erratic "blips" on the survey chart indicate corrosion in well using ordinary inhibitor. Parts of two corroded tubes are shown at right.



Evenly spaced "blips" in this chart show no corrosion, merely indicate tubing joints in well using inhibitor containing Sunaptic acid. The tubes look like new. Both surveys taken after one year.

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Typical applications of Sunaptic acid derivatives include anti-oxidants, oil-soluble detergents, lubricant additives, plasticizers. A switch to a Sunaptic acid can possibly improve any product you're now making with fatty, rosin, synthetic, or ordinary naphthenic acids.

For full information on Sunaptic acids and their uses, see your Sun representative, or write SUN OIL COMPANY, Phila. 3, Pa., Dept. SA-10.

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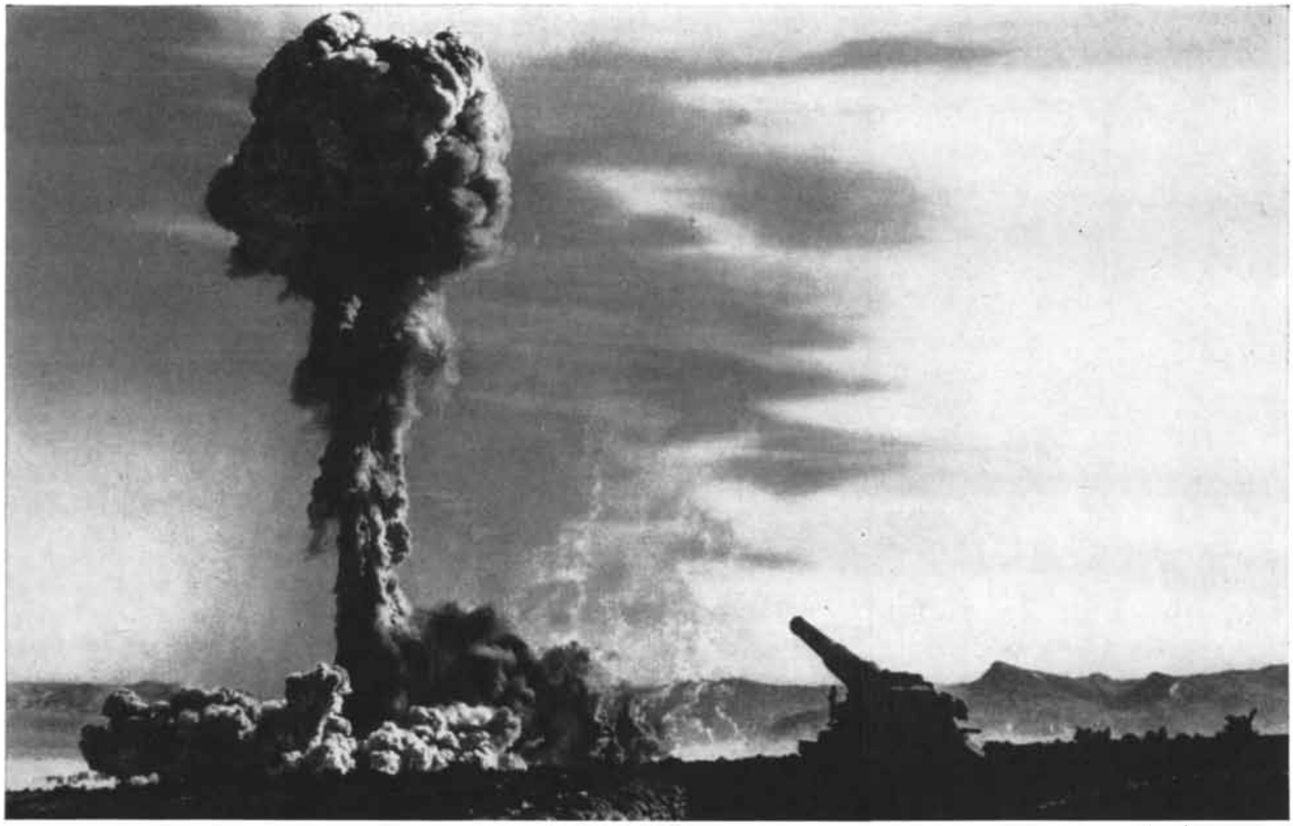
1929 as a fellow in astronomy and was appointed to the faculty in 1933. While Bok's research has dealt with many aspects of astronomy, his major interest lies in the structure of the Milky Way. Since the center of this galaxy can best be seen from the Southern Hemisphere, Bok undertook the planning and responsibility for installing the Baker-Schmidt telescope in South Africa, and in 1950-51 spent 18 months there in study [*see his article* "The Southern Sky," SCIENTIFIC AMERICAN, July, 1952]. It was primarily through his leadership that Harvard recently built the 60-foot radio telescope at Agassiz Station. Bok's wife also is an astronomer, and they have collaborated on a book on the Milky Way and in other writings.

NORMAN H. HOROWITZ ("The Gene") is professor of biology at the California Institute of Technology, where he took his Ph.D. in 1939. He has long been associated with George W. Beadle, first at Stanford and then at Cal Tech, in research on the biochemical genetics of *Neurospora*. Last year he worked at the *Institut de Biologie* of the University of Paris as a Fulbright and Guggenheim fellow.

SERGIO DEBENEDETTI ("Mesonic Atoms") is professor of physics at the Carnegie Institute of Technology. He was born in Florence in 1912, and studied in the Laboratory of Arcetri, near the hill where Galileo died. He took his Ph.D. at Florence, where he was associated with Bruno Rossi, the cosmic ray expert. In 1938 he left Italy for the Curie Laboratory in Paris, and there developed an interest in positrons. DeBenedetti has been in the U. S. since 1940; in 1946–1948 he was principal physicist at the Clinton Laboratories in Oak Ridge. His interest in elementary particles has led him to the special, and enjoyable, occupation of making atoms with new particles. As for hobbies, he says: "The thing I really like is to see the world, and with the excuse of physics and of cosmic rays I have touched all continents but Asia and Australia, a situation which I intend to remedy before too long. Of course I am interested in world affairs. I also like to draw and paint." DeBenedetti has been at Carnegie since 1949; he spent this summer working with the Cosmotron at the Brookhaven National Laboratory.

JAMES OLDS ("Pleasure Centers in the Brain") is engaged in physiological and behavioral studies at the University of California at Los Angeles. He was



U. S. Army Photo

Firing of 280 mm Atomic Shell at Las Vegas Proving Ground in May, 1953. This shell was designed jointly by Picatinny Arsenal and Los Alamos engineers and scientists.

ARMY ATOMIC MUNITIONS ARE BORN AT PICATINNY ARSENAL

Picatinny Arsenal at Dover, N. J., is composed of a group of Ammunition Development Laboratories responsible for Army ammunition technical development. Its responsibilities include research and development of ammunition for artillery, mortars, and recoiless rifles, mines, grenades, warheads for bombs and guided missiles, and rocket propellants.

One of Picatinny's principal laboratories is the Atomic Applications Laboratory, which is responsible for Army research and development of atomic munitions. This Atomic Applications group operates as the nerve center for all activities in atomic development for the Department of the Army.

To execute its mission responsibility, the Atomic Applications Laboratory draws not only on its "in-house" capabilities, but on the facilities of other Army arsenals, proving grounds, and on industry. Its "in-house" capabilities include an engineering technical organization that uses the full facilities and capabilities of the arsenal.

As well equipped as it is to solve the multitude of complex technical problems which confront it, Picatinny Arsenal has no greater asset than the long years of accumulated experience and unfailing loyalty of its career government employees. A recent example of its effectiveness is the crash program which resulted in the 280 mm Atomic Shell.

Picatinny's technical capabilities are utilized basically in expanding the frontier of mechanical, electrical and explosive development.

The scientific personnel in organizations such as the Atomic Applications Laboratory will determine America's ability to meet potential aggressors with the most effective Atomic Weapons possible.

This is one of a series of ads on the technical activities of the Department of Defense.

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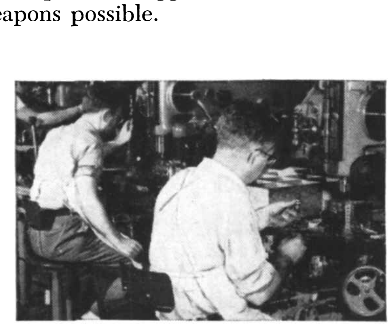

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born in Chicago in 1922, attended the University of Wisconsin, St. Johns College at Annapolis, and Amherst College, with three years out for the U. S. Army, and went to Harvard for his Ph.D. in social psychology. His wife received a doctorate in philosophy at Radcliffe in the same year. Olds later studied physiological psychology for two years with D. O. Hebb at McGill University. There he began the series of experiments discussed in his article.

EDWARD F. MOORE ("Artificial Living Plants") is a mathematician in the switching research department of the Bell Telephone Laboratories at Murray Hill, N.J. He attended Virginia Polytechnic Institute and received a Ph.D. in mathematics at Brown University in 1950. After working on digital computer programming at the National Bureau of Standards and the University of Illinois, he joined the staff of Bell Telephone Laboratories in 1951. Moore has done research on a wide variety of computers, ranging from game-playing machines to machines for designing relay circuits. His chief present interest is in the theoretical capabilities and limitations of automata.

W. H. THORPE ("The Language of Birds") is director of studies at Jesus College and a university lecturer in entomology at the University of Cambridge, from which he holds the degrees of Ph.D. and Sc.D. Born at Hastings in 1902, he developed his interest in bird behavior after a long and varied career studying the behavior of insect parasites, which has taken him to many parts of the world. He was a research fellow of the Rockefeller International Education Board at the University of California in 1927-29 and Prather Lecturer in biology at Harvard in 1951-52. Among the other places in which he has conducted research are Hawaii, Panama, Trinidad, Tanganyika, Kenya, Southern Rhodesia and the Yerkes Laboratory in Florida. Thorpe is now investigating bird song as a means of exploring the general relation between learned and inborn behavior. The Ornithological Field Station at Madingley, near Cambridge, where he is working, was established five years ago. Thorpe is president of the Zoological Section of the British Association for the Advancement of Science and president of the British Ornithologists' Union. He was elected a Fellow of the Royal Society in 1951. His book on *Learning and Instinct in Animals* will be published in the U. S. shortly by the Harvard University Press.

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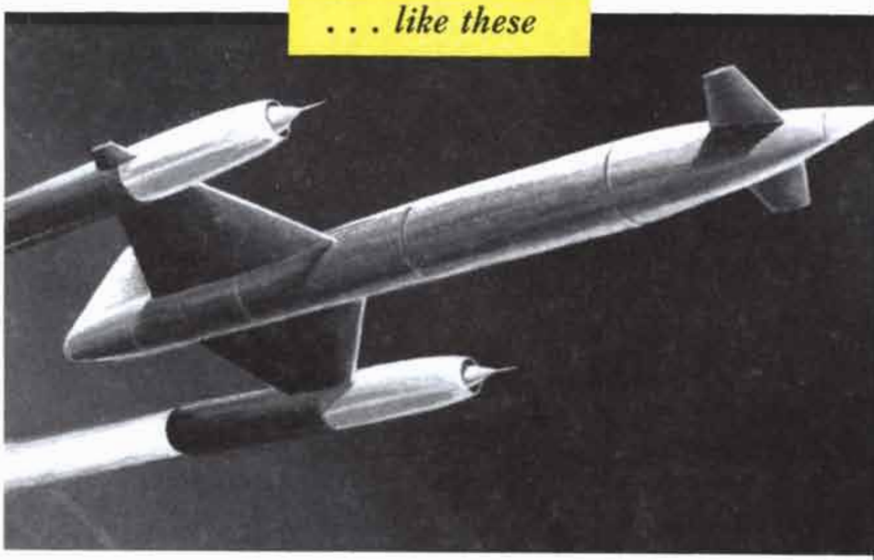

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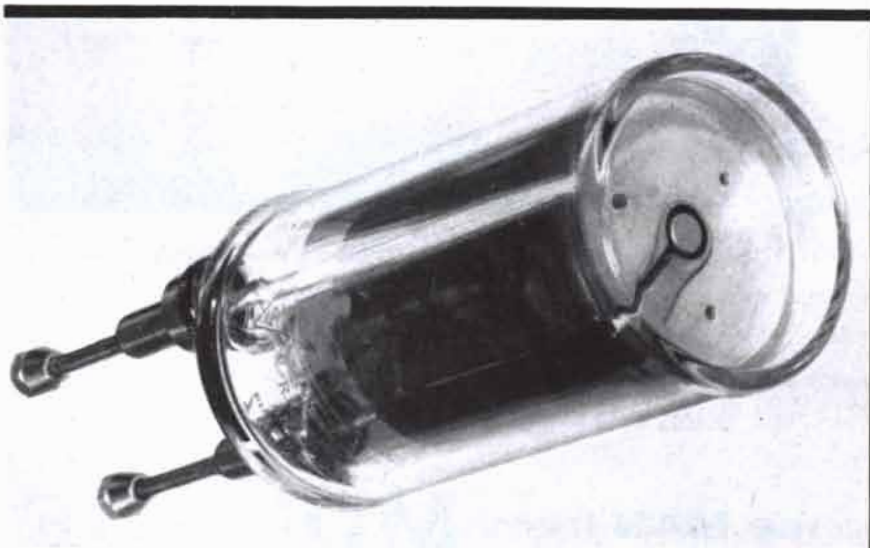

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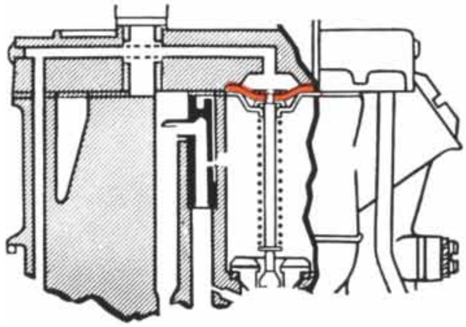
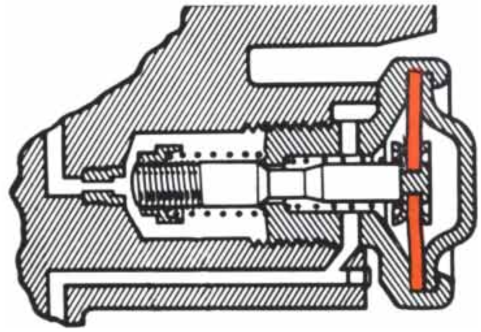
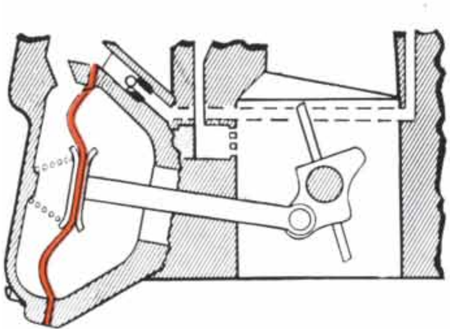


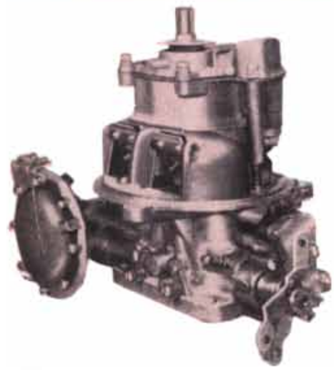
Economizer diaphragm (shown in red) functions automatically to control the correct amount of fuel for the fuel-air mixture. Du Pont "Fairprene" diaphragm resists aging—remains sensitive even in the presence of gasoline vapors at engine operating temperatures.



The acceleration pump diaphragm (shown in red) prevents backfiring or slowdown during sudden acceleration. Diaphragm must withstand severe flexing in the presence of gasoline vapor. "Fairprene" withstands this service with no flex cracking or deterioration.



Secondary throttle diaphragm (shown in red) regulates fuel on the four-barrel carburetor. This diaphragm must be sensitive and resist permanent set and drift. Dependable performance of Du Pont "Fairprene" helps explain the successful operation of the Holley carburetor.



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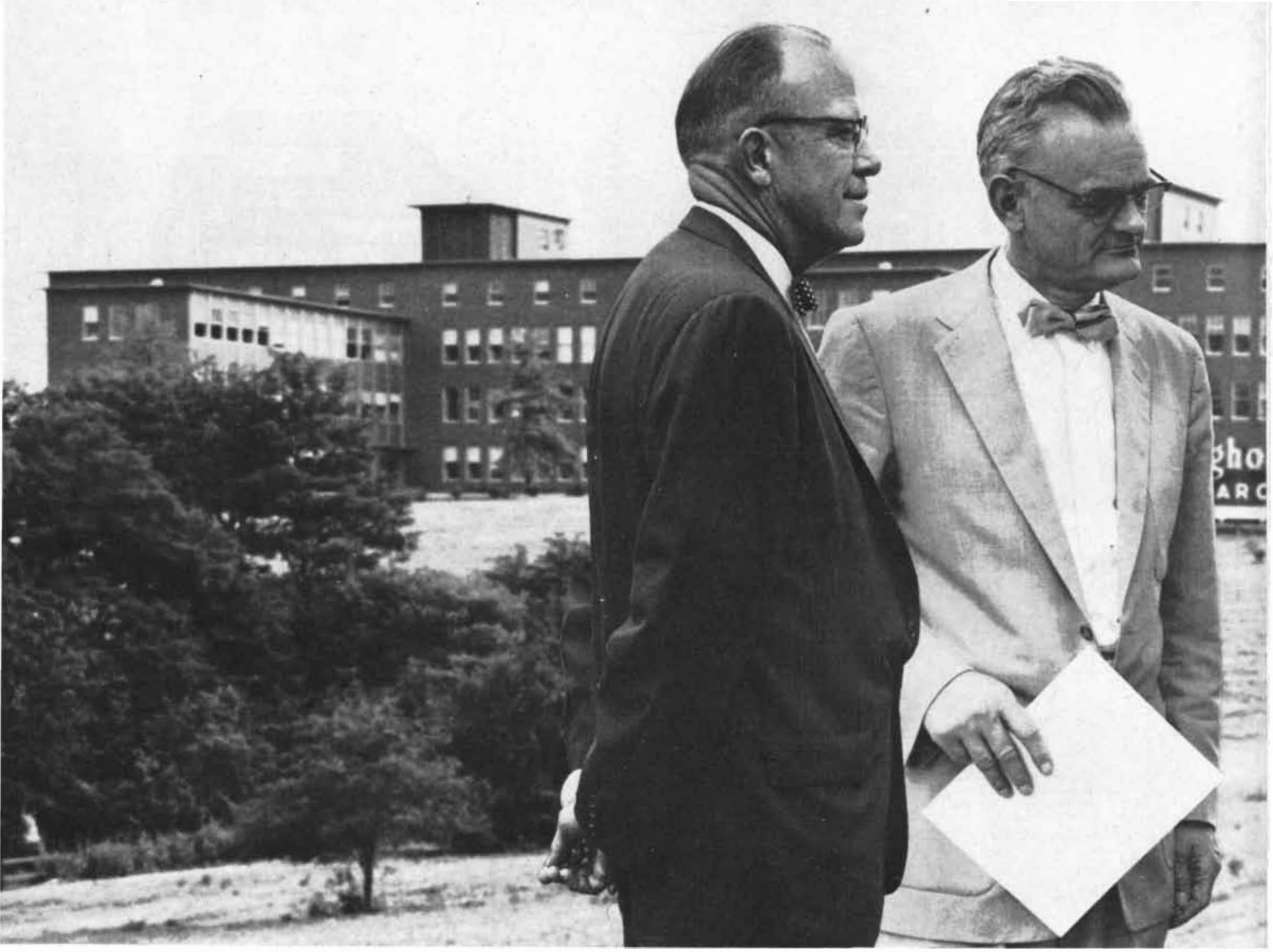

Pictured in front of new Westinghouse Research Laboratories are these key men:

DR. J. A. HUTCHESON
Westinghouse vice president in charge of engineering

DR. CLARENCE ZENER
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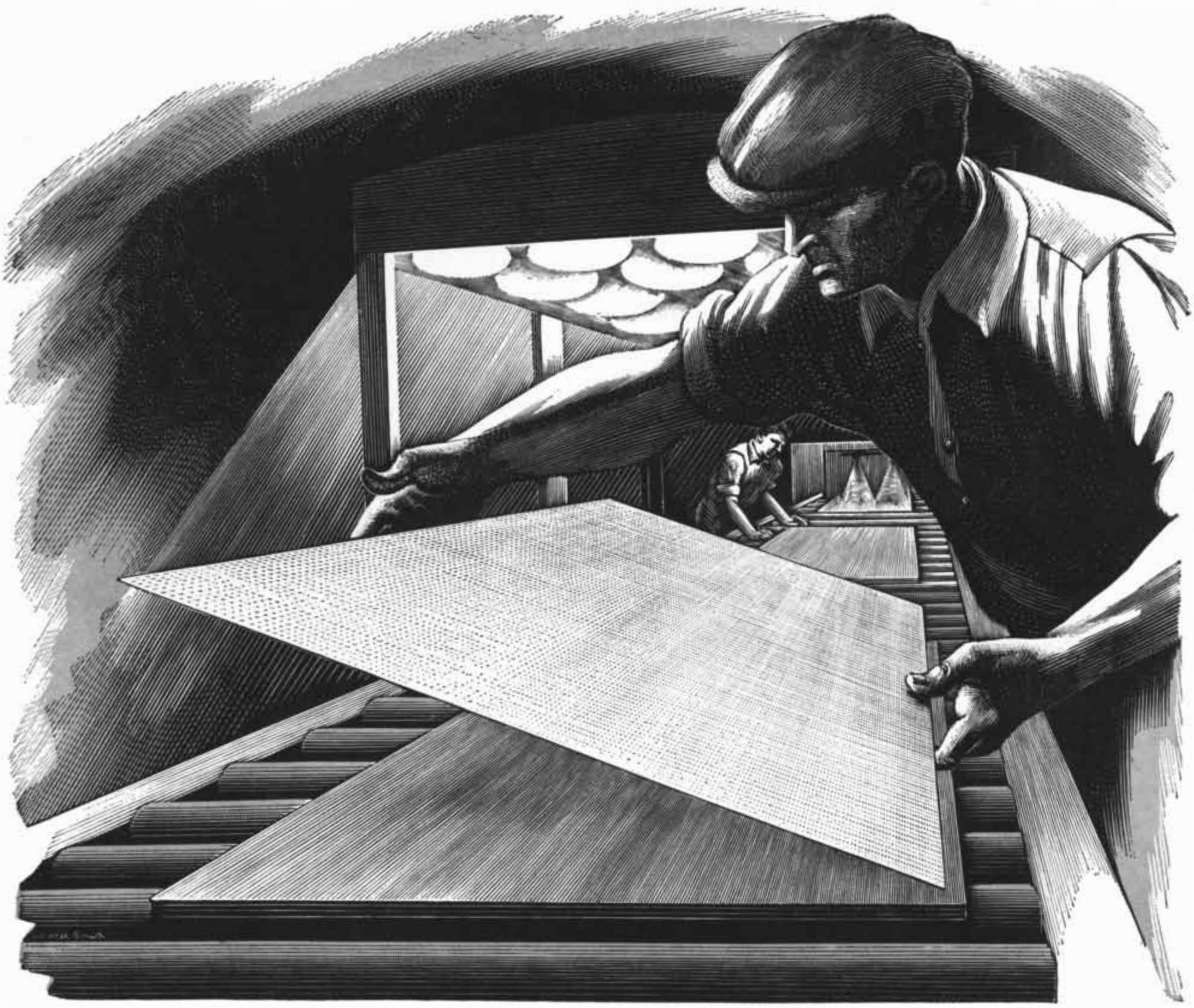

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The Fuel Situation

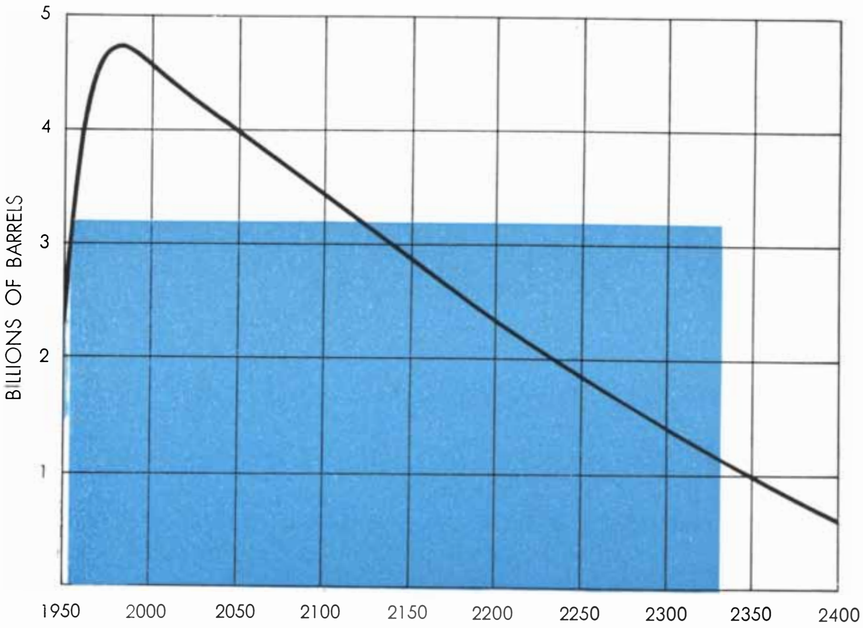
Earth's finite reserves of petroleum, natural gas and coal cannot continue to supply much longer the rising demand for energy. The development of new sources of energy must now have high priority

by Eugene Ayres

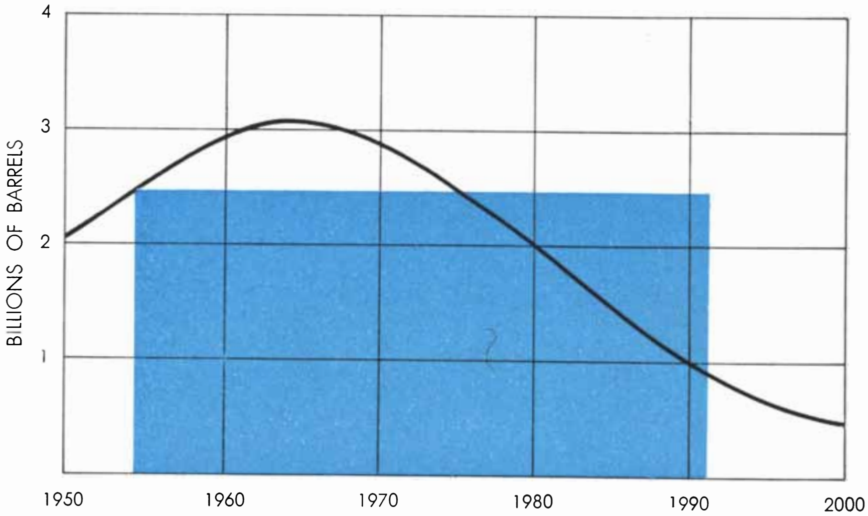
Every hour of the day and night three quarters of a million barrels of petroleum are being pumped into the fuel-burning devices of the world. The U. S. consumes about half of this torrent, most of it in the internal-combustion engines that have so radically transformed the American landscape and way of life during the past two generations. The consumption of liquid fuel continues to rise so fast that the world will be burning a full million barrels per hour within three years or so. It is drawing ever more rapidly upon the finite supply of oil in the earth. How do we stand today; how much longer shall we have oil to burn? Seven years ago, in an article here [see "The Fuel Problem," by Eugene Ayres; SCIENTIFIC AMERICAN, December, 1949], the author expressed the opinion that "allowing for all possible postponements, the day of petroleum shortages cannot be very far away." That day is now almost upon us.

Since 1949 the picture of the trends in petroleum demand and supply has become clearer. We can now forecast reliably that production of oil will begin to decline in the U. S. in 10 or 15 years and in the rest of the world not very

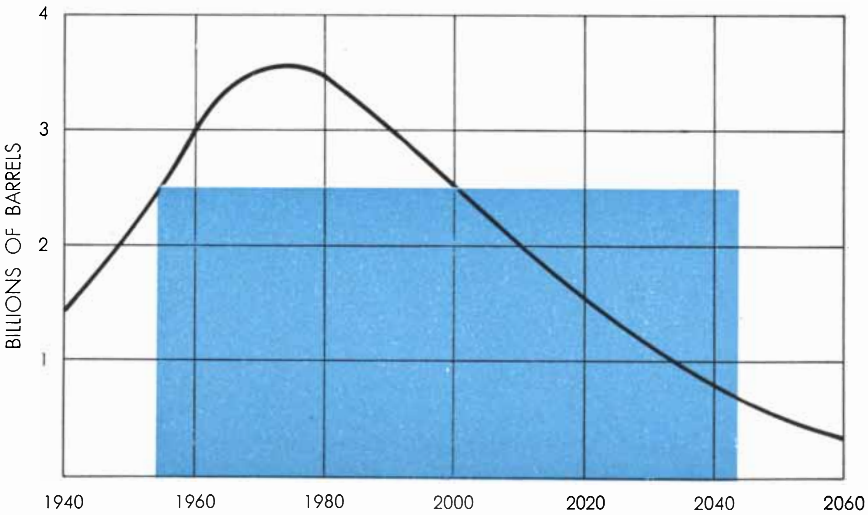
OIL WELL RIG in the Mississippi delta country of Louisiana taps one of the richest reserves of the U. S. The fields of the Gulf States extend offshore under the waters of the Gulf, where an estimated but unproved 20 billion barrels of petroleum may yet be recovered.



WORLD OIL PRODUCTION (*black curve*), assuming a total 1,220-billion-barrel reserve (*colored rectangle*), will reach its peak before the end of this century and then fall away.



U. S. OIL PRODUCTION will reach its peak during the next decade, if the present rate of increase continues and if the geological estimate of reserves at 87 billion barrels is sustained.



HYPOTHETICAL CURVE for U. S. oil production is based on an assumed 250-billion-barrel reserve, three times the geological estimate. This figure would only postpone decline.

long afterward. It seems certain that the world's annual production of petroleum will have fallen far behind demand by 1965. No conceivable new find of reserves could long postpone the evil day. We would be pleasantly excited by the discovery of a new 100-million-barrel oil field in the U. S., but such a field would amount to only a 12-days' supply at our current rate of consumption.

Nor can we take much comfort in other sources of fossil fuels. Natural gas will probably begin to decline in production by 1970. Oil shales and tar sands cannot possibly yield more than a brief supply of oil. As for coal, the bituminous beds of the eastern U. S. will be so depleted by 1970 that we shall either have to pay higher costs or find ways to use coals of poorer quality. It is doubtful that we have enough economically minable bituminous coal to justify the investment in plants necessary to convert it into liquid fuel.

In short, all the signs indicate we are within sight of the end of the fossil fuel era on our planet. Our technology must press rapidly ahead to the development of other sources of energy. And we must exercise the full ingenuity of modern research and invention to utilize our remaining resources of fossil fuels with maximum efficiency and economy.

What is the basis of these forecasts? It is instructive to look at the situation in some detail.

Even if the world had unlimited reserves of petroleum, it would still face a temporary shortage in the near future. U. S. domestic production began to run seriously behind consumption in 1948. To make up for this we have had to depend upon imports. Our imports have been increasing at the rate of 70 million barrels a year and this year will come to nearly 500 million barrels. Meanwhile the consumption of oil abroad has been increasing at the rate of 10 per cent per year. Germany, because of its domestic coal shortages, is increasing its consumption of petroleum at the rate of 20 per cent per year. Recently Great Britain has given up hope of improving its coal output and is committing its technological future to liquid fuel. By 1959, if present trends continue, the demand for petroleum outside the U. S. will reach 3.9 billion barrels. Foreign production now stands at 3.2 billion barrels and has been increasing at an average annual rate of 230 million barrels. Few technologists believe that this rate of increase can be improved upon during the next three years. If it can be maintained, production in the rest of the world will just equal its demand, at 3.9 billion barrels, in 1959. On the other hand, by 1959 we shall probably need no less than 700 million barrels in imports from foreign fields. That 700 million barrels is a measure of the world shortage now in immediate prospect.

This calculation, of course, assumes continuation of present trends. The U. S. could ameliorate the pinch by stepping up domestic production closer to its potential capacity, but the need for a military reserve makes this undesirable. The rate of increase in oil consumption might be slowed by a world-wide economic slump, or production might be accelerated by an increase in investment. But no such drastic shifts in trends seem to be indicated. The best guess for the next three years, therefore, indicates a world-wide shortage of nearly 250 million barrels in 1957, rising to 700 million barrels in 1959. Of course this shortage is not apparent, for it is masked by economy in fuel use and substitution of other fuels. But it is reflected in the rising price of liquid fuel and in the sharpening tensions of political contest for control of the world's oil fields.

We are misled by the fact that the curve of petroleum production is still rising sharply in the U. S. and abroad. But it is in the nature of such a curve that things look better and better until they begin to look worse and worse. The curves of oil production for individual oil wells, oil fields, states and countries all follow much the same pattern: they rise to a peak and then fall gradually. All the important oil fields in the U. S. opened before 1940 and nearly all those tapped before 1945 have now passed their peak; so too has oil production in nine states of the U. S. and eight entire oil-producing countries abroad.

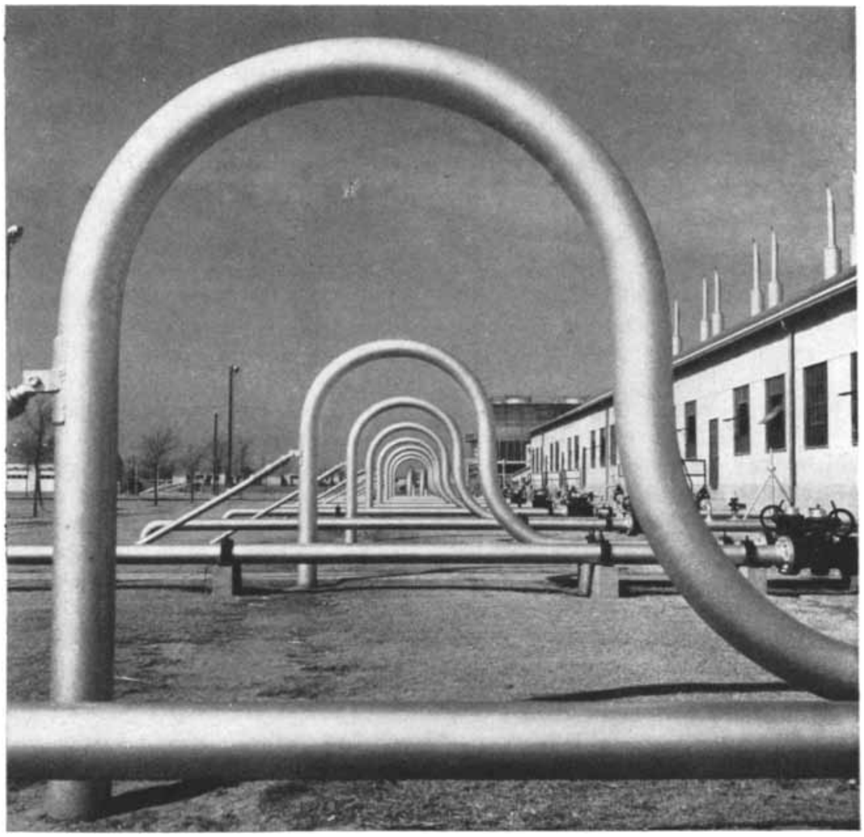
Let us use the available data to project the curves of supply and demand for the U. S. and for the world as a whole. Nearly all current discussion of U. S. and world petroleum reserves is based upon the scholarly work of Lewis G. Weeks, chief geologist of the Standard Oil Company of New Jersey. Experience since 1940, when he first began to publish, has sustained the soundness of his estimates. Long before the major centers of the Near East and western Canada came under exploitation, Weeks had correctly predicted their potential. No good reasons have been advanced for drastic modification of Weeks's figures for the onshore reserves of the U. S. and the rest of the world.

Using estimates published by Weeks in 1950 and deducting production since then, we get 67 billion barrels as the remaining onshore reserve of the U. S. About half of this has been proved by drilling. The Weeks figure for the rest of the world is 600 billion barrels. Of this about one fifth has been proved; Weeks believes that the total foreign reserves may be as much as 50 per cent larger than his estimate.

Offshore oil—in the continental shelves extending from fruitful fields on land—will not add a great deal. U. S. offshore reserves, mostly in the Gulf of Mexico, have been estimated by geologists between 10 and 20 billion barrels. In the rest of the world they have been estimated around 300 billion barrels—mostly under the Mediterranean Sea. Here we are in an area of wide divergence of opinion. Apart from the uncertainty of offshore geology, obstacles to production put the reserves in doubt. It is generally believed that most of this oil cannot be produced until new engineering methods are developed.

Taking the largest reasonable estimates, we get 87 billion barrels for the total U. S. onshore and offshore reserves and 1,280 billion barrels for the rest of the world. The accompanying charts [*opposite page*] forecast the curves that U. S. and world production from these reserves are likely to follow, on the basis of a set of assumptions derived from experience. Providing that new discovery—the proving of reserves—keeps pace with rising demand, we may expect that production will continue to rise for a few years at the present rate, then flatten out gradually before it turns downward. The curves thus drawn reach their peak around 1965 for U. S. production and around 1980 for the rest of the world.

The date of these peaks cannot be much affected either way by changes in the assumptions. If the rate of discovery should lag, for example, the dates of the production peaks would be postponed for a few years, but the shortage during the intervening years would be greater. If discovery runs ahead, it may speed production, but in that case the reserves will be exhausted sooner. The dating of the peaks of production is not affected much if we assume that the total reserve is greater than estimated. Because consumption is rising so rapidly, even a 50 per cent increase in reserves would post-



COMPRESSOR STATION in Oklahoma gathers natural gas from the great Hugoton field and pumps it to market centers. Loops in pipes provide slack for expansion and contraction.

WORKED-OUT COAL MINE in Ohio is graded by bulldozers in first step toward reclamation of land. This strip mine was worked by power shovels. Grading will reduce erosion.

pone the peak dates only a few years, though it would increase the height of the peaks.

From this analysis it is apparent that the shortages indicated for the next few years by current trends in supply and demand are of minor consequence compared to the shortages to be expected a few years later. Demand will still be on the rise when production begins its inexorable decline. If we projected demand forward at its present rate of increase, by 1975 the U. S. would want twice as much oil as it is likely to be able to produce from its own wells, and the rest of the world would itself fall short of its own demand. There are important political and economic implications in the prospect that serious shortages will come to the U. S. before they are felt abroad.

Before we consider the various paths that technology may take around this impasse, let us look briefly at the prospects that the other fossil fuels afford. Some of the burden of demand for petroleum during the past 20 years has been taken over by natural gas. It is the most convenient of all fuels for furnaces and stationary engines. Since 1940 natural gas production in the U. S. has been climbing faster than that of petroleum; its average annual increase has been 8 per cent. How long can this go on? A number of uncertainties make it difficult to estimate gas reserves as definitely as oil. Some gas is produced with oil and some from wells that yield gas but no oil. Almost 70 per cent of our present proved reserve is made up of the great stores of nonassociated gas first discovered about 30 years ago. Relatively little nonassociated gas has been found in this country or abroad since the 1920s, and most experts doubt the possibility of future strikes like the Carthage field in Texas or Hugoton in Kansas. The discovery of gas associated with oil has provided almost all of our recent additions to proved reserves. Because drillers have been going deeper for oil, the ratio of gas found with oil has been increasing. Very deep wells may yield gas under extremely high pressure. This and other complicating factors make it difficult to estimate volume. In the case of one gas field three experts appearing before the Federal Power Commission presented three different estimates of 865, 1,600 and 3,200 billion cubic feet, respectively.

The total reserve in the explored fields of the U. S. is estimated at 250 trillion cubic feet, which represents a compromise among experts rather than a firm figure. To predict the date of peak production we need a figure for unproved along with proved reserves. Geological estimates range from a low figure of 150 trillion cubic feet to a high of 350 trillion. Taking the larger figure we get 600 trillion cubic feet as the total area to be brought under the production curve. The curve [*see opposite page*] is projected on the conservative assumption that production will increase at 4 per cent, half the present rate, over the next few years. The peak is further flattened by consideration of the fact that gas production requires considerable investment in pipelines. As we get closer to the peak, entrepreneurs will hesitate to build new lines if they are not assured that the gas will last long enough to amortize their investment. With these assumptions, the peak of gas production may be predicted to occur between 1965 and 1970, at around 13 trillion cubic feet per year.

Let us consider next the reserves of oil shale, of which the U. S. has an estimated 55 per cent of the world supply. If we could exploit our entire oil-shale resource, we could reckon it as equivalent to 1,000 billion barrels of petroleum. But most of the material assays at five gallons of oil or less per ton of shale and may never prove economic for extraction of fuel. Our richest deposit is in Colorado, where the Bureau of Mines estimates that 1,000 square miles might be amenable to commercial development. But most of this deposit is believed to assay at no more than 15 gallons per ton. Recovery of oil from this material would run quite a bit higher than the pilot plant figures that bring shale oil in sight as a substitute for petroleum. Realistic speculation must be restricted to the part of the 1,000 square miles that appears to assay around 30 gallons per ton. This rich shale, in the famous Mahogany Ledge, is estimated to contain 126 billion barrels of oil. The Bureau of Mines has calculated that from one to two million barrels of oil per day could be developed from Colorado oil shale in about 20 years. The limiting factors would be the availability of water in that arid region for processing the material and the problem of disposing of the oil-shale ash. Even from rich shale a million barrels of oil per day would mean a million tons of ash per day.

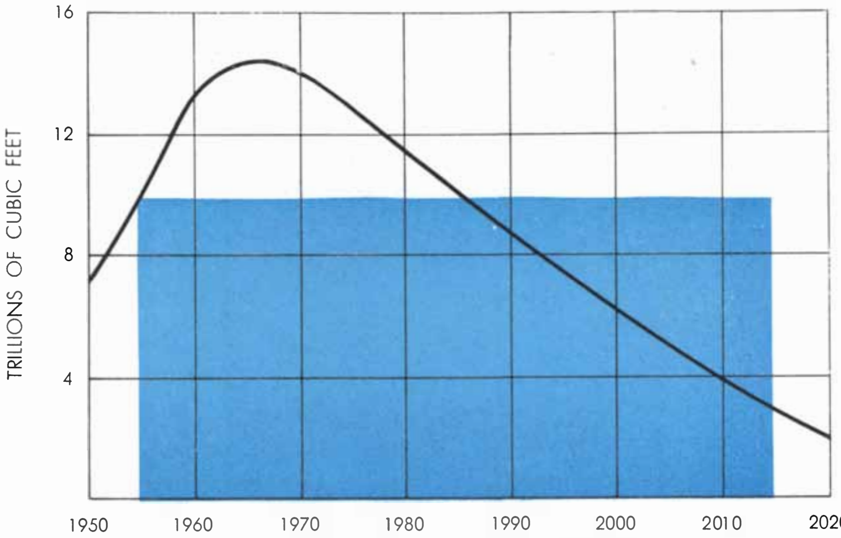
If the Bureau of Mines estimate is realistic, the peak of production for this lower-cost shale oil would probably come to an annual rate of about 1.5 billion barrels at the end of the century. This projection is beset by such uncertainty that it should not be taken too seriously. But it probably represents the best that can be expected. It shows that shale oil can make at best only a tiny dent in the oil-shortage problem.

Tar sands seem even less promising. Estimates of the recoverable oil in the tar sand beds of Athabasca in northern Alberta range from 100 to 300 billion barrels. But nearly all of this lies from 50 to 250 feet underground. The oil could be produced, but at rather fantastic cost. About one billion barrels could be recovered from the Athabasca tar sands accessible to surface mining. Some of this may be recovered before the end of the century and will extend the world's supply of liquid fuel a month or two. An additional one or two months' supply may eventually be obtained from tar sand deposits in several states in our country.

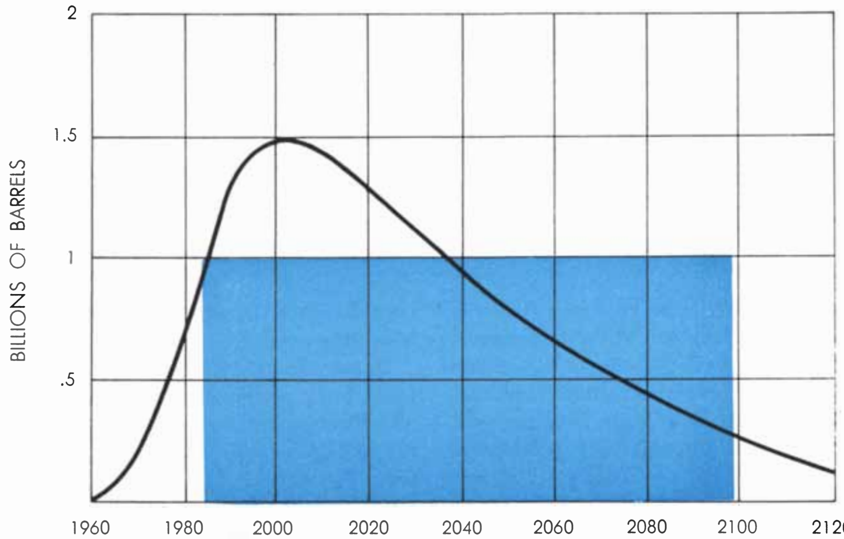
Until recently concern about future fuel supplies could be relieved by the notion that we had enough coal to last us for "thousands of years." The U. S. Geological Survey early in the century had estimated our coal reserve at 3.4 trillion tons. This total included the immense deposits of lignite and subbituminous coals in the western states. During the past decade the size of the coal reserve has shrunk to a supply for "hundreds of years." A reappraisal by the U. S. Geological Survey now under way has scaled down the total to 1.9 trillion tons, with further reductions "in prospect." At the same time, mining engineers have been arriving at a consensus that the economically recoverable coal may amount only to about one tenth of the geological estimate. The readily accessible coal—beds 28 inches or more thick at depths of no more than 1,000 feet—totals less than 100 million tons. Another 400 billion tons are estimated to lie in beds of adequate thickness at depths between 1,000 and 2,000 feet. Some authorities project a figure of 250 billion tons as our total producible reserve.

If we are talking about coal as we mine it and use it today in our industrial system, we must cut this figure even further. The grades of bituminous coal important in the manufacture of coke for the blast furnaces of our steel industry will amount to only a few hundred million tons until we dig deeper than 1,000 feet. We can figure that we have about 27 billion tons of fuel-grade bituminous coal that can be produced at something like present costs.

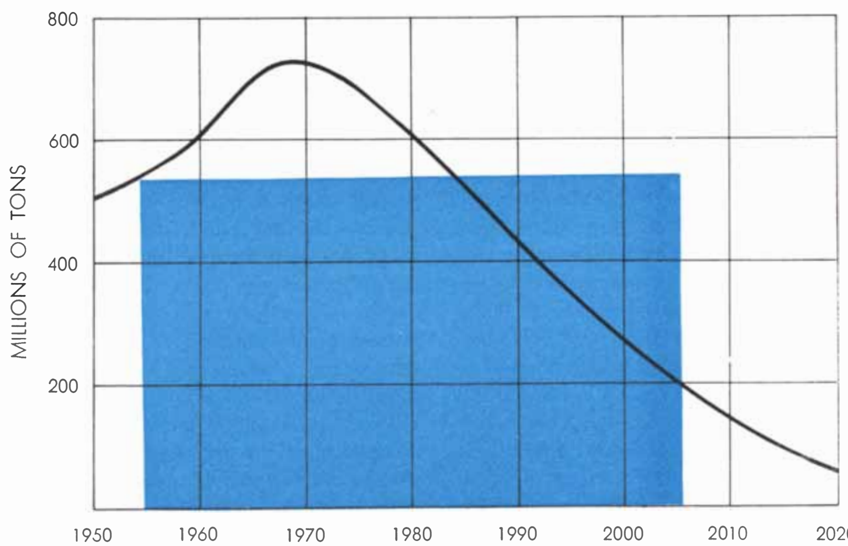
The pressure of our economy on this reserve of "cheap" bituminous coal has been reduced during the past 25 years by heavy replacement with oil and gas. We can expect to see a much heavier demand for coal during the second half of this century. Oil, which has replaced 100 million tons of coal per annum in household and industrial furnaces, now is on its way out as a coal competitor, for the obvious reason that it is becoming more profitable to convert it to motor fuel. Electric power production, which consumes an important fraction of our annual output of 500 million tons of coal,



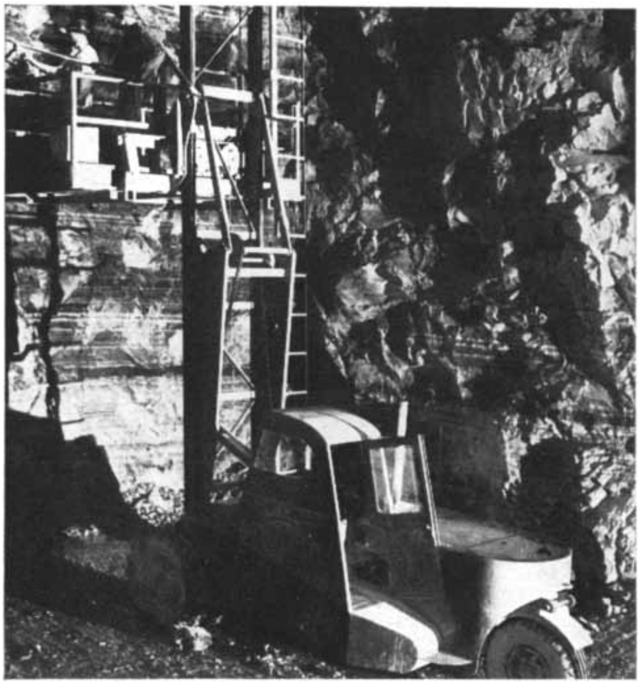
NATURAL GAS reserve of the U. S. is estimated at 600 trillion cubic feet (*colored rectangle*). Production of this reserve at present rate of increase will reach its peak before 1970.



OIL SHALE of the U. S. is estimated at 126 billion barrels recoverable from high-grade shale. Rising price of oil may soon make exploitation of this reserve economically feasible.



COAL reserve of the U. S. comprises 27 billion tons of present commercial quality and cost. Production of this coal, now increasing at accelerating rate, will reach its peak around 1970.



OIL-SHALE MINING methods were developed by Bureau of Mines engineers at Rifle, Colorado. The picture shows mobile platform used for charging blastholes in the working face of the mine.

OIL-SHALE ASH, making a dust cloud at foot of the retorting plant, presents a major problem of disposal. Even rich oil shale, assaying at 30 gallons per ton, yields a ton of ash per barrel.

is rising at the rate of 8 per cent per year. Taking account of these demands, and making no allowance for conversion to liquid fuel, coal production should begin to rise at about 3 per cent per year around 1960. On this basis production from our bituminous coal reserve will pass its peak around 1970, and the pinch of shortage should be felt before 1965.

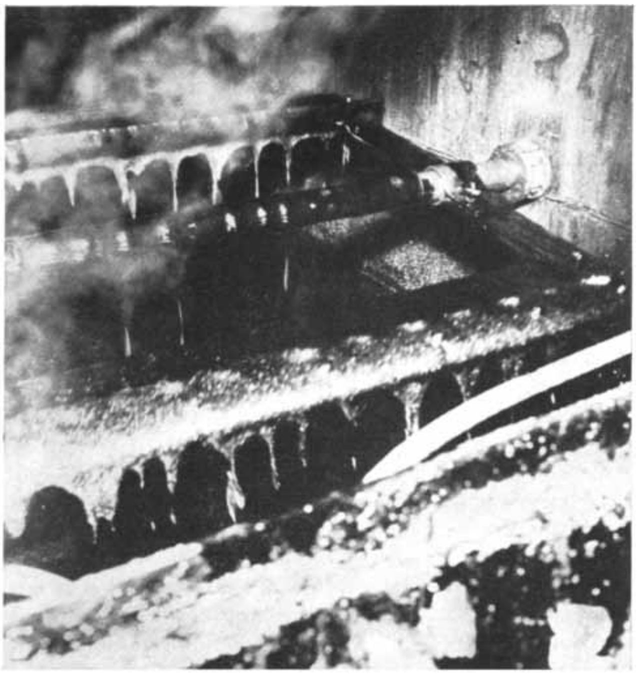
The shortage can be made up, of course, by mining coal of good quality at higher cost and by using coals of poorer quality. But it now seems clear that if we are to use coal to make liquid fuel, we shall have to convert sub-bituminous coal and lignite. This will require the development of cheaper and less wasteful processes than those that have been employed so far. An estimated 21 billion tons of sub-bituminous coal and lignite can be mined economically. Some of this contains too much moisture and ash to be used efficiently as boiler fuel. Low-temperature carbonization, however, yields a char which is often an excellent boiler fuel and a tar which can be converted to motor fuel. This has already started on a moderate commercial scale. Engineering concerns are promoting the idea and the process has high priority in several industrial laboratories. The time may come when the burning of bituminous coal instead of char will be considered as wasteful as the old beehive coke oven.

In sum, the production curves for the fossil fuels projected in this discussion all indicate that the peak of the fossil fuel era will come before the end of this century. The weight of this prediction is increased by the fact that we cannot expect to recover all of the reserves within the economic framework to which our present technology and habits of use are adjusted. This applies especially to petroleum. It is possible that only about one third of the world's remaining oil can be produced at anywhere near the present cost range.

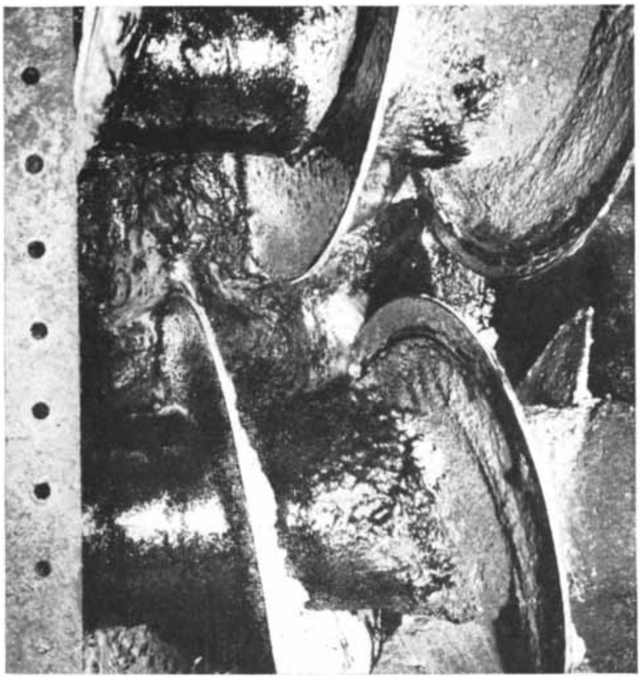
Of course, increase in cost is a spur to invention. Since invention cannot be predicted, there is no way to guess how much of the now inaccessible and expensive fossil fuels may yet be produced for use. For example, it may be possible to apply nuclear heat in some form to the underground retorting of oil shales—a development which might greatly extend the volume of practicably recoverable oil from this resource. The same development might give us the benefit of the deeper deposits of tar and sand and make it possible to recover useful energy from the 1,425 billion tons of deep and scattered coal reserve. Such developments may extend our exploitation of the fossil fuels and may even reduce the cost of energy extracted. But they cannot increase the world's total reserves.

The fuel situation, it is clear, requires a considerable speed-up of research and invention. It is not only a question of developing new sources of energy. We must also find more efficient ways to apply energy in its two major uses: the heating of indoor space and vehicular transportation.

At present, nuclear power offers the most promising alternative to fossil fuels. However, progress in this field so far scarcely touches the heart of the problem. We speak of nuclear "power," but what we are really working on is nuclear heat. We are proposing to hook up the nuclear reactor to the steam turbine, an only modestly efficient invention of the 19th century, and to throw away three quarters of the energy of the nuclear reaction. It seems improvident to waste precious nuclear fuel in this fashion, not to mention the tons of fossil fuel that go into its manufacture. Electric power is destined to play an ever increasing role in our total energy picture. Clearly the next step in power generation must be the elimination of the steam cycle and the direct conversion of radiation to electricity.



TAR SAND OIL is skimmed from surface of hot water by rotating paddles in separation cell at Alberta plant. Tar is separated from sand by heating it to melting point and floating it off on water.



WORKED-OUT SAND is removed from separation cell by screw conveyors. Water and oil froth, lifted along with the sand tailings, flow back into separation cell as the sand is dumped out at right.

Nonetheless, the burning of nuclear fuel will cut down the rapid spending of our fossil fuel reserve. If all of our present electrical power were generated by nuclear reactors, this would save only 12 per cent of our fossil fuel. Where nuclear fuel would help most is in space heating, which now consumes nearly half of our fuel energy. Heat from nuclear reactors might be used directly for central steam heating in large concentrated centers of population, but for most heating the only feasible way to use the energy would be in the form of electric power. Electric heating systems, supplemented by heat pumps, are already coming into use. With such application of electricity in prospect we cannot long wait for really revolutionary developments in the generation and distribution of electric power.

The second largest use of energy is for land transportation. The internal-combustion engine is making the U. S. a nation of suburbs. In tractors, bulldozers, scrapers, motor graders, cultivators, harvesters and many other devices, it builds our highways, constructs our buildings and produces our overabundant food. The bus is superseding electric cars, trucks are taking railway freight, and the Diesel electric has made the steam locomotive obsolete. We use four times as much fuel for internal combustion as for the generation of electric power, and we pay 14 times as much for the fuel. We have based a major part of our existence on liquid fuel. And yet we must face the prospect that supplies will soon be inadequate even for our present population. We can look forward to a profound revolution in automotive transportation within the next two decades.

The eminent physicist Sir George Thomson, in his book *The Foreseeable Future*, pronounces the internal-combustion engine an anachronism and predicts that it will become wholly obsolete as soon as a satisfactory "electrical accumulator" has been devised. Meanwhile, it looks as if we shall soon have the injection engine and the automotive gas turbine. These two engines will still leave us dependent upon liquid fuel, but at least they will eliminate the wasteful conversion of petroleum to high-octane gasoline. With motor fuel almost as cheap as bottled water up to now, we have preferred performance to economy. But radical developments are now in order. It seems that the reciprocating internal-combustion engine has nearly completed its term of usefulness and must be replaced by something of a very different character.

We may take it for granted that the necessary inventions will be made. The U. S. will have to give this technological advance first priority if the mobility of our people is to be maintained. And automotive transportation will not be permanently denied to the majority of the world's population merely because they failed to consummate their industrial development before the supply of petroleum became inadequate.

The outlook on the fossil fuel situation given here is dark. Perhaps it is too dark. Geologists may be wrong in their ideas about reserves. Economists may be wrong about costs. Technologists may have some cheerful surprises to spring in the art of fossil fuel production. Engineers may find ways to multiply fuel-power efficiencies manyfold. But we certainly cannot ignore present indications. Even if present estimates of reserves turn out to be wide of the mark, the timetables of fossil fuel production will be extended only a few years.

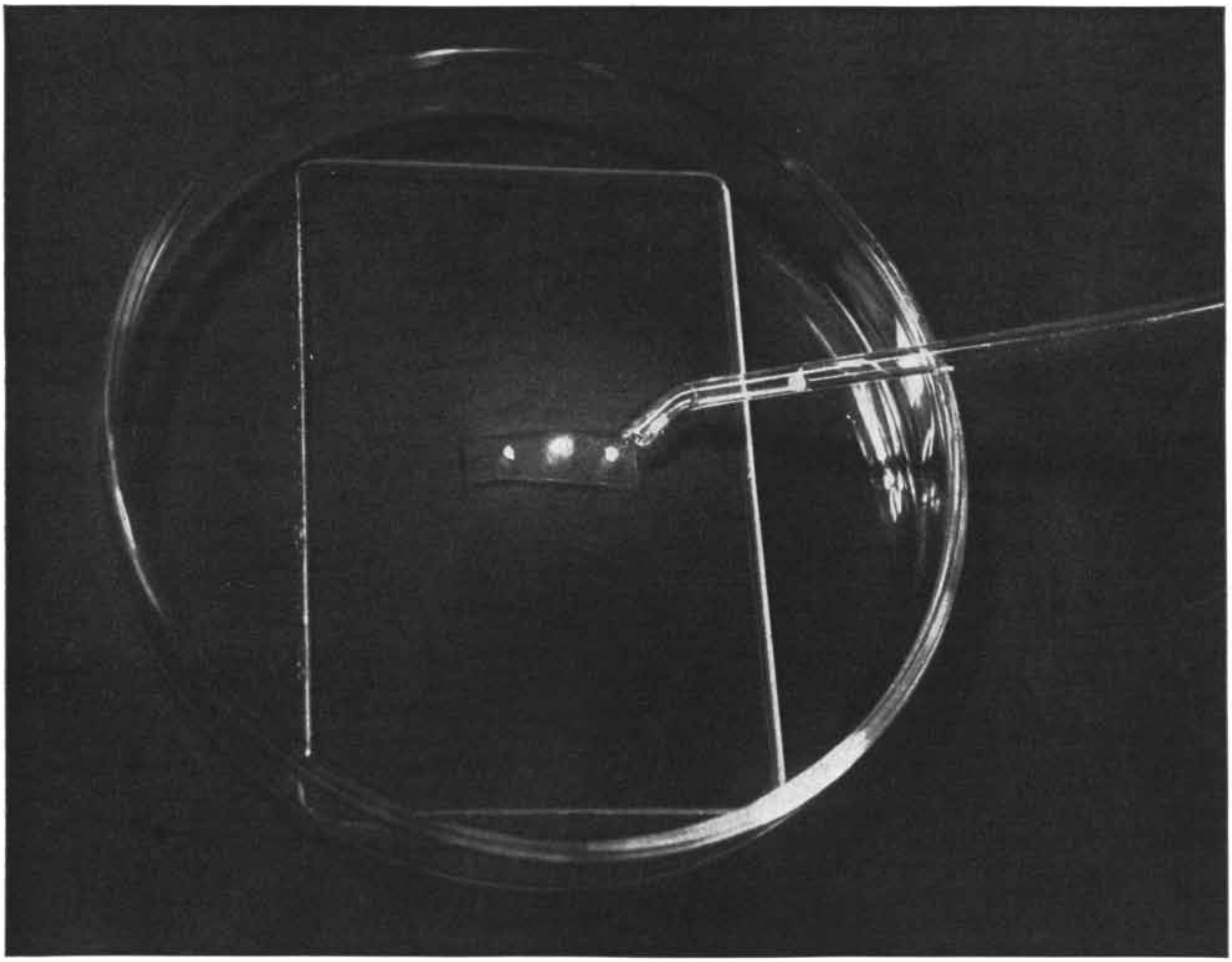
The technical decades ahead are sure to be tumultuous. The inventive genius of our own country, in particular, will have to turn away a little from the present overemphasis on entertainment, convenience, comfort, thrill and appearance to the more bread-and-butter subject of the raw need for energy

TISSUE CULTURE AND CANCER

Animal tissue cells can be grown in almost completely synthetic media and whole colonies of such cells grown from a single cell. These cultures provide convenient subjects for testing new drugs

by John J. Biesele

Just half a century ago Ross G. Harrison, a young biologist at Yale University, cultivated some bits of nerve tissue from frog embryos in a glass flask and succeeded for the first time in growing animal cells outside the living body. His elegant experiment yielded something much more important than frog nerve cells. It was the beginning of the modern technique of tissue culture. Already this great tool has produced richer benefits for mankind than Dr. Harrison and other pioneers could have foreseen. Tissue culture of the poliomyelitis virus made possible the Salk vaccine. The cultivation of living cells in glass is adding steadily to our knowledge of the basic chemistry, machinery and genetics of the cell. And it is our most valuable instrument in the quest for a solution to the problem of cancer.



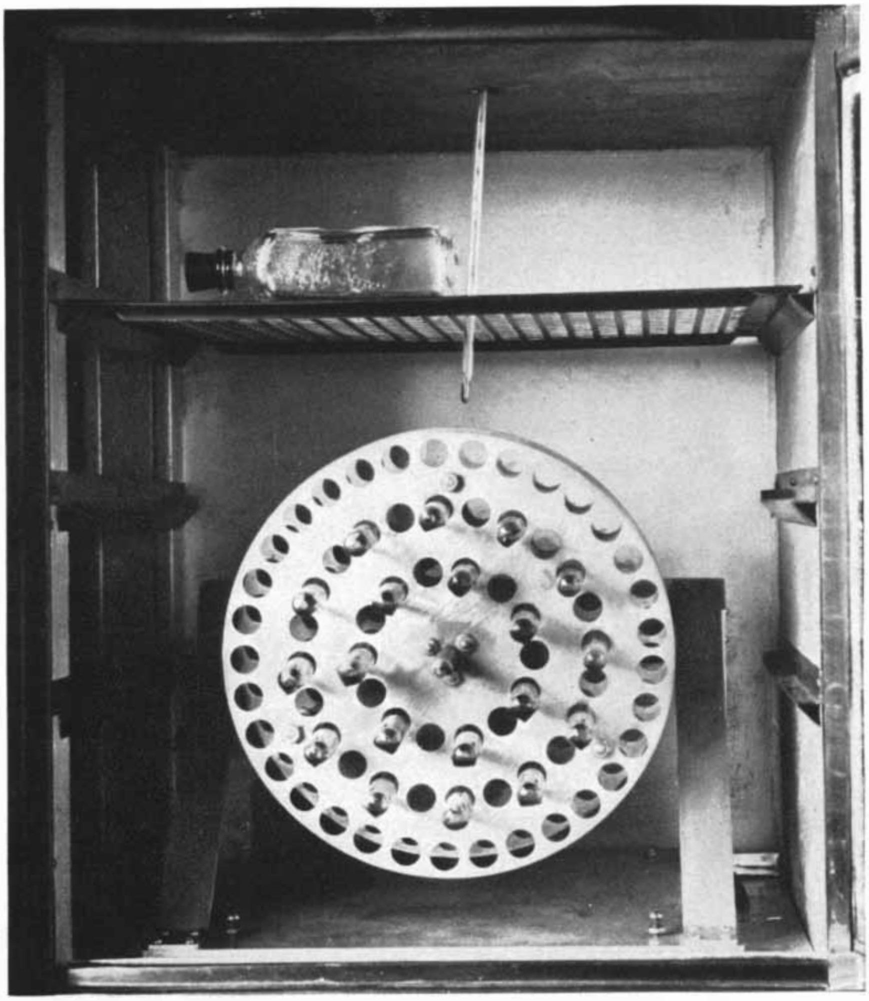
INITIAL PLANTING of tissue culture involves the transfer of a mouse's sarcoma 180 tumor onto a glass cover-slip (*center*) with control specimens of normal tissue on either side. The culture is now ready for insertion in a roller tube (*shown on opposite page*).

We shall consider here how it is being used to test chemicals against this disease.

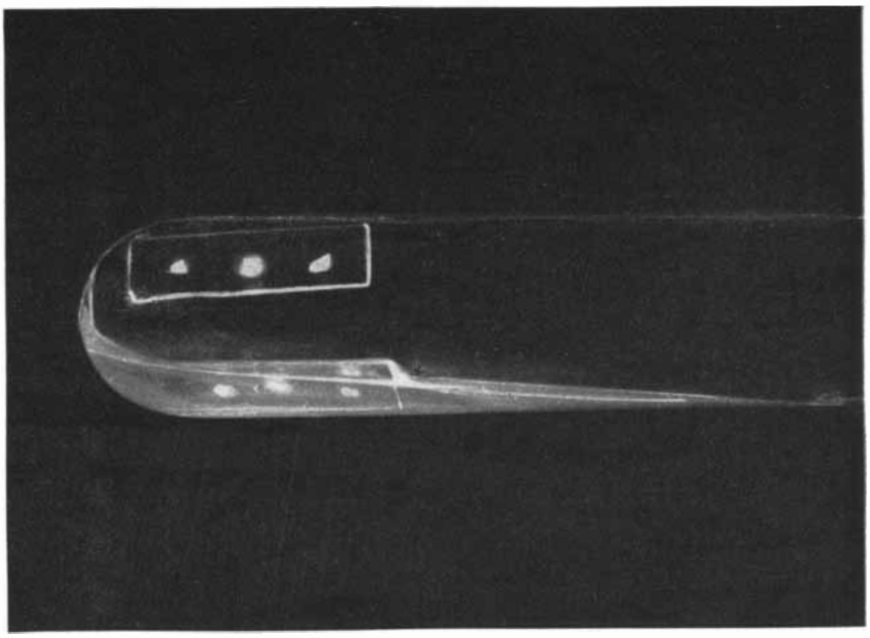
Techniques of tissue culture have advanced remarkably in recent decades. When Harrison began his work, it was possible only to keep tissues of a lower animal embryo alive for a few days. Today many kinds of cells can be cultured and multiplied indefinitely. Cells of mammals, including the human, are cultivated in the test tube in much the same fashion as colonies of bacteria. Progress is being made toward the goal of growing them in completely synthetic media, so that the effects of any ingredient can be measured precisely. All this has come about through a series of improvements in techniques developed in many laboratories—in universities, medical schools, research institutes and pharmaceutical houses—in the U. S. and abroad.

We can describe these improvements, in a way, as meeting two living needs: shelter and food. The first covers the mechanics of the abode in which the cells grow. As a foundation for their growth the experimenters long used clotted blood plasma—a jelly-like medium in which the cells can get a footing, so to speak. The plasma clot has two drawbacks: the composition of the plasma varies, and it is difficult to cut the jelly into absolutely uniform pieces when the population of cells has to be divided for further experiments. Wilton R. Earle and his co-workers at the National Cancer Institute in Bethesda solved these problems by eliminating the plasma clot. The cells are grown on perforated cellophane or on the walls of the glass vessel itself. When the cells are to be separated for transplanting to other vessels, they are dislodged from the cellophane or glass wall by shaking or by a mild chemical treatment; the cells in suspension are then divided into counted groups, so that the starting number in each new population is accurately known. Sometimes the cells are grown in agitated suspension in the nutrient fluid, rather than on a fixed foundation. Whether the cells grow on the glass wall or in suspension, it is desirable to keep the medium in motion, in order to speed the delivery of nutrients to the cells and the removal of wastes from them. For this purpose laboratories commonly use so-called "roller tubes"—test tubes turning in a rotating drum [*see upper photograph at right*].

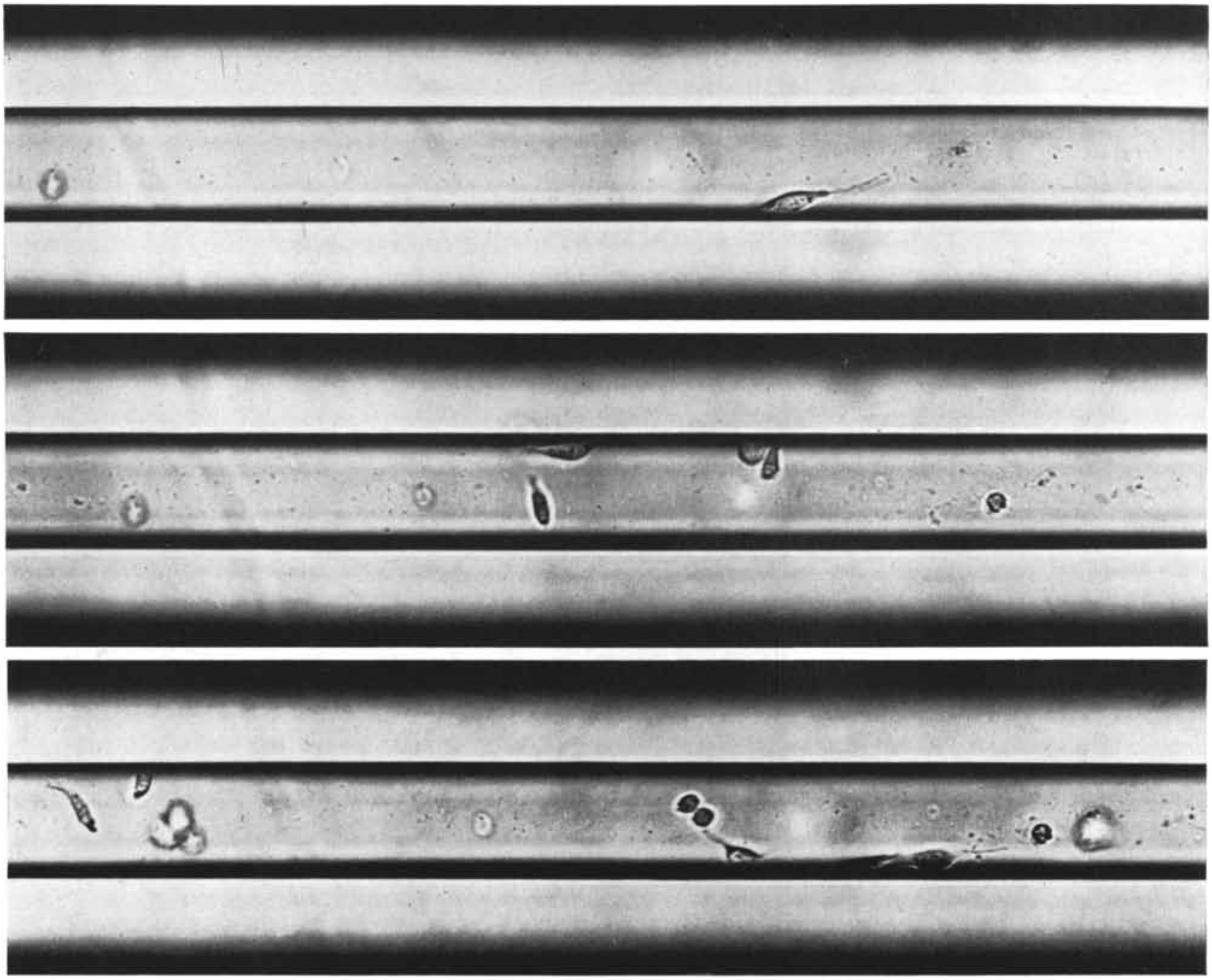
Tissue cultures must be rigorously protected against contamination by bacteria, for microorganisms will quickly take over and kill off a population of



ROLLER TUBES containing cultures in a nutrient medium are revolved six times per hour in a drum. The bottle above them contains a microlayer of tissue in a stationary medium.



SHELTER AND FOOD for the tissue cultures are provided in a roller tube of ultrathin glass suitable for use under the microscope. The cultures face inward toward the medium.



FORMATION OF A CLONE is displayed in these cultures by W. R. Earle. Above are three stages in a culture inside a capillary tube whose inside diameter is one millimeter. At top the tube contains a single cell. After 87 hours (*middle*) and 125 hours (*bot-*

cells. The test tubes are therefore tightly stoppered, and nowadays penicillin or some other antibiotic is often added to the medium to stop any bacteria that may invade the culture.

On what meat do living cells feed? The pioneers in tissue culture had to begin with a broth of natural materials whose ingredients were not exactly known. It included salt solutions, extracts from living embryo tissue, serum and other body fluids. One of the first to try to standardize the nutrient medium was Alexis Carrel, the famous culturist of chicken heart tissue (whose technicians wore black gowns from head to toe when they planted their cultures). The B vitamins, then just becoming known, were added to the medium, and later amino acids and other known biological substances. More than a decade ago Philip R. White of the Institute for Cancer Research worked out a synthetic medium in which he succeeded in keeping tissues alive for some weeks [see "Plant Tissue Cultures," by Philip R. White; SCIENTIFIC AMERICAN, March, 1950]. Advances in biochemistry and in the understanding of nutrition have now brought tissue culturists to the verge of complete identification of all the nutrients needed for growth by some strains of mammalian cells.

Harry Eagle of the National Microbiological Institute in Bethesda has grown various cell strains in a nutrient mixture of 13 amino acids, eight vitamins, six inorganic salts and glucose—supplemented by no more than 10 per cent of serum. The serum appears to be needed either for some of its proteins or for substances it carries in trace amounts. Earle's group at the National Cancer Institute has put together a more complex medium which, even without serum, supports the growth of at least one strain of mouse cells.

With the development of closely controlled culture techniques, tissue culturists have turned to more precise control of the cells themselves. To make sure that the experimental cell population is completely homogeneous, they seek to develop a colony of cells from a single cell as the parent: this kind of colony is called a clone. Here again Earle's group was the first to succeed. Their method involves trapping a single cell in a fine capillary tube and then placing the tube in a suitable nutrient medium. Their experiments indicate that the cell will grow only in a small and confined volume of medium. A single mammalian cell placed alone in an ocean of medium will probably not proliferate, even when the medium has been "conditioned" by the prior growth of cells in it. Apparently certain substances, perhaps emitted by

tom) the cell has proliferated into a colony; the bottom picture shows a cell dividing at right of center. The large photograph shows a similar clone on the 28th day. The cells, now of many shapes and sizes, have begun to proliferate into the outer flask.

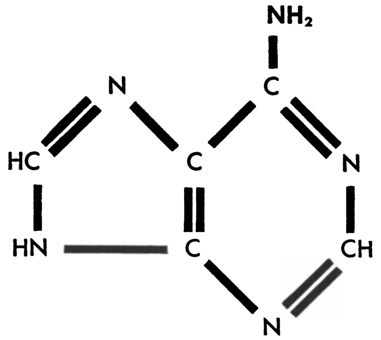
the cell itself, must be kept close to the cell if its growth is to proceed.

A simpler and more reliable method of obtaining clones was devised recently by Theodore T. Puck of the University of Colorado School of Medicine. After bringing the cells growing on glass into suspension by very gentle methods (to avoid damaging them), he plates out the suspension on a mixture of nutrient medium and semisolid agar in a Petri dish. Each of the separated cells then develops into a small colony. Evidently the nonfluid agar restricts the loss of certain essential materials from the cells. After the little colony of cells has grown large enough, it can be placed into a new culture vessel and used to start a new clone. Puck observed that cells of a given clone grow at a more uniform rate than those of the original heterogeneous strain. The technique of plating out cells (the agar can be omitted for some strains) holds great potentialities not only for growing clones but also as an opening wedge for applying microbiological procedures to human and other mammalian cells.

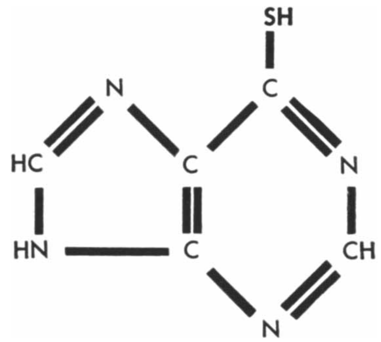
Earle is showing the way to still another important advance in expanding the usefulness of tissue culture. His group is developing a technique for growing cells of a single kind in large amounts—measured in grams. This will facilitate studies of the chemistry and metabolism of specific types of cells under controlled and comparatively simple conditions—away from the complicated environment of the animal body.

All this has given fresh interest to the investigation of cancer cells. For more than a decade workers at a number of laboratories have engaged in a search for chemical agents with which to attack cancer. As everyone knows, the problem is to find substances which are harmless to normal cells but will block the growth of malignant cells. Hundreds of candidate substances have been screened in this search. The usual method of screening has been to test them in tumorous rats and mice. Now, with the recent improvements in tissue culture, the hope arises that chemical agents may be screened more speedily and efficiently in cultures of human cancer cells—just as antibiotics against bacteria are screened in the test tube.

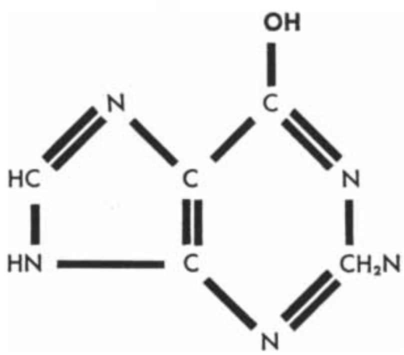
But in the case of cancer such an approach raises some very difficult questions. An infecting bacterial cell is a foreign organism that can be attacked directly. Malignant cells formed by the body itself, on the other hand, are the product of a whole complex of chemical processes within the body. In an *in vitro* culture it is difficult to know whether the active substances are the same as



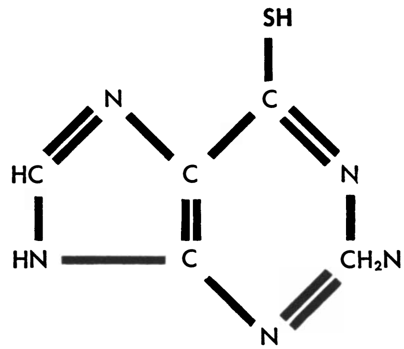
ADENINE



6-MERCAPTOPURINE



GUANINE



THIOGUANINE

METABOLITES and antimetabolites are compared. The antimetabolite 6-mercaptopurine is like adenine except for substitution of sulfur. Thioguanine is a similar analogue of guanine.

those active in the body, or indeed whether the cancer cells themselves have the same properties as when they grow in the living organism. Moreover, no test in glass can predict how a given chemical will affect all the different types of *normal* cells in an animal.

Some information about cancer cells and agents against them has been gained from tissue-culture studies with the older techniques. The Sloan-Kettering Institute for Cancer Research has conducted such studies for about 10 years. We have worked chiefly with mouse cells in culture media made up largely of natural materials. Several other institutions have done similar work. Let us review the findings so far.

In test-tube cultures the only agents that have shown much ability to kill cancer cells selectively are the so-called antimetabolites—counterfeit chemicals which are very like normal cell substances but differ slightly from them in molecular structure and therefore act like monkey wrenches dropped into the cell's machinery. The most effective antimetabolites are those that resemble substances involved in the making of nucleic acids. We have found certain counterfeit purines—altered versions of adenine and guanine—particularly interesting.

Let us take as an example an altered molecule known as 6-mercaptopurine—in which sulfur replaces the amino group (NH_2) normally attached to the carbon atom at the number 6 position in adenine [*see top diagram above*]. If we add this counterfeit substance to a culture of mouse cells growing in a medium of "natural" materials—embryo extract, serum and inorganic salts—it inhibits division and multiplication of the cells. But it has a much stronger inhibiting effect on cancer cells than on normal mouse skin cells. Now if we add some genuine adenine to the culture, it blocks the inhibitory effect of the antimetabolite in some degree—completely so in the case of normal cells, slightly in the case of cancer cells. Certain other substances also display some effectiveness in blocking 6-mercaptopurine. The most effective blocking agent of all, especially for the cancer cells, is coenzyme A, which contains adenine. One molecule of coenzyme A blocks up to 50 molecules of 6-mercaptopurine in their inhibitory effect on the cancer cells (which here are of the type called sarcoma 180).

Guanine has a similar analogue called thioguanine, in which sulfur replaces an oxygen atom. Thioguanine is about 10 times as toxic as 6-mercaptopurine. It inhibits normal and cancer cells alike in mouse tissue cultures. It is only partly blocked by coenzyme A, and cell divisions occurring under its influence contain broken chromosomes.

One important thing these experiments illustrate is that the effect of an antimetabolite depends to a large extent on the composition of the medium. This point is further emphasized by the fact that in a living animal thioguanine has a greater effect on cancer cells than on normal cells, though it does not discriminate between them in a tissue culture. On the other hand, we must not forget that the cell itself is the final determiner of the response, whatever the medium. For example, there is a variant strain of sarcoma 180 which resists the depressing effect of 6-mercaptopurine, both in the body of the mouse and in tissue culture.

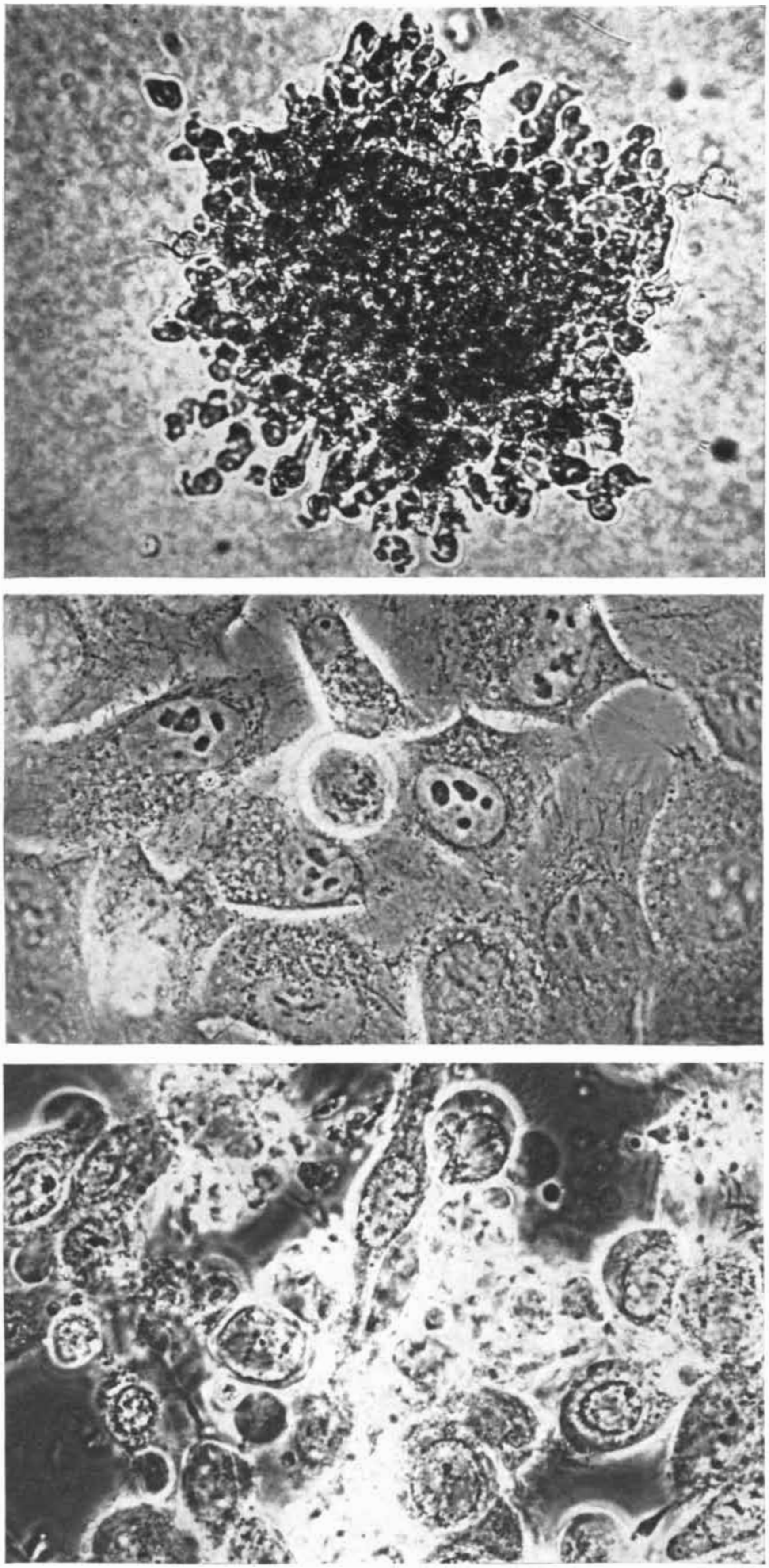
We have lately started tissue culture experiments with human cancer cells, testing the effects of antimetabolites on them as we do on mouse cells. In these tests the human cells have proved to be less sensitive to antimetabolites than mouse cells. The composition of the medium again is important here. In the "natural" medium in which the mouse cells are grown, division of the cells is readily inhibited by adding, for example, an antagonist to glutamine. But in the cultures of human cancer cells, grown in a semisynthetic medium, the glutamine antagonist has little effect unless we first reduce the concentration of glutamine in the medium.

The experiments so far, both on mouse and human cells, have been devoted mainly to studying the effects of a few substances. In weighing the feasibility of applying the technique to screen possible agents against cancer, we have many difficulties to consider. First is the fact that a compound which stops division of cancer cells in a tissue culture often fails to do so in the whole animal. The animal may divert the chemical from the tumor, may excrete it, may change it to an ineffectual substance or may overwhelm it with counteracting normal substances. Secondly, after cells have been cultivated for some time in a tissue culture they may change, as a result of selection of the strains best able to grow under the conditions provided. Differing tumor cells may thus become uniform and differ in metabolism from the original cells in the animal body. Moreover, many experimenters have observed that normal cells long cultivated in a tissue culture have a tendency to become cancerous. In fact, a tissue culture, because it tends to favor anaerobic growth (without oxygen), provides just the conditions needed to transform the metabolism of normal epithelial cells to that of malignant cells.

Obviously it becomes difficult to test the differential effects of cell poisons when the investigator cannot be sure whether the cells in a given tissue culture are the same as the normal or tumorous cells originally taken from the animal body. The prospects for being able to use tissue cultures as a primary screen for testing chemotherapeutic agents against cancer are not altogether promising. In my opinion the technique will be useful only if combined with other test methods. But despite its imperfections, tissue-culture screening will be a very valuable help. After all, cancer patients do not come in triplicate, and a test of an anticancer agent has little meaning unless it can be repeated in a number of identical situations.

Some of the difficulties in using tissue cultures can certainly be overcome. For example, the cells in a culture can be examined and tested periodically to see if they have changed their properties. Moreover, tissue-culture studies of human cancer can be checked by experiments with laboratory animals, for it is now possible to transplant human tumor tissue to rats and mice that have been treated with cortisone.

The aim of tissue culturists is to find a reliable means of comparing the responses of normal and cancerous cells to various chemical agents *in vitro*. But even if this should prove not to be feasible, it has been suggested that tissue cultures might be used simply to identify substances capable of attacking cancer cells. Chemicals above a certain level of potency would then be tested further in animals to determine whether they are toxic to normal cells. Even this limited use of tissue cultures for screening would greatly increase the number of compounds that could be investigated and might bring closer the final victory over cancer.



CELL COLONY is shown in phase-contrast picture at top. Middle picture shows cells of a type of human cancer; bottom picture shows effect of antimetabolite on cells of same type.

A National Radio Observatory

Plans for a 140-foot steerable paraboloid telescope to be located in West Virginia are being drawn by the National Science Foundation. The observatory is a cooperative project of research institutions

by Bart J. Bok

The U. S., where radio astronomy had its birth, has hitherto lagged behind other countries in facilities for the pursuit of this fascinating science. But it will soon have one of the world's largest and finest radio telescopes. Preparations are going forward for the building of what amounts to a national radio observatory in the hills of West Virginia. Too big a project for any one university or institution, it will be built by the National Science Foundation and operated by a cooperative organization. The main feature of the observatory will be a 140-foot steerable paraboloid telescope which will be able to scan the entire northern sky. This antenna will be smaller than the 250-foot dish now being constructed by the British at Jodrell Bank in England, but it will be an instrument of exceptionally high precision, and the equipment of the laboratory as a whole will be unequalled anywhere in the world.

The National Science Foundation has just announced that it has selected a site for the observatory. The site is near the village of Green Bank in Pocahontas County, West Virginia. Congress has appropriated about $4 million toward the purchase of the land and the design and construction of the telescope and supplementary buildings and laboratories. Since the National Science Foundation cannot itself operate facilities, studies and negotiations are now under way to determine what group or organization will be best fitted to manage the observatory.

Radio astronomy (whose tremendous development was admirably reported in last month's issue of SCIENTIFIC AMERICAN on cosmology) began in 1931 when Karl G. Jansky of the Bell Telephone Laboratories discovered radio static reaching us from outer space. In the prewar and wartime years much of the pioneer work in this new field was done by U. S. investigators, notably Grote Reber and G. C. Southworth. But soon after the end of the war Great Britain, Australia, the Netherlands and Canada took the lead in radio astronomy. Ten years ago only one U. S. university—Cornell—devoted major attention to such research. By 1951 Cornell, the Naval Research Laboratory, the National Bureau of Standards and the Carnegie Institution of Washington had organized programs of radio study of the sun, but the British and the Australians had the field of galactic radio astronomy almost to themselves.

Interest in this broader field received a sharp stimulus in the U. S. during 1951 when H. I. Ewen and E. M. Purcell of Harvard University detected radio radiation at the 21-centimeter wavelength from hydrogen in the spiral arms and the center of the Milky Way system. In the summer of 1952 the Harvard Observatory began a radio exploration of hydrogen clouds in the Milky Way, and the Naval Research Laboratory and the Carnegie Institution also became active in this new field. At about the same time the Ohio State University built the first of its large antennas for surveying our own and other galaxies, and began to produce radio maps of the sky.

The new National Science Foundation, which began operations in 1952, saw at once that it had an important function to fulfill in furthering the cause of radio astronomy. Among its first substantial grants two were for radio projects at the Agassiz Station of Harvard Observatory and at Ohio State. In January, 1954, the Foundation sponsored a symposium in Washington to survey the future prospects for this work in the U. S. The symposium was well attended and engendered much enthusiasm among astronomers, physicists and electronic engineers. The Foundation increased its support of radio astronomy, and other organizations, notably the Office of Naval Research and the Air Force, entered the field. The nation now

OBSERVATORY SITE at Green Bank, West Virginia, is a flat, triangular valley has 10 institutions actively working in radio astronomy, and five more will soon join them. There are more than 20 professional radio astronomers in the U. S. and about 20 students doing graduate study in the subject.

As far as instrumentation is concerned, the first big step forward came in 1952 with the construction of the 50-foot steerable paraboloid at the Naval Research Laboratory in Washington. It is a fine piece of equipment which has been admired by many air visitors to Washington, for it stands just across the Potomac from the Washington Airport. The instrument has already made important contributions to radio astronomy: it has told us much about radio radiation from the sun, was the first to detect hydrogen in a radio star and was also the first to record thermal radiation from gaseous nebulae and from the planet Venus.

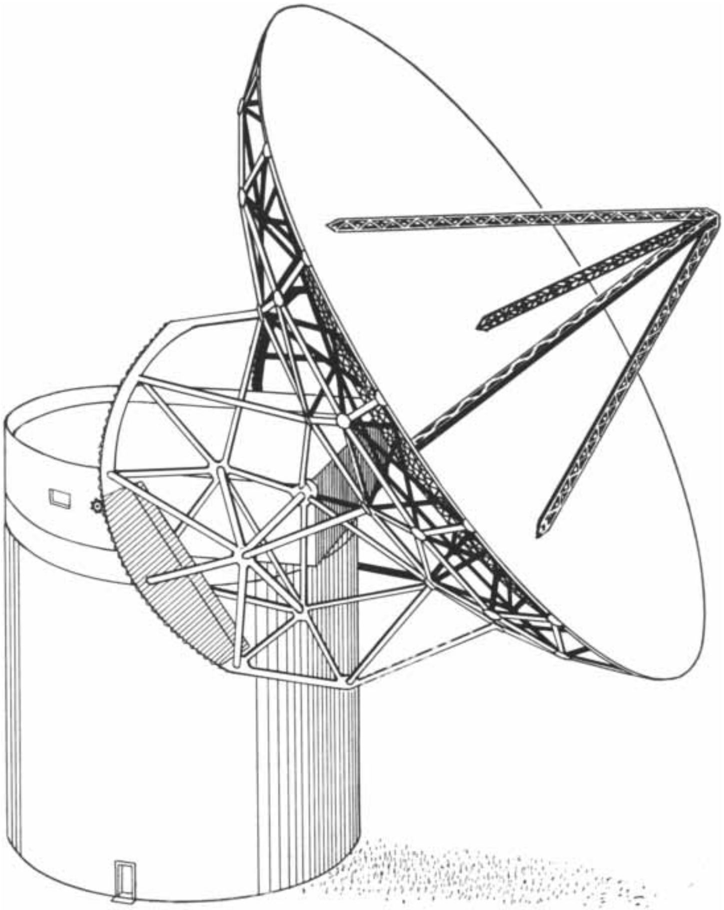
The largest paraboloidal radio telescope now in operation in the U. S. is Harvard's 60-footer. Plans for the construction of several larger ones are already beyond the talking stage. Before long the Naval Research Laboratory will have an 84-foot dish, and 60-footers will soon arise at the Carnegie Institution in Washington and at the University of Michigan. The California Institute of Technology is building a pair of 90-foot steerable paraboloids, to be operated as an interferometer system.

I need mention only a few other results to demonstrate that the U. S. is moving forward rapidly in radio astronomy. Workers at the Carnegie Institution have discovered radio noise from the planet Jupiter, presumably originating by a process not unlike that which produces terrestrial thunderstorms, but on a very much larger scale. At Ohio State the sky surveys have led to a precise determination of the direction toward the center of the Milky Way system; Ohio State has also studied thunderstorm effects on Jupiter and Venus. At the Agassiz Station the Harvard radio astronomers have learned much that is new about the fine structure of the hydrogen clouds in interstellar space, and recently David S. Heeschen detected 21-centimeter radio waves from a very distant cluster of galaxies in the constellation of Coma. T. K. Menon's studies of neutral hydrogen in the Orion Nebula and its surroundings are proving of considerable importance for cosmological studies of stellar evolution.

It is against this background of developing research experience that we must look at the plans for a national radio observatory. The 140-foot telescope will be a major advance in instrumentation of which U. S. radio astronomers are now prepared to take advantage. The big dish itself will be backed up by the latest in electronic equipment for amplifying and recording signals. American radio astronomers have already benefited very much by the happy circumstance that they are doing their research in a country in which there is much emphasis on research and development in electronic engineering.

The first suggestion for the creation of such an observatory came from Harvard

at 2,700-foot altitude, sheltered by 4,000-foot mountain ridges on both sides. The site was chosen to protect the observatory from severities of climate, especially tornadoes, and from man-made radio interference that fills the sky around large population centers.



140-FOOT TELESCOPE design by D. S. Kennedy & Co. of Cohasset, Mass., mounts the reflector on a rotating turret atop a concrete silo. Reflector itself rotates about a horizontal axis.

DIAMETER OF REFLECTOR	140 FEET
FOCAL LENGTH	70 FEET
SURFACE TOLERANCE	±¼ INCH
FOCAL POINT POSITION	±⅛ INCH
SKY COVERAGE	COMPLETE HEMISPHERE
TRACKING ACCURACY	10 SECONDS OF ARC
STABILITY IN WIND	
FULL PRECISION	TO 30 MILES PER HOUR
PARTIAL PRECISION	TO 45 MILES PER HOUR
SAFETY	TO 120 MILES PER HOUR

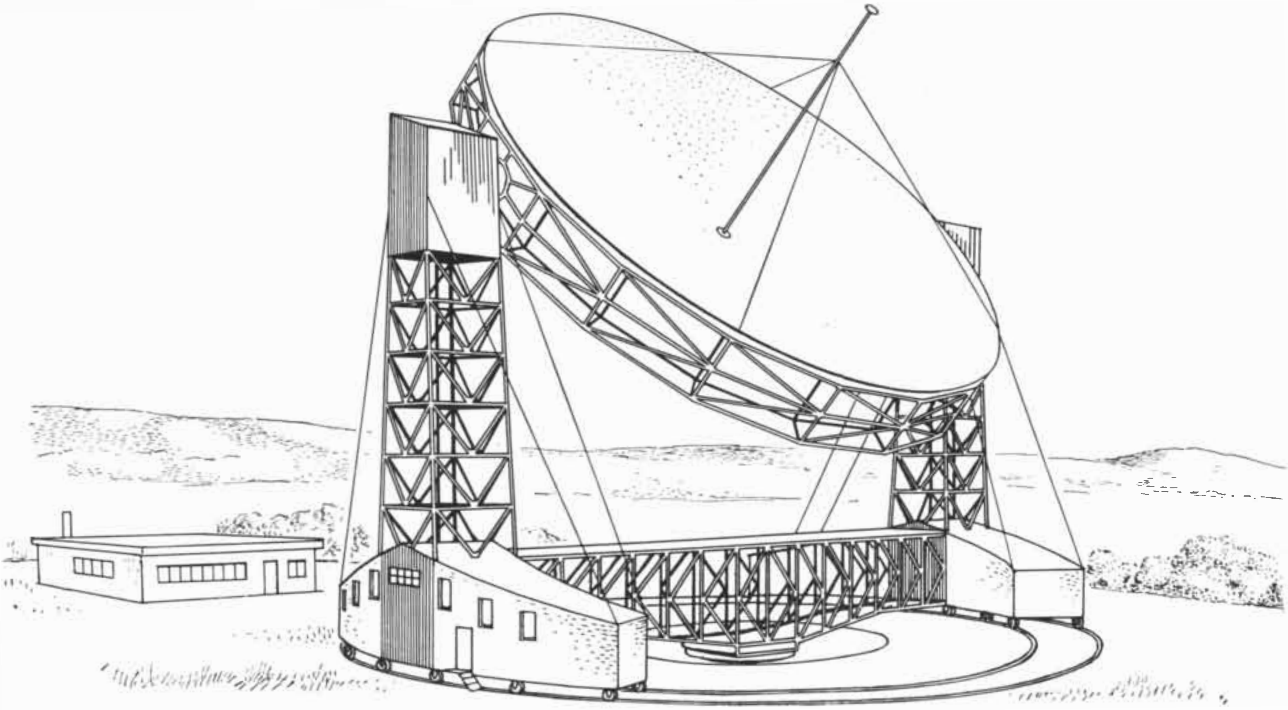
SPECIFICATIONS for the 140-foot antenna approach the limits of modern structural and control engineering. High surface tolerance is needed for work at centimeter wavelengths.

Observatory and the Massachusetts Institute of Technology about three years ago. The National Science Foundation then requested Associated Universities, Inc. (the organization that has operated the Brookhaven National Laboratory) to study the proposal. After deciding that the project was desirable and feasible, the study group had to consider two main questions: What sort of instrument, or instruments, should be built, and where should the observatory be located?

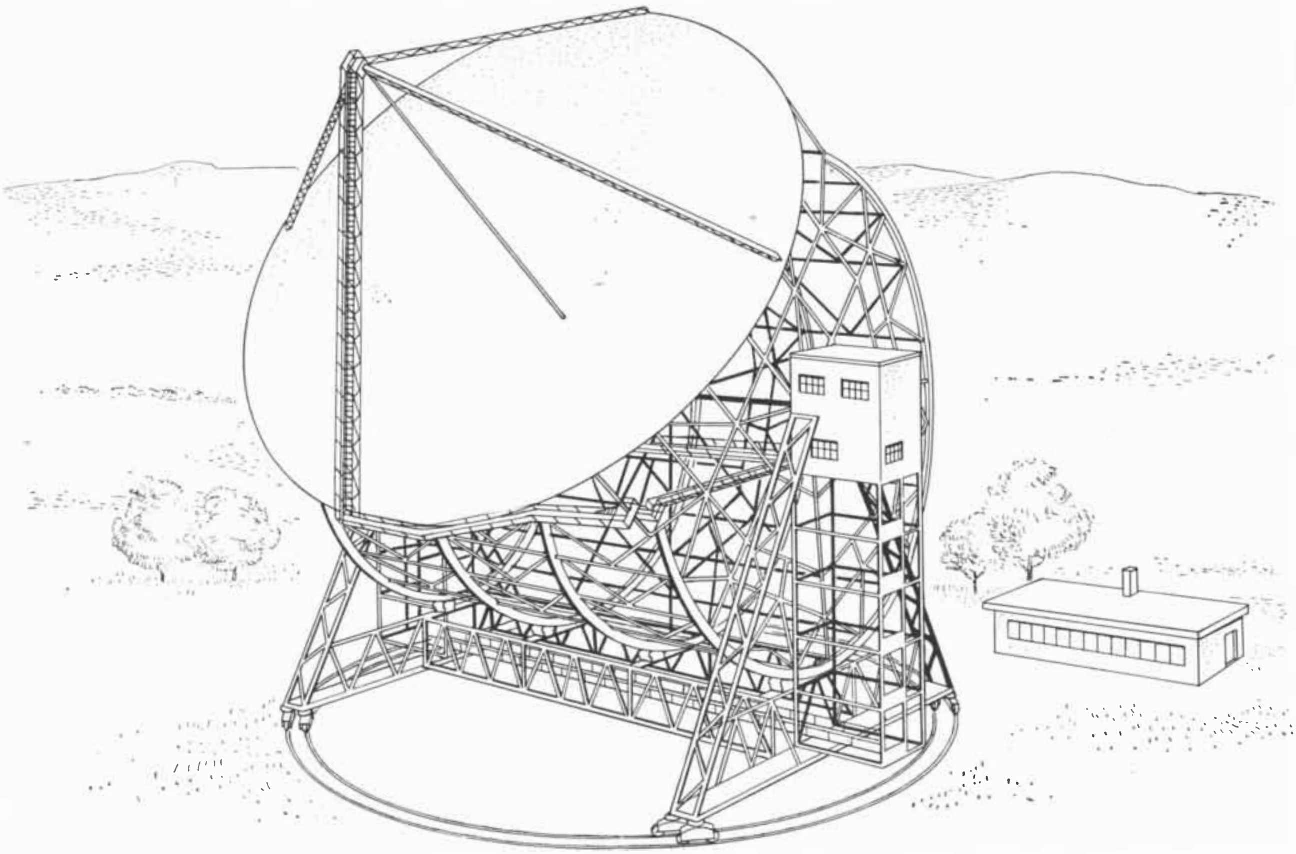
The big, 140-foot dish was a more or less inevitable choice as the first instrument to be constructed. For work in radio astronomy at this stage it is essential to have a telescope of large aperture, both to collect the faint radio signals and to give high resolving power. If three full moons were clustered together in the sky, our 24-foot radio telescope at Harvard would see them (at, say, the 21-centimeter wavelength) as a single blur, but a 140-foot telescope would easily separate their radiations.

Because of the special interests of the radio astronomers now active in the U. S., it was decided not to attempt an instrument as large as the 250-footer at Jodrell Bank but rather to concentrate on a good-sized antenna with a surface of very high precision. There is general agreement among U. S. radio astronomers that our first really big instrument should be geared to very precise work at the short wavelengths, from about 7 to 21 centimeters—the famous hydrogen line. This means that the surface of the 140-foot reflector must not deviate from a true paraboloid at any point by much more than one centimeter, or at most half an inch. The precision requirements present a real challenge to the construction engineers, but it is already clear from preliminary studies that with persistence and care it should be possible to construct the desired instrument, at a cost in the neighborhood of $2 million.

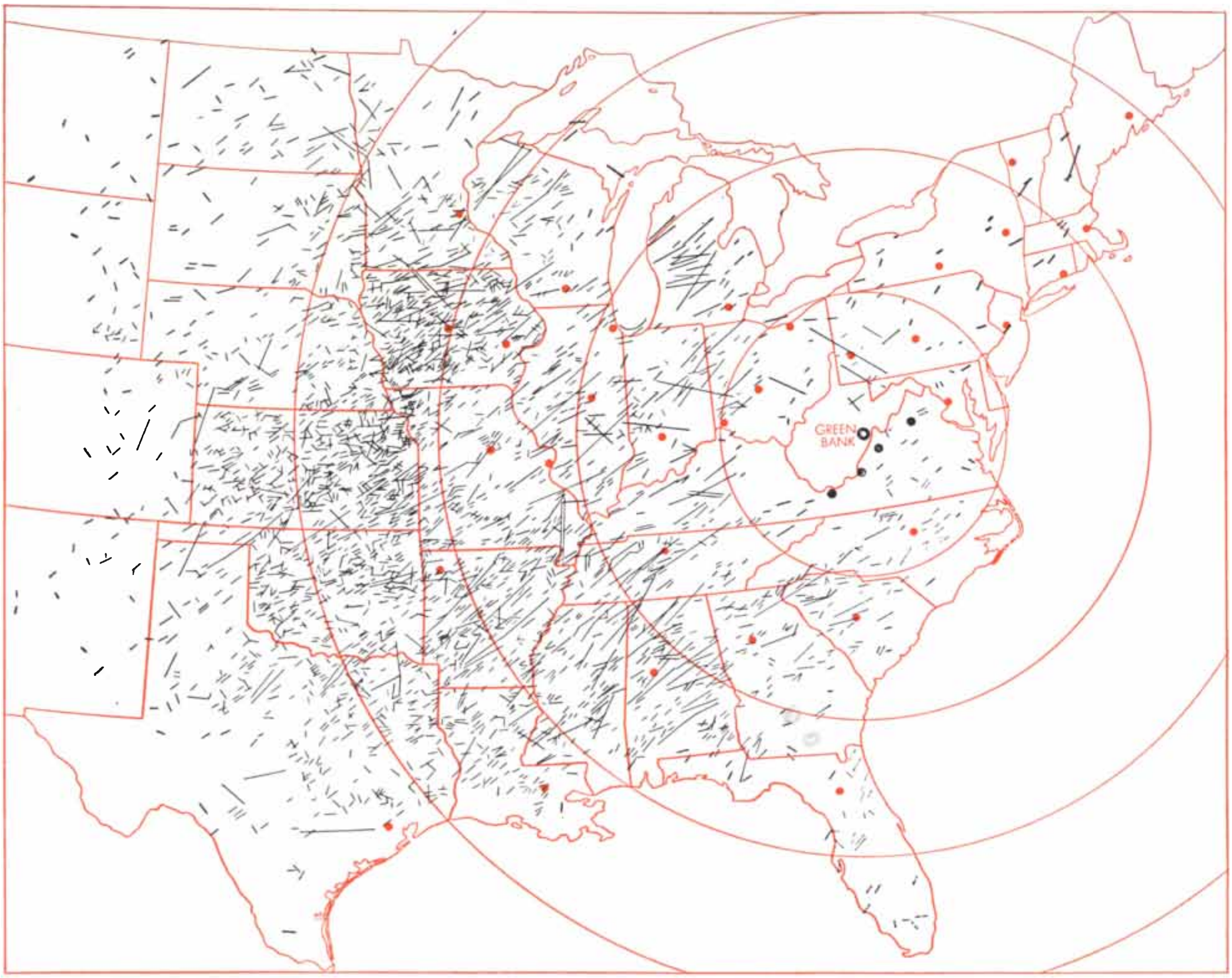
The 140-foot reflector should not, of course, stand alone. At a well-equipped optical observatory the big telescope may be the most impressive instrument, but it would be much less useful if it were not accompanied by a coterie of special-purpose instruments. On Palomar Mountain, for example, the 200-inch Hale telescope is supplemented by the 48-inch Schmidt, a powerful survey instrument which helps to find fields for the 200-inch to probe. In the same way a radio observatory must think in terms of search equipment and various special-purpose telescopes. Ingenious instruments of great power have been built



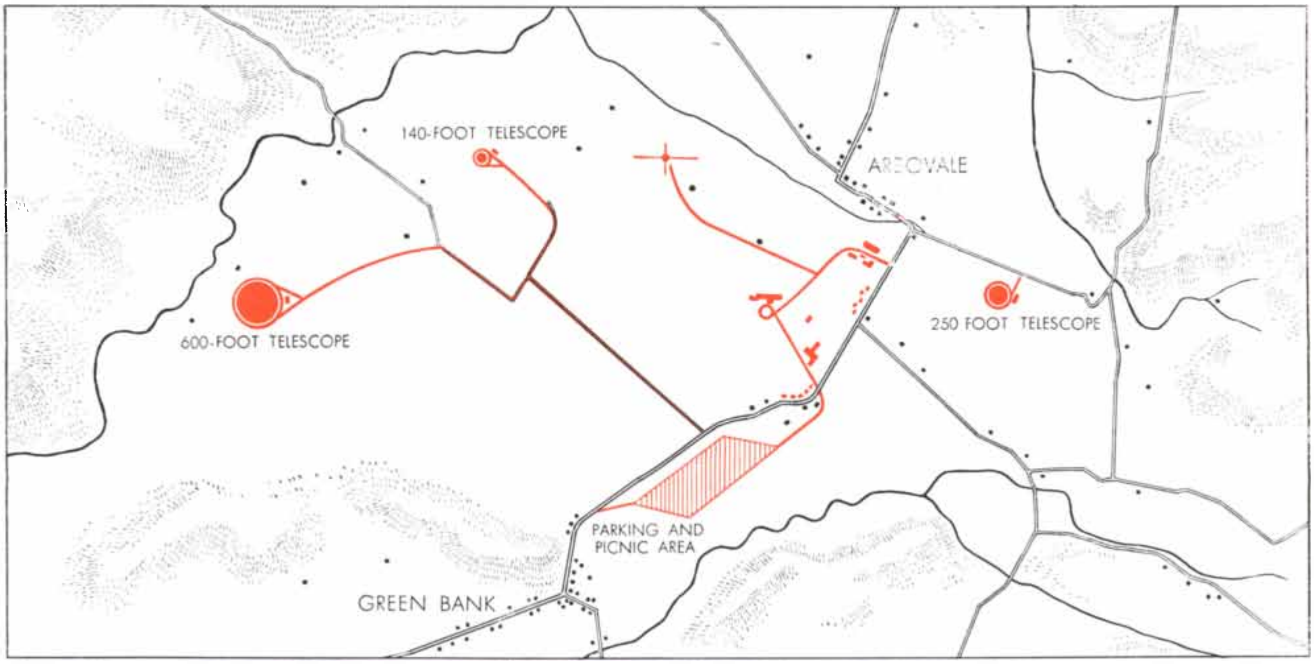
ANOTHER DESIGN for the 140-foot telescope, by Jacob Feld of New York, mounts the reflector between two towers on a cross-bridge which rotates on a central bearing. The reflector is a lightweight shell rigidly supported around its periphery by ring girder.



BRITISH DESIGN, by Husband & Co., builders of the 250-foot Jodrell Bank telescope, mounts the reflector on a massive cylindrical structure. The cylinder rests on rollers, permitting vertical rotation of reflector; the entire telescope rotates horizontally on tracks.



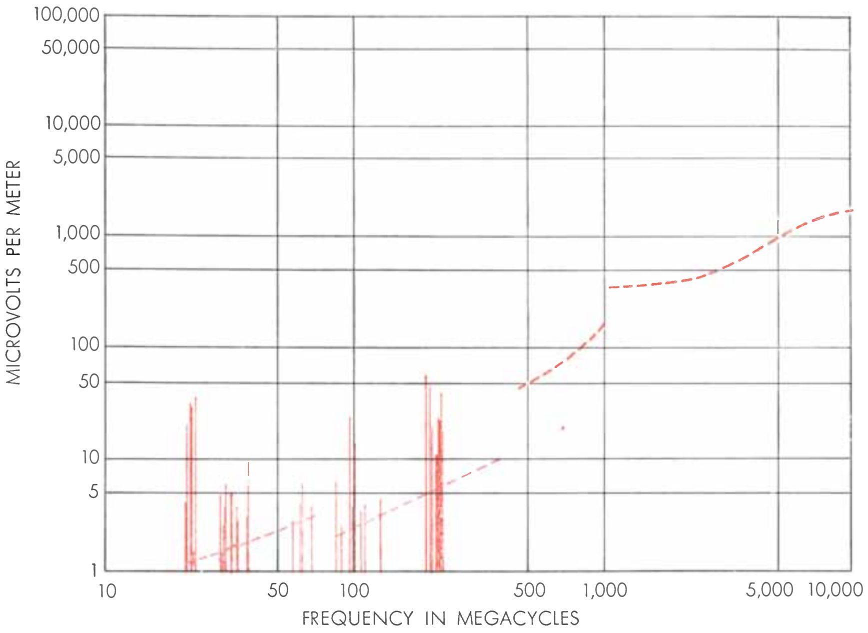
TORNADO MAP of the U. S. indicates that the West Virginia mountain region is comparatively secure from this hazard. Lines represent direction and length of tornado tracks. The Green Bank site is within a half-day's travel of major Eastern universities.



SITE PLAN for the observatory shows tentative location of the 140-foot telescope and of the even bigger instruments that may be built in the future. East-west orientation of the telescopes will make it possible to operate them in pairs as interferometers.

or designed to search for distant sources and to pinpoint and study radio stars [see "Radio Telescopes," by John D. Kraus; SCIENTIFIC AMERICAN, March, 1955]. Other types of equipment have been built and are being proposed for special studies of the radio radiation from the sun.

The big arrays and interferometer types of telescopes, designed to work at the longer wavelengths, have their advantages, but when all is said and done, the large paraboloid remains the most useful type as an all-purpose instrument. It can receive and focus radiation over the entire range of accessible radio wavelengths, and it is adaptable for use with many different varieties of electronic receiving and recording equipment. The paraboloid reflector is therefore an ideal instrument for a cooperative radio observatory. Eventually larger reflectors might join the 140-footer at Green Bank. Paraboloid antennas of 250 and even 600 feet are possibilities.



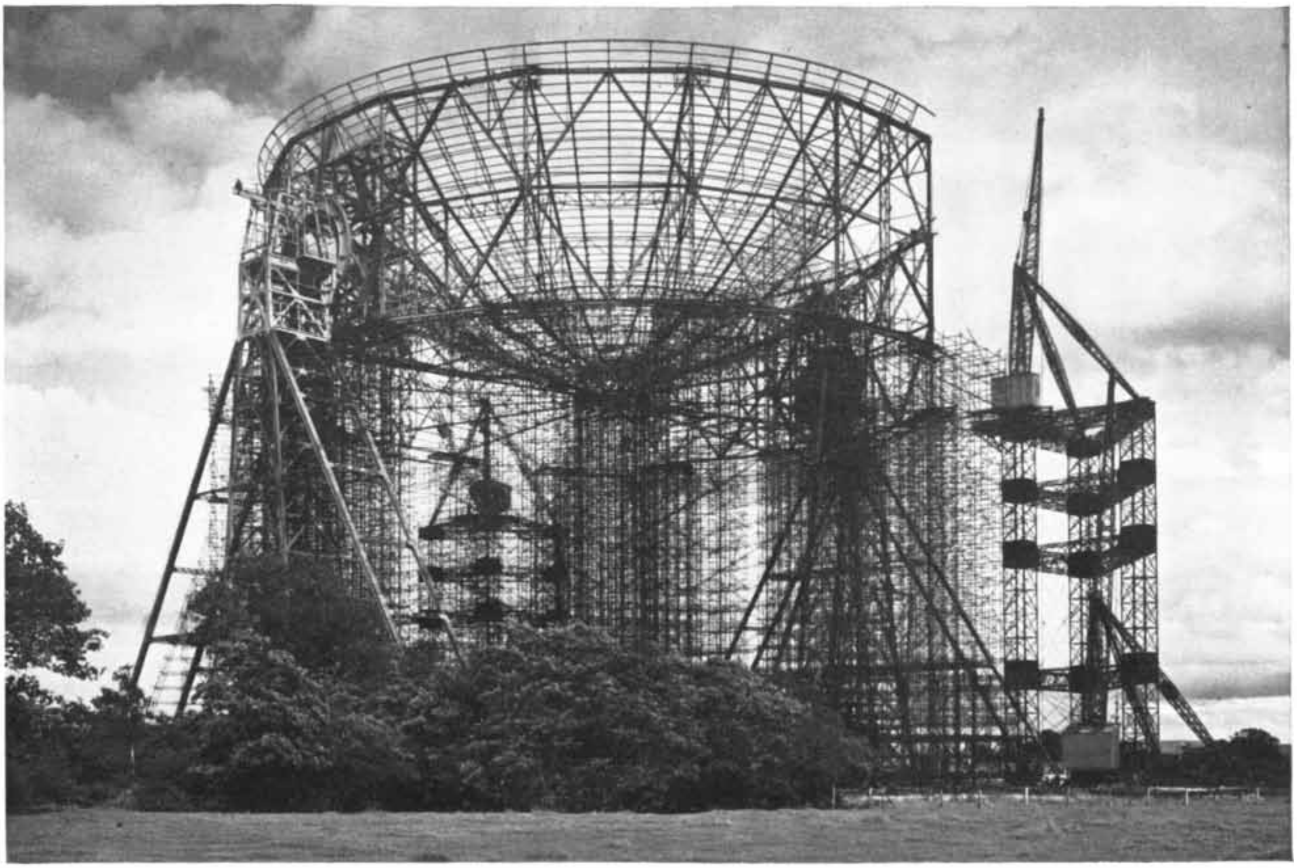
RADIO INTERFERENCE chart for Green Bank shows static from man-made sources only in the less important lower frequency range. Dotted line indicates minimum measurable signal.

The selection of the site for the observatory was a long and painstaking job, and it was decided only after a thorough search, headed by Richard M. Emberson of Associated Universities. The specifications for the site were that it should be within relatively easy reach of research centers in the Northeast, Midwest and Southeast, in a locality as free as possible from man-made radio interference, from hurricanes and high winds and from snowfall. All these requirements pointed toward a location in the mountains somewhere to the southwest or west of Washington, D.C. Optical observatories are usually built on mountaintops, but a radio observatory, in order to be shielded from earthly radio broadcasts, should be in a flat, shallow valley, preferably cupped among mountains rising 1,500 feet or more. The rather remote valley in the West Virginia mountains at Green Bank (altitude: 2,600 to 2,700 feet) seems to be the answer to the radio astronomers' prayers. It has more than 15 square miles of relatively flat land, with mountains 4,500 feet high around it. There is an airport at Elkins, W. Va., about 50 miles away, and several railroads and major highways come close to the site. By plane and car an astronomer starting in the morning can reach Green Bank by midafternoon from Boston, New York, Chicago, Toronto or New Orleans. Radio noise at Green Bank appears to be more than a thousandfold below the level at the Naval Research Laboratory radio telescope in Washington. The site is surrounded by a national forest, and the state of West Virginia has been most cooperative in enacting protective legislation. All in all the valley looks like a Shangri-La for radio astronomers.

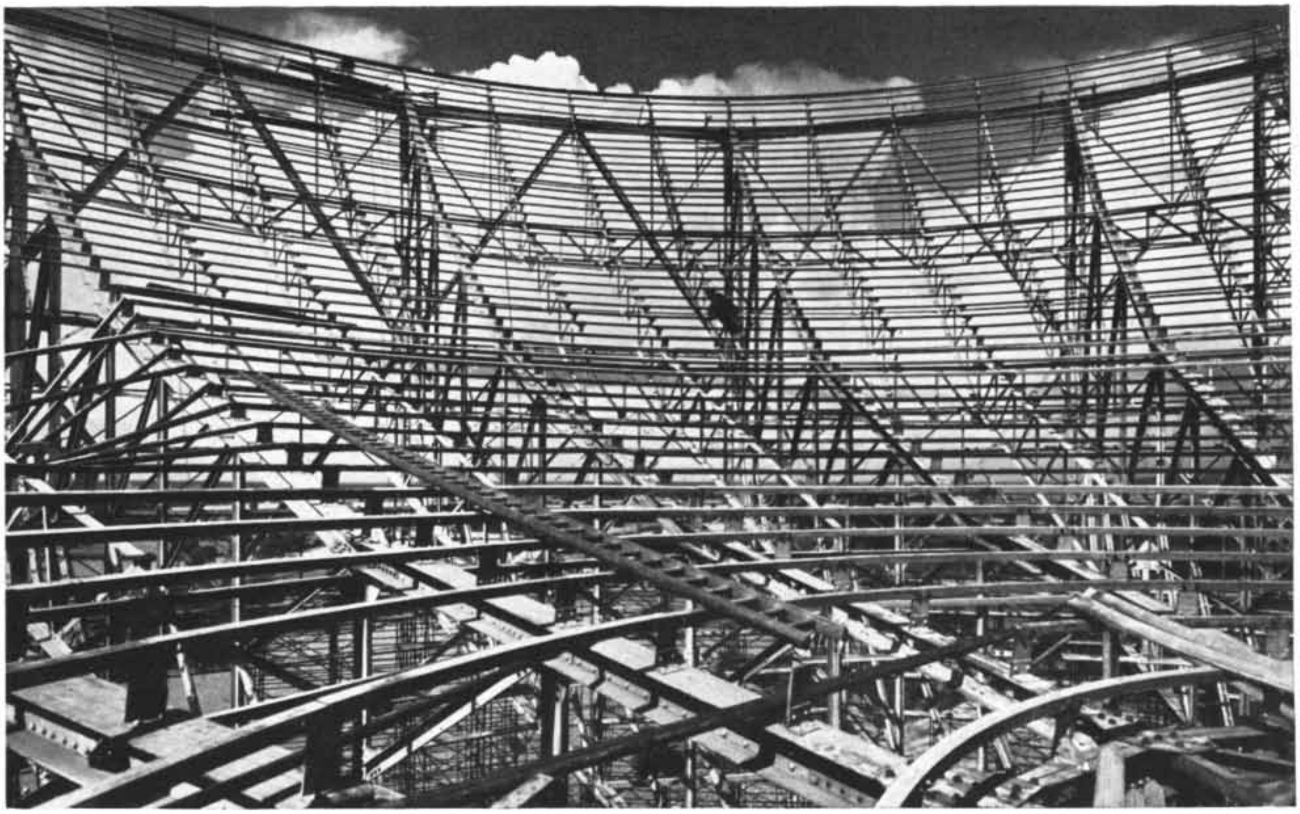
What will the observatory study? The research program for the 140-foot reflector is not easy to define in detail, since many astronomers, both resident and visiting, will be using it for various purposes. But it is certain that surveys of interstellar hydrogen will rank high on the list of early projects. It lies within the power of a 140-foot instrument to take up seriously the task of unraveling the cloud structure of the interstellar gas. With a really narrow, pencil-like beam it should become possible to locate small and dense concentrations of atomic hydrogen, which may be gas clouds on the way to condensing into young stars. For studies of stellar evolution it is essential to examine all the known star clusters and stellar associations for associated hydrogen gas, and to learn to what extent certain peculiarities in the atmospheres of stars are associated with nearby atomic hydrogen. Another topic for future research is that of locating the regions near the central plane of our Milky Way system which are devoid of neutral hydrogen gas. We want to know also how much hydrogen resides in the very rarified regions between the spiral arms of our Milky Way system.

The 140-foot radio telescope should have a stimulating effect upon electronic development. The electronic apparatus now being used for 21-centimeter research is remarkably good, but the big new telescope will call for improvements to make the most of it. The effectiveness of a large radio telescope depends on three elements: the quality of the mechanical apparatus, the quality of the electronic apparatus and the quality of the scientific personnel who plan the programs and operate the equipment. One may well defend the thesis that it is a wise policy to match every dollar spent on mechanical apparatus with a dollar for electronic research and development and another dollar for scientific salaries.

Thanks to the fact that the 21-centimeter radiation passes undisturbed through dust clouds, it has already been possible to explore by radio parts of our Milky Way forever out of reach of optical telescopes. Now hydrogen is being examined in distant galaxies. A. E. Lilley and E. F. McClain at the Naval Research Laboratory in Washington have discovered hydrogen in Cygnus A, a pair of colliding galaxies about 270 million light-years away, and as we have noted, Heeschen at Harvard has discovered the 21-centimeter emission in the Coma cluster of galaxies [see "Colliding Galaxies," by Rudolph Minkowski; SCIENTIFIC AMERICAN, September]. This is just the beginning. The Great Nebula in Andromeda has not yet been "seen" on the 21-centimeter line, but it should succumb very soon. There is some hope that our radio telescopes with apertures



250-FOOT TELESCOPE nears completion at Jodrell Bank in England. At left is triangular structure of one of the supporting towers; the other can be seen through the scaffolding at right. The whole structure is mounted on railroad tracks on which it will be rotated.



REFLECTOR of 250-foot telescope will be faced with sheets of metal contoured to form a precise parabolic surface. Original design called for woven-wire reflecting surface; importance of 21-centimeter wavelength prompted redesign for higher surface tolerance.

of 60 to 100-feet may be able to detect it, and it will certainly be within reach of the 140-footer.

Our colleagues in Australia have even better prospects for extragalactic radio research. They have in their sky the Clouds of Magellan, the closest galaxies to our own Milky Way. Optical astronomers at the Commonwealth Observatory and radio astronomers in Sydney have already collaborated in exploring these systems. The time seems to have arrived when optical astronomers can profitably go to radio astronomers for information to interpret their optical data. In other words, radio astronomy is not a separate science but just one of many techniques for the study of the universe. Great scientific results may be expected from a proper blending of the radio and optical techniques.

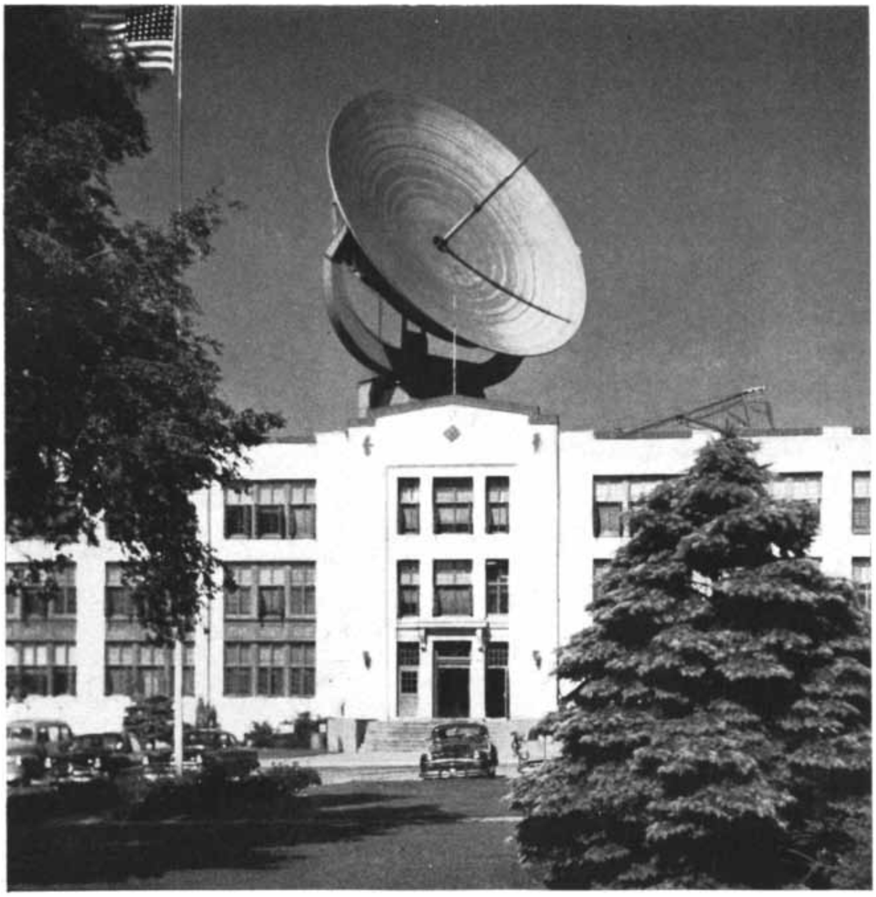
Furthermore, the 21-centimeter observations of distant galaxies show that radio astronomy has important contributions to make to cosmology. Studies of Cygnus A have disclosed a radio "red-shift" corresponding to the red-shift of light, and thereby provided an important check on the expansion of the universe. Heeschen has just obtained a confirming radio red-shift from the Coma cluster of galaxies [see "Science and the Citizen," page 66].

The 140-foot reflector, surveying the radio spectrum over the whole band of frequencies received from objects in space, will be able to determine the relative strength of their emissions at various wavelengths. Because of the simplicity of interpreting records obtained with a paraboloid, the instrument should also be able to pinpoint radio sources quite precisely, and thus help considerably in the optical identification of the objects. The high precision of the reflector's surface will be most helpful in the centimeter wavelength range; the new radio telescope promises to open up the whole field of research into the thermal radiation of gaseous nebulae in the centimeter range.

Up to the present only one specific wavelength in the spectrum of radio radiation from celestial space has been recognized—the 21-centimeter line of neutral hydrogen. There should be numerous other identifiable lines, but these are too weak to be singled out with present-day equipment. The 140-foot antenna, together with improvements in the sensitivity of electronic apparatus, will make it possible to search hopefully for other radio spectrum lines. High on the list of possibilities are an emission of the OH molecule near a wavelength of 18

RING GEAR for vertical rotation of the 250-foot reflector is shown here. Entire telescope will be rotated horizontally by driving the wheels that bear the weight of the structure.

60-FOOT TELESCOPE of Harvard Observatory has equatorial mounting, which is preferred by astronomers but requires heavy counterweights, visible at left behind the reflector.



50-FOOT TELESCOPE at Naval Research Laboratory in Washington, D. C., has altitude-azimuth mounting; *i.e.*, mirror rotates in supporting fork and fork rotates about central axis.

centimeters and a spectrum line of the deuterium atom (heavy hydrogen) near 90 centimeters.

While the major justification for a paraboloid antenna with an aperture of 140 feet or more rests upon its research potential for studies of galaxies, an instrument of this sort also has great possibilities for investigation of our solar system. In studies of the radio radiation from the sun much attention is being paid these days to very rapid variations in this radiation at the time of solar outbursts or flares. The large paraboloid should assist considerably in locating these eruptions precisely and in connecting the flare-ups of light with the bursts of radio energy. It should also help in following events as an outburst or flare makes its effects felt in higher and higher layers of the sun's atmosphere. The very large aperture and receiving area of the 140-foot reflector will make possible ultra-high-speed recording of the resulting radio radiations.

Finally, we should not overlook the great potential value of the large paraboloidal reflector for studies of the planets. Already we have a subject for follow-up investigation in the recent discovery of radio radiation from the atmospheres of the planets Jupiter and Venus, caused in part by a phenomenon resembling giant thunderstorms. In the case of the planet Venus, thermal radiation from the outer parts of the planet has now been detected at the Naval Research Laboratory. The high angular resolution of the 140-foot reflector should assist immeasurably in isolating clear and undisturbed signals. Other planets, notably Mars and Saturn, should be added to the list of subjects for observation.

Ever since the moon was first reached by radar, just 10 years ago, radio astronomers and electronic engineers have dreamed of bouncing radar signals off a planet, specifically Venus, Mars or Jupiter. Electronic techniques are not yet capable of producing the powerful signal needed to obtain an echo from Venus or Mars, but once electronic research and the electronic industry provide us with the necessary tubes, the 140-foot reflector looks like the ideal instrument for initial tests.

All in all, there is certainly ample scientific justification for proceeding without delay to build the 140-foot radio telescope. Scientists everywhere will look forward to the time when the first fruits of scientific research will be produced by the new instrument.

Kodak reports to laboratories on:

how come we tout another manufacturer's camera . . . a pair of replacements for the orchard grass around the old apple tree . . . a material to coat a pattern on metal

Out on the ghostly curve

If called upon to explain how come the world's best known camera manufacturer spends money in this space to tout another manufacturer's camera, we would argue thus:

The new "Graphic 70" is a military combat camera now available to whoever can spend $1850. Doubtless $1850 hand-held still cameras are harder to sell to civilians than $1850 automobiles. On the other hand, Graflex, Inc., has built quite a camera there and has done so on a basis more solid than to satisfy an occasional whim for conspicuous consumption. The principle is that when a man is trying to get some useful pictures at grave risk to his life, a thousand dollars one way or the other is a small price to pay for mechanical and optical refinements that may boost his chance of success a percent or two. In non-military affairs, where calculations happily involve only money instead of lives, situations are also encountered where good sense dictates a position very far out along the ghostly curve connecting quality of equipment with probability of success.

So Graflex builds a 5-pound camera to use our new faster, finer-grained films in the 70mm width that requires little enlargement. The most elaborate precautions are taken in controlling the geometrical relationship between the film and the lens. This is worth doing because of the lenses used on the "Graphic 70." They are the result of taking a generation to build up a strong organization in optical research, design, and manufacturing, then handing it the assignment to produce a 4-inch, an 8-inch, and a 2½-inch lens that will do the best job of putting down a 56mm by 72mm image that the current state of knowledge in optics permits.

And what does it say on the lenses? It says *Kodak Ektar.*

Those interested in the "Graphic 70" camera can learn more by writing Graflex, Inc., Consumer Correspondence Department, Rochester 8, N. Y. Those who wish they had an optical organization like ours to whom to hand design or manufacturing problems can write to Eastman Kodak Company, Apparatus & Optical Division, Rochester 4, N. Y.

Chicken economics

Even if your only relationship with chickens is to enjoy them fried or roasted, chicken economics is more interesting than you might think. No longer is the chicken the symbol of dietary luxury that it used to be when chickens lived on the crude scratch feed that the farmer's wife threw them. Maybe the chicken is no healthier today than it was then, but the chicken business is healthier, and people can afford to eat its product on weekdays.

When the ratio of pounds of feed to pounds of marketable chicken is carried to two decimal places (as the ag schools do in teaching that new folkway, cost accounting), little room is left in the feed bag for certain protective substances that the chickens' free-running ancestors used to get from the orchard grass around the old apple tree. Such things the chemical industry now provides. Poets of pastoral bent may rankle, but certainly not the people who make the machines that cut the gears that go into the automatic transmissions that drive the station wagons that successful farmers now buy. And chicken sandwiches taste better than ever.

As part of the chemical industry, we not only make real vitamin E for feed manufacturers in a form more than 200 times as concentrated as found in dried orchard grass, but now we have launched *Tenox BHT, Agricultural Grade* to preserve and extend whatever vitamin A and vitamin E are already present in natural feed materials. This butylated hydroxytoluene has emerged victorious as a chemical anti-oxidant of unassailable safety even in human food. Now it is for the feedmen, the poultry growers, and their academic advisors to decide merely how much protection from what business risks is worth how much cash outlay.

Myvamix Vitamin E Feed Supplement, *commercial data about it, and a spate of scientific literature are obtainable from Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).* Tenox BHT, Agricultural Grade, *in the form of free-flowing, non-dusting granules of a particle size to assure rapid, permanent blending is now on sale by Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company).*

Mr. Gabler beats the glue

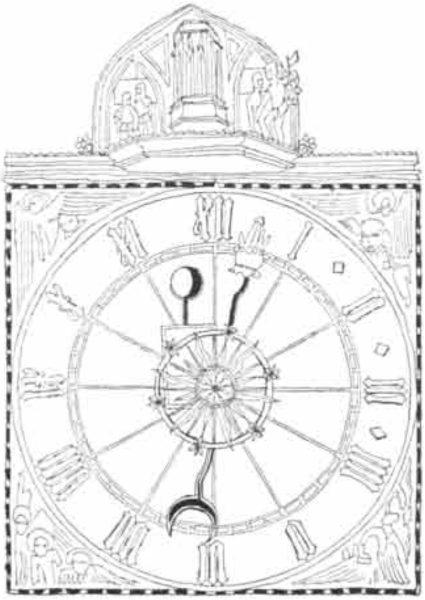
You should see what a fine job Bob Gabler has been doing lately in converting the steel industry over to *Kodak Photo Resist*. Who is Bob Gabler? A man we keep in Pittsburgh to help work out any photographic ideas that come up in the various industries there. What is *Kodak Photo Resist?* A liquid which quickly hardens to a tough, tenacious coating on metal, but only in areas where bright light has hit it before flushing with a certain solvent called *Kodak Photo Resist Developer.*

Before Mr. Gabler showed *Kodak Photo Resist* to the men who make the tensile measurements on sheet steel, they had mostly been using old-fashioned bichromated glue as the light-sensitive substance for photographically printing a measurement grid onto their samples before deformation. Bichromated glue is not nearly as light-sensitive as *Kodak Photo Resist*, but more annoying to the steel testers is its tendency to flake off in the test instead of stretching with the metal the way a grid pattern of *Kodak Photo Resist* does. Bob, of course, had no way of knowing in advance that *Kodak Photo Resist* would work out so well, since the product is one we thought we were making merely for photoengravers, photolithographers, and electronic-circuit printers. But when the steelmen called, he went in there pitching and everything turned out OK. That's what we pay him for.

If you have a problem for a Kodak Technical Representative like Bob Gabler or if you just want literature on Kodak Photo Resist, *write Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y.*

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

Kodak TRADE MARK



SCIENCE AND

Biggest Red-Shift

A new red-shift measurement of light from a cluster of galaxies believed to be about 1.8 billion light-years away—nearly twice as far as any previously studied—was reported from Palomar Mountain last month. The measurement, made by William A. Baum of the Mount Wilson and Palomar Observatories, diverges from findings of Milton L. Humason, as discussed by Allan R. Sandage in the September issue of SCIENTIFIC AMERICAN on "The Universe." Humason, measuring the red-shifts of distant galaxies up to about one billion light-years away, found that their speed of recession seems to increase faster than in direct proportion to distance. According to Baum's measurement, such a trend is not borne out by the more distant cluster: its speed seems to be directly proportional to its distance. If his observation is confirmed, it may revise the California astronomers' tentative conclusion that the expansion of the universe is slowing down at a rate which indicates it is closed and finite. Baum's finding suggests a flat, infinitely expanding universe.

Humason measured the red-shifts of 18 distant clusters of galaxies receding at velocities up to 60,000 kilometers per second. The relation between their velocity and estimated distance follows a curve which indicates that when the light left the most distant galaxies, the universe was expanding substantially faster than it is now. Humason's observations have been interpreted to support a model which pictures the universe as a cyclic system that expands, contracts and expands again.

Baum made his measurements with photoelectric equipment newly installed at the 200-inch telescope. The apparatus supposedly allows more sensitive and more accurate observations of faint starlight [see "Electronic Photography of Stars," by William A. Baum; SCIENTIFIC AMERICAN, March]. Focusing on an extremely faint group of galaxies known as Cluster 1448, Baum computed that the cluster is 1.8 billion light-years away and its red-shift amounts to a velocity of about 120,000 kilometers per second—approximately 40 per cent of the speed of light. The cluster's velocity would therefore be directly proportional to its distance, and this would mean that space is Euclidean, or flat.

Baum believes that as observations are extended to greater distances and the precision of the measurements is improved, space may well turn out to have a "mild" curvature, but not as great as indicated by earlier measurements.

Radio Red-Shift

David S. Heeschen of the Harvard College Observatory has been exploring hydrogen gas in the Coma cluster of galaxies with the 24-foot radio telescope at Harvard's Agassiz Station Observatory. Studying the radio radiation of neutral (un-ionized) hydrogen, he concludes that this gas makes up a third or more of the total mass of the Coma system. He now reports that he has been able to measure the red-shift of the 21-centimeter radiation from the hydrogen, and it amounts to a recession velocity of 7,000 kilometers per second. Measurements of the red-shift of light from the Coma cluster come to 6,680 kilometers per second. Allowing for the uncertainties of measurements, Heeschen says the radio and visual red-shifts agree well enough to confirm that the red-shift is a true measure of the speed of recession of the Coma cluster. His findings are to be published in *The Astrophysical Journal.*

Psychologists and Segregation

The American Psychological Association, meeting in Chicago last month, decided not to hold its 1957 convention in Miami Beach, as it had planned to do. After several heated discussions, the Association's council of representatives voted 34 to 10 against meeting in the South because of segregation. Hotels in Miami Beach had assured the group that all their facilities would be available to Negroes, but most of the council members objected to meeting there on the ground that Negro delegates would be discriminated against in the city and during travel through the South.

At their Chicago meeting the psychologists heard a report on a study of attitudes toward school segregation in a town of West Texas. The town has two separate high schools. Herbert Greenberg of the Texas Technological College, who took part in the survey of the students' attitudes, reported that more than three quarters of the white students agreed with the Supreme Court decision ordering desegregation in schools. The psychologists making the survey concluded that pupils would be ready to accept integration but for their parents' attitude.

New Surgeon General

Leroy E. Burney, a career man in public health, has been appointed Surgeon General of the U. S. Public Health Service to succeed Leonard A. Scheele, who resigned in July. For the last two years Burney had been the Assistant Surgeon General.

Burney was born in Burney, Ind., 49 years ago and received his M.D. from Indiana University. Under a Rockefeller fellowship he did postgraduate work at the Johns Hopkins University School of Hygiene and Public Health. He joined the PHS in 1932.

Shortly before the war Burney established the first mobile venereal disease clinic in Brunswick, Ga. During the war he was assigned to the Navy and went to Europe to help fight the spread of venereal disease among U. S. servicemen. From 1945 to 1954 he was public health commissioner of Indiana.

A recent act of Congress raised the salary of the Surgeon General to $22,626 a year.

New Security Regulations

Government agencies will no longer deny grants for unclassified research to scientists charged with being security risks, presidential assistant Sherman Adams announced last month. This change in policy follows the recommendations made last April by a National Academy of Sciences committee headed by Detlev W. Bronk.

Adams said that a contract or grant will be awarded solely on the basis of whether a scientist is qualified to do the work. If a government official receives information questioning the scientist's loyalty he will report it to a Federal law enforcement agency, instead of canceling or halting the research.

In a letter to Bronk, Adams stated that the Government "recognizes that an atmosphere of free inquiry and protection of individual rights are prerequisite to sound scientific progress. . . ."

The problems of individual scientists and engineers involved in security trouble are being studied by the Scientists' Committee on Security, an independent volunteer group formed at the beginning of this year. The Committee, headed by Ernest C. Pollard of Yale University, says that clearance problems are keeping many men from appointments outside classified areas. The Committee is now surveying this problem and is also assisting the Commission on Government Security in revising government regulations. Pollard and his associates are soliciting information and suggestions.

Thermonuclear Size

A single thermonuclear reactor could produce five times as much electrical power as the entire U. S. now uses, according to Hsue-Shen Tsien, who was formerly Robert H. Goddard professor of jet propulsion at the California Institute of Technology.

Speculating about thermonuclear power in the August issue of *Jet Propulsion*, journal of the American Rocket Society, he calculates that the smallest workable thermonuclear reactor would occupy a tank 3,300 feet long and 330 feet in diameter. This is more than 30 times the volume of the *Queen Mary*. The reaction would generate a temperature of 10 million degrees centigrade and produce enough heat to quintuple the U. S. output of electricity in 1954.

Fortified Fluorocarbons

An advanced development in the construction of fluorocarbons, the new class of tough materials created since the war, was announced last month. Fluorocarbons are compounds like hydrocarbons, with fluorine replacing hydrogen. Because fluorine has a greater affinity for carbon than hydrogen does, the fluorocarbons are more resistant to chemical attack and damage from high temperature. *Chemical and Engineering News* reported that John A. Young of the University of Florida is now synthesizing fluorocarbons in which some of the carbon is replaced by nitrogen. The strong chemical bond between carbon and nitrogen adds to the stability of the fluorocarbon compound.

The chemistry of fluorocarbons fortified with nitrogen is only five years old. But, says the journal, "it would be surprising if some valuable applications were not found in the next five years."

Chemical Cap for Reservoirs

Australian engineers have worked out an ingenious way to conserve water in reservoirs, according to *Chemical and Engineering News*. They cover it with a film of liquid which reduces evaporation by 20 to 70 per cent.

The liquid is hexadecanol, a large-molecule alcohol which floats on water and does not mix with it. The alcohol itself evaporates slowly. The Commonwealth Scientific and Industrial Research Organization, which developed the technique, estimates the cost at less than three cents per 1,000 gallons saved.

Investigators from Kenya, India and several other areas where water is short are looking into the method. Recently the Southwest Research Institute in San Antonio, Tex., allotted $25,000 for an 18-month study to improve the process and make it cheaper.

Food and Cancer

The International Union against Cancer, meeting in Rome last month, issued a warning that many common food additives and impurities may cause cancer. Forty-two experts representing 21 countries reached this conclusion on the basis of several reports, particularly one given by Wilhelm C. Hueper, chief of the environmental cancer section of the U. S. National Cancer Institute.

Hueper listed 20 groups of hazardous chemicals often added to foods as dyes, thickeners, sweeteners, flavors, preservatives, shortenings, bleaches, oils or fat substitutes. Among the preservatives used are the potent compounds thiourea, thioacetamide and hydroquinone. Hueper also cautioned that there may be cancer hazards in antibiotics and hormones used for fattening animals, in insecticide residues and in certain oils and waxes used for coating milk cartons.

The International Union's report par-

Beads by the cubic foot

Sitting here for their portrait are beads representative of several AMBERLITE® ion exchange resins. They and the paper on which they are posed have been magnified 24 times—to the detriment of the paper, perhaps, but not to the uniformity of the beads.

Actually, Rohm & Haas Company produces over 20 ion exchange resins, a variety large enough to serve such diverse uses as water conditioning, metals recovery, pharmaceutical production, sugar refining, chemical processing, and decontamination of radioactive wastes. Some AMBERLITE ion exchange resins even act as medicinals.

Gem-like in appearance, the AMBERLITE resins are nonetheless rugged and durable, serve efficiently for many years. They are manufactured in bulk and are sold by the cubic foot.

Can these resins help you? Why not discuss your processes or products with our technical staff? Meanwhile, for a better understanding of ion exchange, write for "Ion Exchange with the AMBERLITE Resins." There's no charge.

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA ticularly emphasized the danger of dyes. No food dye, it said, can be considered entirely safe, and the report listed 29 as definitely unsuitable or potentially dangerous. It also questioned the use of radiation for sterilizing food.

A committee appointed by the National Research Council to study the Food and Drug Administration's certification of dyes recently came to the same conclusion. The committee reviewed the 116 dyes the FDA has approved for various applications, and found that 101 of them have not been intensively studied. "On the basis of available information," the scientists said, "only five dyes have not manifested some deleterious effects on experimental animals." They recommended that the FDA stipulate not only what dyes are permissible in food and cosmetics but what concentrations are safe.

Hormone v. Insects

Insects and some related lower animals have a growth-control hormone which has long fascinated physiologists and has been investigated intensively by Carroll M. Williams of Harvard University. After a year of work on silkworms at the University of Cambridge, where he was a Guggenheim fellow, Williams now reports success in isolating the hormone. His experiments with it suggest that hormones may be used as a potent new type of insecticide.

The substance Williams has isolated is the so-called juvenile hormone. It is found in the head region of insect larvae. While it is present there, the insect remains a larva, but eventually the hormone disappears and the larva promptly begins to metamorphose to the flying form of the insect. Williams isolated the hormone from the abdominal section of adult male silkworm moths. He then found that when he applied a tiny amount of the substance to the surface of a larva, part of the insect's body metamorphosed and the rest remained larval. The creature grew into a monster and soon died.

Williams points out that such a hormone, or a hormone-like chemical, might control insects just as plant hormones already are used to kill weeds. The advantage of this approach is that an insect is scarcely likely to develop resistance to an essential hormone.

Hormones and the Brain

Within the last three years experimenters have made a major breakthrough in exploring the functions of the brain. They have tapped various parts of it electrically and located centers which control broad aspects of an animal's behavior [*see article by James Olds on page 105*]. Some investigators have now proceeded to inject hormones into brain centers. Last month Alan E. Fisher of the University of Wisconsin reported some interesting results.

Fisher worked with rats and sex hormones, which he dripped into the rats' brains through thin tubes inserted deep in the head. When he injected testosterone, the male hormone, into the brains of male rats, some showed male sexual reactions, others began to behave like mothers. A number of them built nests, as the female does, and a few also exhibited maternal care for the young. Fisher then turned to female rats and injected a female hormone; he succeeded in bringing two of them to heat.

Fisher interprets the results to mean that the rat's reaction depends on the location where the hormone is injected. In other words, a hormone applied to different parts of the brain may cause different reactions. In his report on the experiments, published in *Science*, he expresses the hope that further work along this line may throw light on the effects of drugs and on "the dynamics of behavior."

Gibberellic Growth

A new growth-stimulating hormone of plants is being investigated by Bernard O. Phinney, a botanist, and Charles A. West, a chemist, at the University of California at Los Angeles. It is known as gibberellic acid. The two experimenters obtain it from rice plants infected by a fungus, and they have also extracted what seem to be similar substances, producing the same growth-promoting effect, from young seeds of beans, peas, plums and other plants.

They tested their substances on dwarf strains of corn which, because of a gene mutation, grow no taller than two feet. These plants could not be stimulated to grow further by treatment with the well-known plant growth hormone indoleacetic acid. But when Phinney applied gibberellic acid or the seed extract, the dwarf plants shot up to a height of eight feet. The California experimenters believe they have opened up a new field for study of how plants grow.

Mental Filter

The human mind possesses filtering mechanisms which enable it to grasp two or more messages received simul-

DOW CORNING

SILICONE NEWS

Aid for Maintenance-Weary Plants

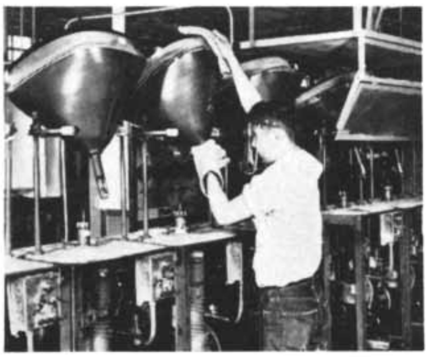
- New Silicone defoamer kills production bug-a-boo, reduces downtime
- Higher vacuum, lower cleaning costs . . . with Silicone diffusion pump fluid
- Motors insulated with Silicones give more mileage per maintenance dollar

KILLING A BIG HEADACHE—Foam steals valuable production space, breeds costly maintenance problems. During the past decade, Dow Corning silicone defoamers have flattened foam during processing of products ranging from Fudgsicles to auto parts. Now are generally conceded to be the most versatile and efficient foam killers available.

Enter Antifoam B, a new Dow Corning silicone defoamer . . . kills foam with all the deftness of its contemporaries but adds a new measure of convenience. Speedy dispersibility is the important key, as illustrated by the underwater photo above. Other features—ready to use, no delays for diluting or mixing—excellent stability, long storage life—stays uniform even if frozen or boiled. No. 35

CORROSION BOWS OUT—More and more maintenance engineers plagued by the high cost of finishing and refinishing metal surfaces are standardizing on protective coatings made with Dow Corning Silicones. A typical example: Reynolds Metals Company has found that silicone based aluminum paint lasts at least 8 times longer than a conventional aluminum paint on diesel exhaust stacks where temperatures average 950°F to 1100°F. Consumers, too, want products that stay good looking longer. That's why foresighted appliance manufacturers are trending toward silicone based product finishes. No. 36

LOW COST HIGH VACUUM — When Thomas Electronics began making TV picture tubes, organic oils were used in the 400 high vacuum diffusion pumps on the production line. Opening and closing these pumps 5 times every 8 hours caused rapid evaporation and breakdown of the oils. Result: Carbon deposits required costly, time-consuming cleanings. In 1951 Thomas switched to Dow Corning silicone pump fluids. Maintenance costs were sharply reduced, because semi-inorganic silicone fluids do not break down to form carbonaceous deposits. Thomas also found that oil consumption dropped 30% with silicone fluid. No. 37



SALVE FOR VALVES—Effective at temperatures from —40°F to 500°F and resistant to many chemicals, "Valve Seal," a salve-like silicone compound, protects valve stems from corrosion, seals against leakage of process fluids. Impressed with the freedom-from-maintenance provided by Valve Seal, the Foxboro Valve Co. now offers its well-known "Stabilflo" valves equipped with a lubricator for injecting this versatile Dow Corning silicone lubricant. Other Valve Seal applications — flow meter bearings, pump packings, plug cocks. No. 38

MORE MUSCLES FOR LESS MAINTENANCE—New dimensions of efficiency in electric motors have been

realized through the use of insulating materials made with Dow Corning Silicones. More power per pound and greater reliability are part of the story. Smoother production and lower maintenance costs are additional reasons why silicone insulated electrical equipment is getting the nod from utilities like the Philip Sporn plant on the American Gas and Electric System.

Philip Sporn's first silicone insulated motor, a 1000 hp, 1190 rpm fan motor, has been operating over 4 years in ambient temperatures up to 120°F. Starting against cold air 4 times a day, it is overloaded by 30% bringing its total rise to 250°F with an output of 1300 hp. Built by the Elliot Co., this motor has coils wrapped with "R Tape," made from Silastic*, Dow Corning's silicone rubber. No. 39

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

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CANADA: DOW CORNING SILICONES LTD., TORONTO GREAT BRITAIN: MIDLAND SILICONES LTD., LONDON FRANCE: ST. GOBAIN, PARIS taneously. So reports D. E. Broadbent of the British Medical Research Council, who has been experimenting in methods of reducing confusion.

As a simple illustration of his point Broadbent presents the following jumble: "The my cat aunt sat went on into the the mat garden." When a single voice intones this series of words, no one can understand it. But if a basso and a soprano alternate in speaking the words, a listener can resolve them into two separate messages: "The cat sat on the mat" and "My aunt went into the garden." The physical difference between the voices permits the listener to distinguish the two alternate series of words.

Broadbent observes that when a listener receives two simultaneous messages both of which are rich in information, he tends to become confused and to understand little of either. If, however, he decides that one message is unimportant, the "biological filter" in the brain allows him to disregard it and to concentrate on the other.

Broadbent's experiments show that when two messages closely follow one another, the brain temporarily stores the second while it deals with the first. It can also do the same thing with two messages received simultaneously if they arrive through different senses—for example, a flashing light and a spoken sentence.

The studies have a workaday pertinence, Broadbent points out, for observers in airport traffic control towers and others who have to unravel flows of information from different sources.

Deep Breath

Robert W. Keast, a young San Rafael, Calif., anesthesiologist, recently broke all records for holding one's breath. He plunged under water and held his breath for almost 11 minutes.

In preparation for his ordeal Keast breathed pure oxygen for 15 minutes, then inhaled air deeply for the next five. Then he slipped on a skin diver's mask and descended into the water. An associate watched him through the window of the mask and also kept an eye on instruments recording his heartbeat and blood pressure. When Keast emerged from the water, after 10 minutes and 58.9 seconds, his pulse rate was only 86 and his blood pressure was still normal.

He commented: "In one respect I was a little disappointed. I had no discomfort, no anoxia, no feeling of impairment of the senses. And yet I misjudged the time a little. What I was trying to do was to come up after 11 minutes."

VOODOO ... AMERICAN STYLE

The supersonic McDonnell F101 "Voodoo" is typical of the high performance aircraft for which Servomechanisms, Inc. designs and produces Central Data Computers. These reliable subsystems measure physical factors, transduce this data to common form, produce corrected information, and compute desired input variables for all other systems in the aircraft.

The Wind Drift Computer, conceived by McDonnell engineers and developed jointly with Servomechanisms' is typical of our Mechatronics design philosophy, which assures maximum reliability as well as minimum down-time through pull-out, plug-in replacement of the individual packaged functions.

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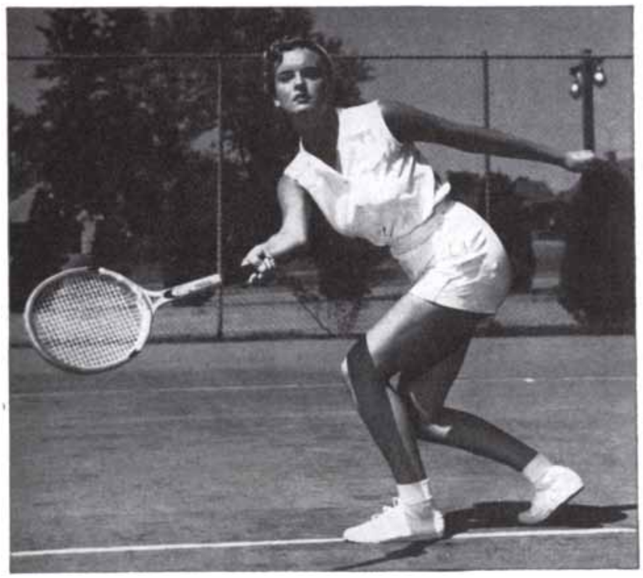
Life

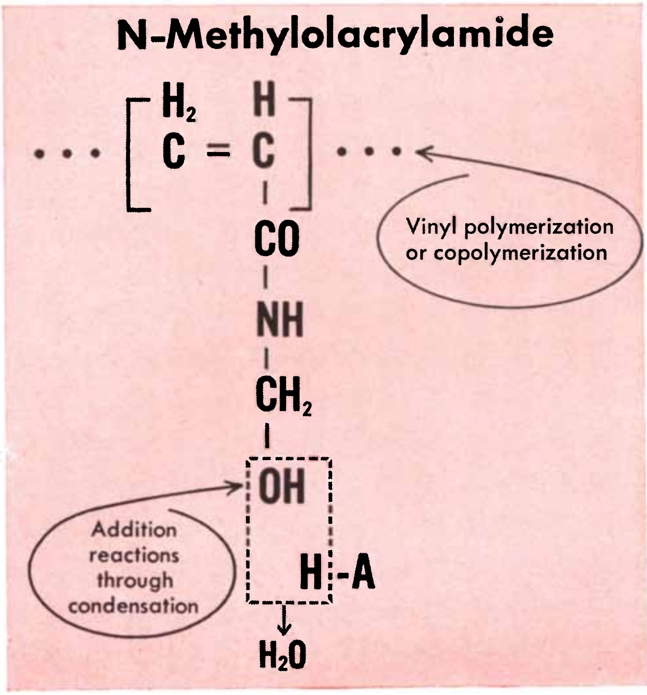
on the Chemical Newsfront

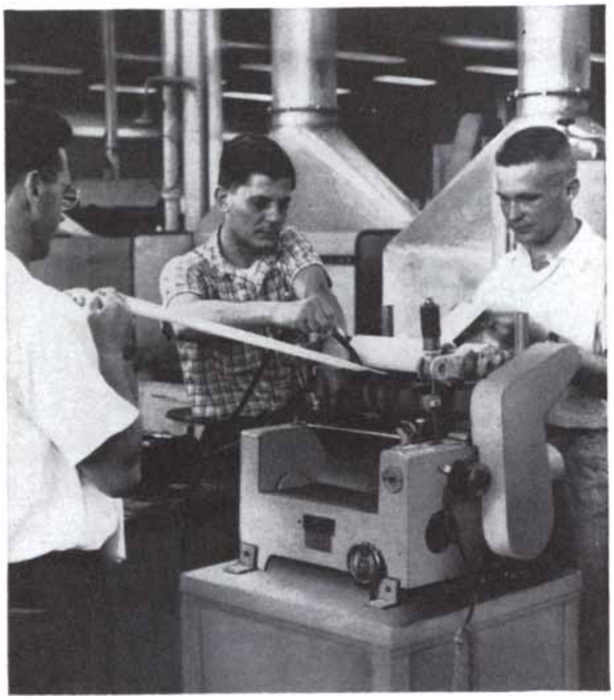
NEW HIGH-STYLED COLORPHONES show the unlimited color range and unsurpassed hardness that account for the expanding use of CYMEL* melamine molding compounds in consumer and industrial products. Color is built in for lifelong beauty, in any shade, any tone you can imagine, from sparkling white through the spectrum to deep black. Since color is molded in, there are no extra finishing steps and no coating to drip, stain or wear off. Not only telephones, but fine dinnerware, appliance housings and other molded products benefit from the excellent resistance of CYMEL to heat, abrasion, staining and household chemicals. Many types of CYMEL molding compounds are available to meet various molding and application requirements. (Plastics and Resins Division)



IT LOOKS LIKE A TOUGH SERIES for uniforms as for players. Hard wear, soiling, perspiration and frequent laundering take a lot out of the crisp flannels that start the season—but this year things look better. Eight major league clubs specified Cyanamid's LANASET® Finish for their uniforms because they found that the built-in shrinkage control and abrasion resistance keep them looking and fitting better. In all types of woolens, LANASET Resin penetrates the wool fibers, preserves their original finish and set, and makes shrinkage negligible. (Organic Chemicals Division)

FOOTWEAR THAT LASTS LONGER and does not discolor is one result of the use of Antioxidant 2246®. This product is well known for its ability to protect natural rubber compounds against surface deterioration, loss of flexibility and discoloration. Now its use as a stabilizer in "non-staining" synthetic rubber polymers adds a new phase to its versatility. Improved storage stability, little or no gel build-up, freedom from discoloration and protection against oxidation of the cured product are all built into these new polymers stabilized with Antioxidant 2246. (Organic Chemicals Division)





NEW BI-FUNCTIONAL MONOMER is N-methylolacrylamide, offering both addition and condensation polymerization possibilities through the active vinyl and methylol groups. The water solubility of the polymerized monomer may be modified to a desired degree through the incorporation of suitable hydrophobic monomers. Such resins show promise for sizing, dye additives and similar applications. Chain polymers or copolymers may be subsequently cross-linked through condensation, suggesting applications in adhesives, cements and thermosetting plastics. N-methylolacrylamide is available in research quantities. (New Product Development Department, Dept. A)

CONTROLLED PARTICLE SIZE is the criterion for the series of new improved CALCOLOID* Vat Dyes developed by Cyanamid. Above, a speck test is one of many performed to insure the high quality of these Vat Dyes now being shipped to the textile industry. Application characteristics dependent on controlled particle size, such as reduction rates, penetration and dispersion, are now more predictable, leading to better dyeing and more consistent results with continuous and batch production. Based on many years' research into dye technology, new manufacturing methods assure optimum particle characteristics for each dye for best performance. (Organic Chemicals Division)

*Trademark

GROWING POPULARITY OF VINYL RAINWEAR and other vinyl products has increased demand for plasticizers based on phthalic anhydride. These and other important uses in polyester resins and intermediates for dyes, pigments and fine chemicals put domestic consumption today at 350,000,000-pound annual level. As quantity use grows, large-volume users are finding convenience and economy by switching to molten AERO* Phthalic Anhydride. Labor is reduced in handling, storing and charging into process equipment. Loss of material is minimized. Fire hazard is reduced by storage under inert gas. Plant housekeeping is greatly simplified. Cyanamid, one of the world's largest producers of phthalic anhydride, ships it in molten form throughout the country. (Industrial Chemicals Division, Department A)

Additional information may be obtained by writing on your letterhead to the Division of American Cyanamid Company indicated in the captions.

Building for the Future Through Chemistry

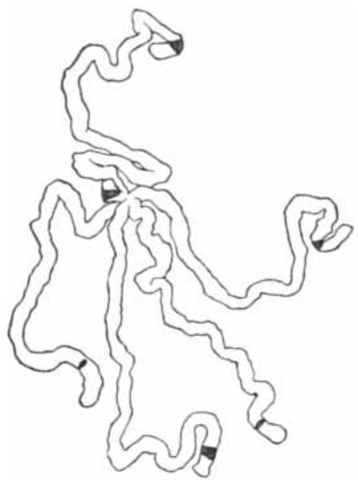
THE GENE

Biologists have yet to see it or to find out exactly what it is made of, but its role in determining the continuity and the variation of living things grows steadily clearer

by Norman H. Horowitz

The distinguished theoretical physicist Erwin Schrödinger has called the science of genetics "easily the most interesting of our days." No branch of science in the 20th century has contributed more to man's understanding of himself and the living world in general. Genetic discoveries have provided new insights into such fundamental problems as the origin of life, the structure of living matter and evolution; and they have yielded practical benefits over a broad range of human concerns, from plant and animal breeding to the investigation of disease. Genetics, in short, has become the theoretical backbone of biology.

The central concept of genetics is the gene, the elementary unit of inheritance. This article presents an account of the development of the gene concept and of modern researches into the nature and mode of action of genes.



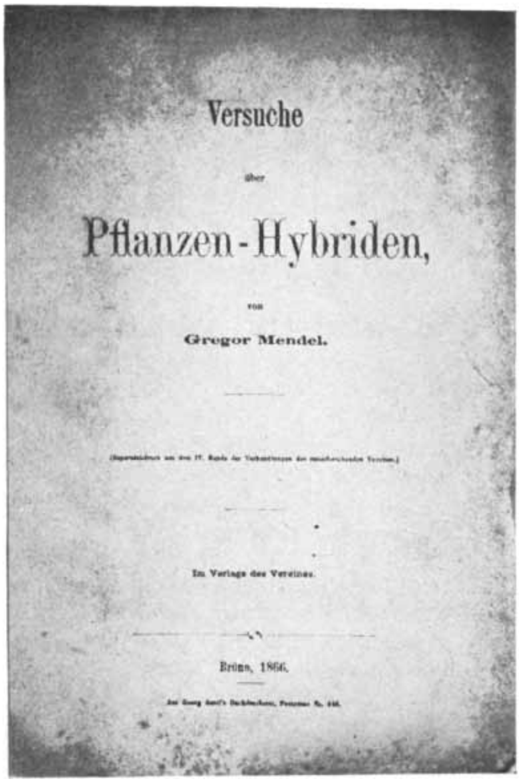
CHROMOSOMES in the cells of the salivary glands of *Drosophila*, sometimes called the vinegar fly (*opposite*), are useful to geneticists because they are large and easy to "read." On the diagram above are marked the loci of certain identifiable features in the chromosomes which are found in association with heritable characteristics, especially color, in the eye of the vinegar fly.

Almost everyone knows that the science of genetics was founded by a monk named Gregor Mendel, who carried on plant breeding experiments as a hobby in the garden of his monastery at Brünn in Moravia (now Brno, Czechoslovakia). The story of how Mendel's remarkable paper, published in 1866 in the proceedings of a provincial natural history society, was ignored by his contemporaries and was rescued from oblivion by three separate investigators in the year 1900, 16 years after Mendel's death, is one of the most dramatic incidents of modern science. Many historians of biology have speculated on why so far-reaching an advance was disregarded at the time it was made, only to be enthusiastically welcomed 35 years later. The interment of Mendel's paper is commonly attributed to the fact that he was an amateur and to the obscurity of the journal in which it was published. But Charles Darwin also was an amateur, and the standing of amateurs in science was still strong in the 19th century. As for the journal—the *Proceedings of the Brünn Society for the Study of Natural Science*—it was regularly received by the leading research centers of Europe, and Mendel is known to have called his paper to the attention of Carl K. von Nägeli, one of the leading botanists of the day. A more likely answer to the puzzle is that Mendel's contemporaries were incapable of appreciating the significance of his discoveries. His conclusions were essentially of an abstract nature, based on numerical data obtained by counting the various kinds of offspring produced by crosses of pea plants. Because chromosomes and many other aspects of the biology of reproduction were unknown in Mendel's day, his paper must have seemed to his contemporaries arbitrary and formalistic—mere numerology.

It is curious to reflect that although Mendel is justly entitled to acclaim for his discovery, the development of genetics would have been the same even if he had never lived. His three rediscoverers—Carl Correns in Germany, Hugo de Vries in Holland, Erich Tschermak in Austria—were led to his paper only after they had independently arrived at the same conclusions. Some geneticists believe that Correns, Tschermak and de Vries were greatly aided in the interpretation of their experiments by Mendel's brilliant paper, but this cannot be proved by the historical record.

"The Elementary Game"

The essence of Mendel's discovery was that hereditary traits—or "characters"—are independent of one another and each is transmitted as a separate unit from a parent to the offspring: in other words, the organism is a mosaic of distinct and independent qualities. The units of inheritance are distributed in families and populations according to the laws of independent events—*i.e.*, the laws of chance. This view contrasts with the older idea that the characteristics of the parents are blended in the offspring, as one might blend two liquids by mixing them together (a misconception which still persists in the expressions "full-blooded," "half-blood" and the like). Mendel showed that there is no blending or dilution of individual characters in a hybrid. The expression of a given character may disappear, but the hybrid


Versuche

über

Pflanzen-Hybriden,

von

Gregor Mendel.

Im Verlage des Vereines.

Brünn, 1866.

GREGOR MENDEL published his first comprehensive report on his investigations in 1866. Copies of his paper were circulated to most of the university libraries of Europe and to many contemporary scientists, yet its significance went unrecognized until 1900.

carries the character as a "recessive" unit, and it may emerge in later generations. Mendelian inheritance is essentially atomistic, the heritable qualities of the organism behaving as if they were determined by irreducible particles (we now call them genes). Mendel was not concerned with the nature of the particles but with showing that inheritance can be understood in these terms and with working out the rules of transmission of traits.

An individual is composed of thousands of heritable characteristics. Each character may take one of several possible forms. For example, there are three principal forms, called A, B and O, of a gene for human blood type. Every person carries a pair of the genes, the possible combinations being AA, AO, BB, BO, AB and OO. A and B are "dominant" and O is "recessive" to them, so that the blood of a person with the combination AO, for instance, shows the properties of the blood group A.

Mendel's laws can be understood in terms of a game of chance in which the genes are represented by counters. There are two players (the parents) and each is provided with a pair of counters for each of the thousands of hereditary characters (*e.g.*, AA or AO or the like for blood group). To play the game each player selects at random one counter from each of his pairs and puts it in a pile in the middle of the table. In the end the pile will contain just as many counters as were originally held by each player, half of them contributed by each player. The pile of counters represents the genetic endowment of an offspring of the two players. In principle this is all there is to the game of Mendelian inheritance. We shall call it the "elementary game."

Mendel's great achievement was to recognize that this simple game—that is, the random separation and reuniting of pairs of inheritance determiners in the germ cells—would provide an orderly explanation of the seemingly unsystematic results of his experiments. Mendel found the evidence for the separation of determiners in a statistical analysis of pea-plant offspring: the characters tended to occur in certain orderly proportions among the members of successive generations as the determiners were shuffled and reshuffled. Nowadays the separation of genes (technically called "segregation") can be demonstrated in a direct way by experiments with some of the lower plants, such as the red bread mold *Neurospora* [see "The Genes of Men and Molds," by George W. Beadle; SCIENTIFIC AMERICAN, September, 1948]. For example, the segregation of a certain gene pair results in exactly equal numbers of black and white spores in every mature set of eight spores produced by this fungus. The Lysenkoists in the U.S.S.R. used to attack Mendelian genetics on the ground that it was based on statistics, which, for reasons not explained, they aimed to eliminate from biology. It was a moment of some dramatic interest, therefore, when, at the International Botanical Congress in Stockholm in 1950, a Portuguese scientist rose to ask a Soviet speaker how he explained the nonstatistical demonstration of segregation in Neurospora and similar organisms. It appears from the official account of the meeting that the Soviet delegate was unaware of these demonstrations.

Enter the Chromosome

In the years following the rediscovery of Mendel's laws at the turn of the century, the new science of genetics advanced rapidly. Investigators soon showed that the Mendelian rules of inheritance applied to animals as well as plants. The most important advance came when T. H. Morgan and his group at Columbia University, working with the vinegar fly *Drosophila*, discovered that the genes are material particles carried in the chromosomes of the cell nucleus. They were led to this discovery by their finding that genes are not altogether independent, as Mendel had thought, but tend to be transmitted in groups. In terms of the elementary game, we would say that the choice of counters is not entirely free: when one counter is selected, there is a tendency for certain other counters to be selected also, as if they were linked by a weak physical bond. Morgan and his students A. H. Sturtevant, C. B. Bridges and H. J. Muller found that genes in the same chromosome (where they are arranged like beads on a string) are transmitted sometimes as an intact group, sometimes not. That is to say, a pair of chromosomes may exchange segments of their strings of genes, forming new chromosomes which consist in part of one and in part of the other—a process known as "crossing over." By grouping genes in chromosomes and yet allowing them some freedom to change their lodgings, nature reconciles two conflicting requirements of inheritance and evolution. On the one hand, total disorganization of the genes in a cell would make the reproduction of cells exceedingly difficult. The tiny vinegar fly has something of the order of 10,000 genes. If they were loose in the cell nucleus, like buckshot, the problem of passing them on in exactly equal number to every daughter cell would be formidable. The problem is reduced to manageable proportions by the fact that the genes are grouped in four pairs of chromosomes: thus the cell has only eight objects to cope with, instead of 10,000. On the other hand, if the genes were forever bound in the same chromosomes, the organism would lack the flexibility for recombination of genes which is essential for evolutionary development. The situation is saved by the fact that genes may cross over from one chromosome to its partner when the germ cells are formed.

The Mendelian theory led to a new understanding of the biological significance of sex. It showed that the sexual method of reproduction provides an elaborate lottery which serves the function of recombining genes in new ways, thus permitting living things to explore a practically limitless range of possible variations. If each of 10,000 genes determining the make-up of a species of organism existed in only two different forms, the number of different gene combinations possible would be $3^{10,000}$. As we have seen, some genes are known to occur in more than two forms. The practically infinite number of possible combinations provides a vast reservoir of potential variability upon which the species can draw for its evolutionary

BOTANIQUE. — *Sur la loi de disjonction des hybrides.* Note de M. **Hugo de Vries**, présentée par M. Gaston Bonnier.

« D'après les principes que j'ai énoncés ailleurs (*Intracellulare Pangenesis*, 1889), les caractères spécifiques des organismes sont composés d'unités bien distinctes. On peut étudier expérimentalement ces unités soit dans des phénomènes de variabilité et de mutabilité, soit par la production des hybrides. Dans le dernier cas, on choisit de préférence les hybrides dont les parents ne se distinguent entre eux que par un seul caractère (les monohybrides), ou par un petit nombre de caractères bien délimités, et pour lesquels on ne considère qu'une ou deux de ces unités en laissant les autres de côté.

» Ordinairement les hybrides sont décrits comme participant à la fois des caractères du père et de la mère. A mon avis, on doit admettre, pour comprendre ce fait, que les hybrides ont quelques-uns des caractères simples du père et d'autres caractères également simples de la mère. Mais quand le père et la mère ne se distinguent que sur un seul point, l'hybride ne saurait tenir le milieu entre eux; car le caractère simple doit être considéré comme une unité non divisible.

» D'autre part l'étude des caractères simples des hybrides peut fournir la preuve la plus directe du principe énoncé. L'hybride montre toujours le caractère d'un des deux parents, et cela dans toute sa force; jamais le

HUGO DE VRIES, in Holland, discovered Mendel's paper after he had performed the same experiments and come to the same conclusion. His first publication was in March, 1900.

19. C. Correns: G. Mendel's Regel über das Verhalten der Nachkommenschaft der Rassenbastarde.

Eingegangen am 24. April 1900.

Die neueste Veröffentlichung HUGO DE VRIES': „Sur la loi de disjonction des hybrides"[1]), in deren Besitz ich gestern durch die Liebenswürdigkeit des Verfassers gelangt bin, veranlasst mich zu der folgenden Mittheilung.

Auch ich war bei meinen Bastardirungsversuchen mit Mais- und Erbsenrassen zu demselben Resultat gelangt, wie DE VRIES, der mit Rassen sehr verschiedener Pflanzen, darunter auch mit zwei Maisrassen, experimentirte. Als ich das gesetzmässige Verhalten und die Erklärung dafür — auf die ich gleich zurückkomme — gefunden hatte, ist es mir gegangen, wie es DE VRIES offenbar jetzt geht: ich habe das alles für etwas Neues gehalten[2]). Dann habe ich mich aber überzeugen müssen, dass der Abt GREGOR MENDEL in Brünn in den sechziger Jahren durch langjährige und sehr ausgedehnte Versuche mit Erbsen nicht nur zu demselben **Resultat** gekommen ist, wie DE VRIES und ich, sondern dass er auch genau dieselbe **Erklärung** gegeben hat, soweit das

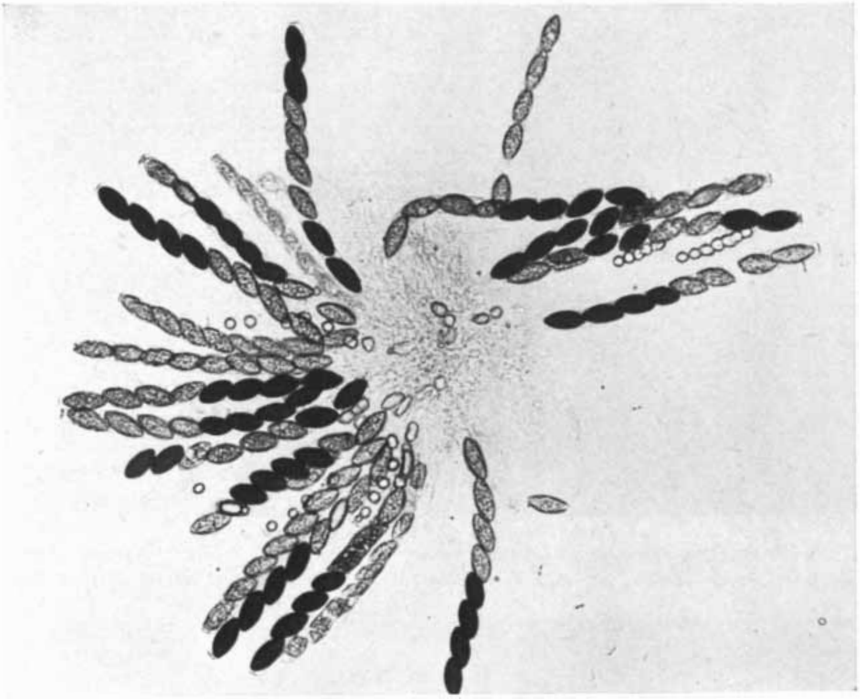
CARL CORRENS, in Germany, saw de Vries' paper and wrote in April, 1900: "The same thing happened to me." He thought he had something new but then found Mendel's work.

26. E. Tschermak: Ueber künstliche Kreuzung bei Pisum sativum[1]).

Eingegangen am 2. Juni 1900.

Angeregt durch die Versuche DARWIN's über die Wirkungen der Kreuz- und Selbstbefruchtung im Pflanzenreiche, begann ich im Jahre 1898 an *Pisum sativum* Kreuzungsversuche anzustellen, weil mich besonders die Ausnahmefälle von dem allgemein ausgesprochenen Satze über den Nutzeffect der Kreuzung verschiedener Individuen und verschiedener Varietäten gegenüber der Selbstbefruchtung interessirten, eine Gruppe, in welche auch *Pisum sativum* gehört. Während bei den meisten Species, mit welchen DARWIN operirte (57 gegen 26 bezw. 12), die Sämlinge aus einer Kreuzung zwischen Individuen derselben Species beinahe immer die durch Selbstbefruchtung erzeugten Concurrenten an Höhe, Gewicht, Wuchs, häufig auch an Fruchtbarkeit übertrafen, verhielt sich bei der Erbse die Höhe der aus der Kreuzung stammenden Pflanzen zu jener der Erzeugnisse von Selbstbefruchtung wie 100:115. DARWIN erblickte den Grund dieses Verhaltens in der durch viele Generationen sich wiederholenden Selbstbefruchtung der Erbse in den nördlichen Ländern. In Anbetracht

ERICH TSCHERMAK, in Austria, was busy on "the second correction of my own paper" when he saw de Vries' and Correns' reports. His abstract was published in June, 1900.



NEUROSPORA SPORES reflect crossing of dark- and light-colored strains. Spore groups have four light and four dark spores, just as pea plants bear peas in fixed ratios (*see opposite*).

progress. This is true of all species that reproduce sexually, from microbes to man.

Self-Duplication

Let us turn to the genes themselves. How are genes reproduced in the cell? How do they act in controlling heredity? What are they made of?

The genes are, of course, self-reproducing. In this they are like the cell or an organism as a whole, such as a bacterium. Bacteria, as we know, arise only from pre-existing bacteria. We can prepare a broth that contains all of the raw materials needed for the production of bacteria, and we can provide all the necessary environmental conditions—acidity, temperature, oxygen supply and so on—but if we fail to inoculate the broth with at least one bacterial cell, then no bacteria will ever be produced in it. The situation is the same with respect to gene production, the only difference being that we cannot prepare an artificial broth for growing genes: the only medium in which they are known to multiply is in the living cell itself. Indeed, it appears that the genes are the only self-replicating elements in a cell; all the other components of cells apparently are produced, directly or indirectly, by the activities of genes.

Just what is involved in the process of self-duplication as we have defined it? One way to explore this question is to look into certain chemical reactions which seem to parallel reproduction by a living organism. An interesting case in point is pepsin, a gastric enzyme which is important for the digestion of proteins. As a catalyst, pepsin acts upon pepsinogen, a protein found in the wall of the stomach, and the product of its breakdown of pepsinogen is pepsin itself. Thus pepsin in the formal sense is self-duplicating: it acts upon the appropriate substance to produce a molecule exactly like itself. Moreover, its production of pepsin from pepsinogen over a period shows a curve of increase like the growth curve of a population of organisms. In other words, the equations for the production of pepsin and the production of cells are the same. The question now is: Does this formal similarity reflect a similarity in the mechanism of duplication?

A number of years ago Roger M. Herriott, Quentin R. Bartz and John H. Northrop at the Rockefeller Institute for Medical Research carried out the following interesting experiment. They added pepsin obtained from chickens to pepsinogen prepared from pigs, and *vice versa*. Their purpose was to learn whether the pepsin produced would depend on the species of pepsin or on the species of pepsinogen. If pepsin behaved like a living organism, the pepsin formed should be the same as the pepsin added, regardless of the source of the pepsinogen, just as the species of bacteria obtained from a culture depends on the species inoculated, not on the nutrients supplied. But the results were just the opposite. Swine pepsin reacting with chicken pepsinogen produced only chicken pepsin, and the mixture of chicken pepsin with swine pepsinogen yielded swine pepsin.

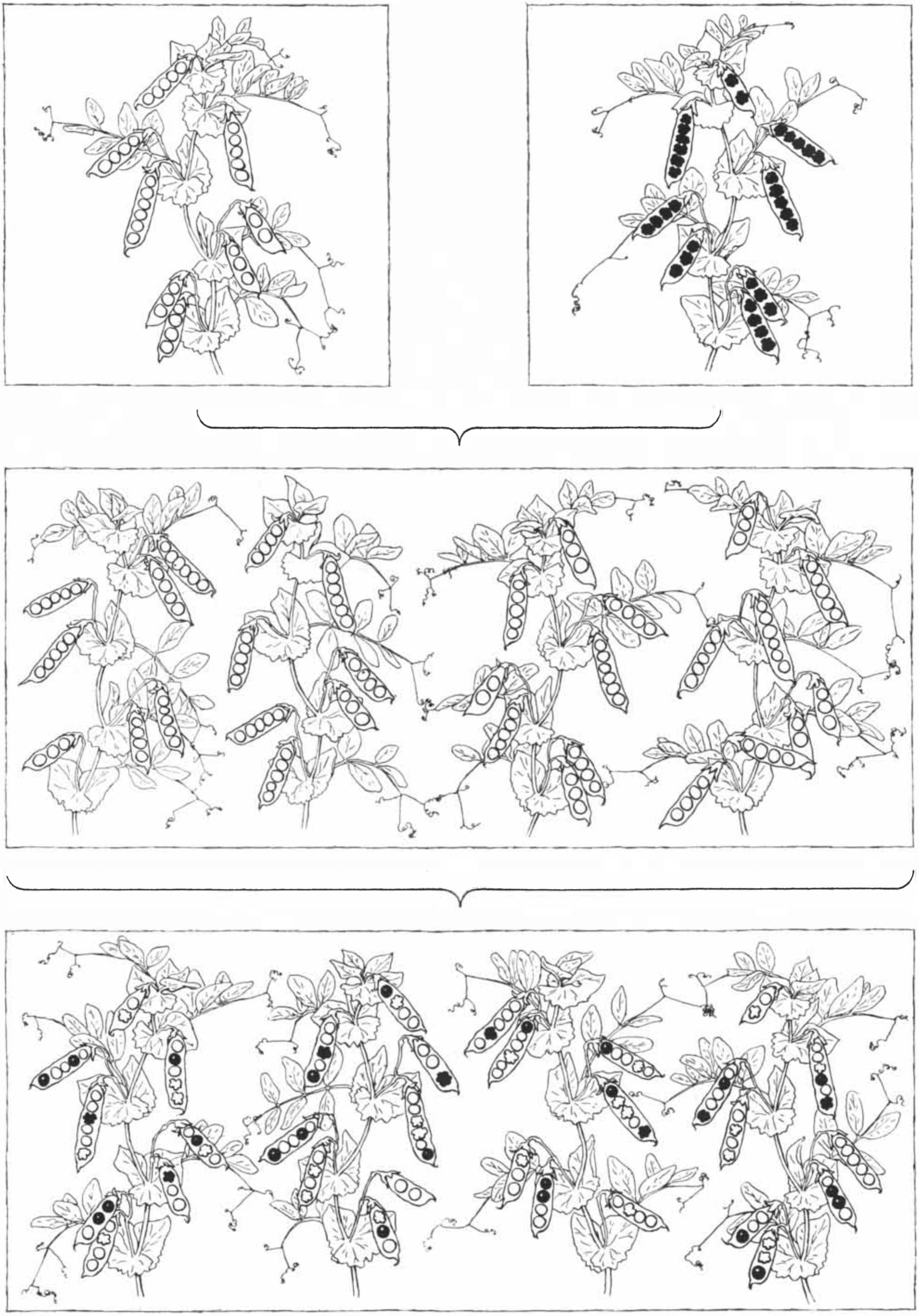
It follows that pepsin is not strictly self-duplicating. The product is determined not by the pepsin but by the material on which it acts. This is not the case with living organisms, as we have seen, and neither is it the case with genes. The reproduction of genes is a *copying* process: they copy themselves when they multiply, and if a gene happens to mutate to a new form, the new type reproduces itself in its mutant version. No such copying process has been found in simple chemical reactions.

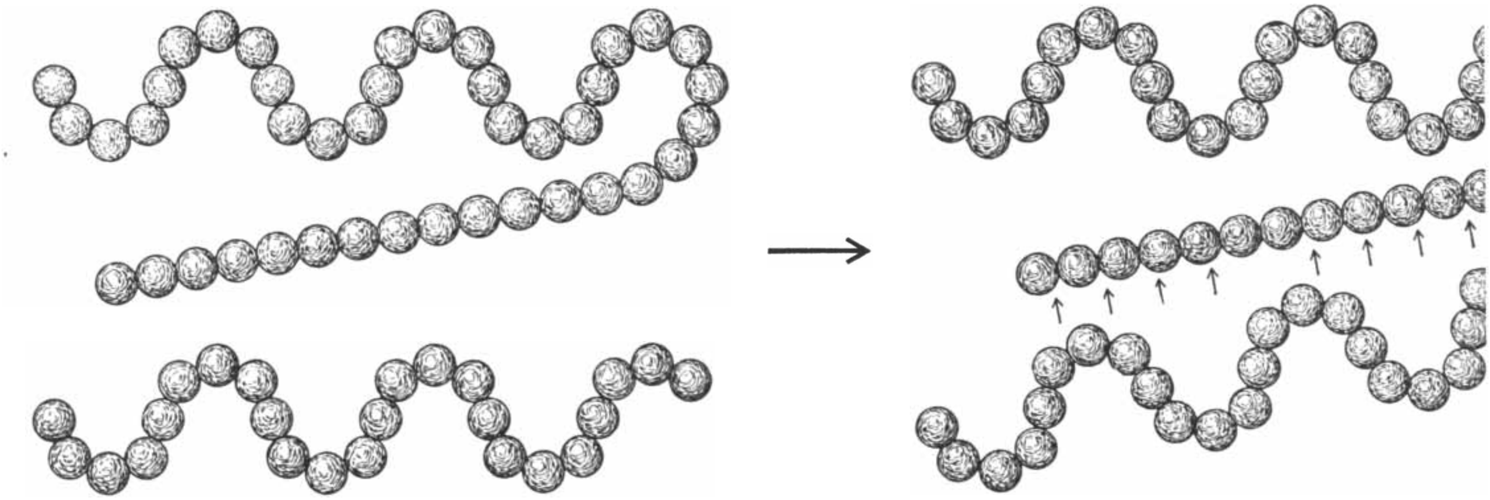
Mutation

The mutation of genes has been investigated very extensively by experimental work with X-rays and other radiations. This exploration began in 1927, when Muller, working with Drosophila, and L. J. Stadler, working independently with barley, discovered that treatment of cells with X-rays speeded up the rate of mutation. The alteration of the genes undoubtedly is due to a chemical change, which is caused by the ionization of atoms (*i.e.*, removal of electrons) by the radiation. The main conclusion drawn from the many experiments with radiation is that a single ionization, in the right place, suffices to cause a gene mutation. This conclusion is particularly interesting because it suggests that the gene is a single molecule. Other ideas have strong champions—among them the theory that the only real unit is the chromosome, a kind of supermolecule—but there is little doubt that at the present time the gene-molecule theory provides the most satisfactory general account of the properties and behavior of genes.

From a practical point of view this

MENDELIAN LAWS are illustrated on the opposite page. At top, a plant bearing smooth yellow peas is mated with one bearing wrinkled green peas. In the first generation (*middle*) the plants bear only smooth yellow peas because smooth and yellow are dominant. In the next generation (*bottom*) the plants bear smooth yellow, wrinkled yellow, smooth green and wrinkled green in the approximate ratios 6:3:3:1.





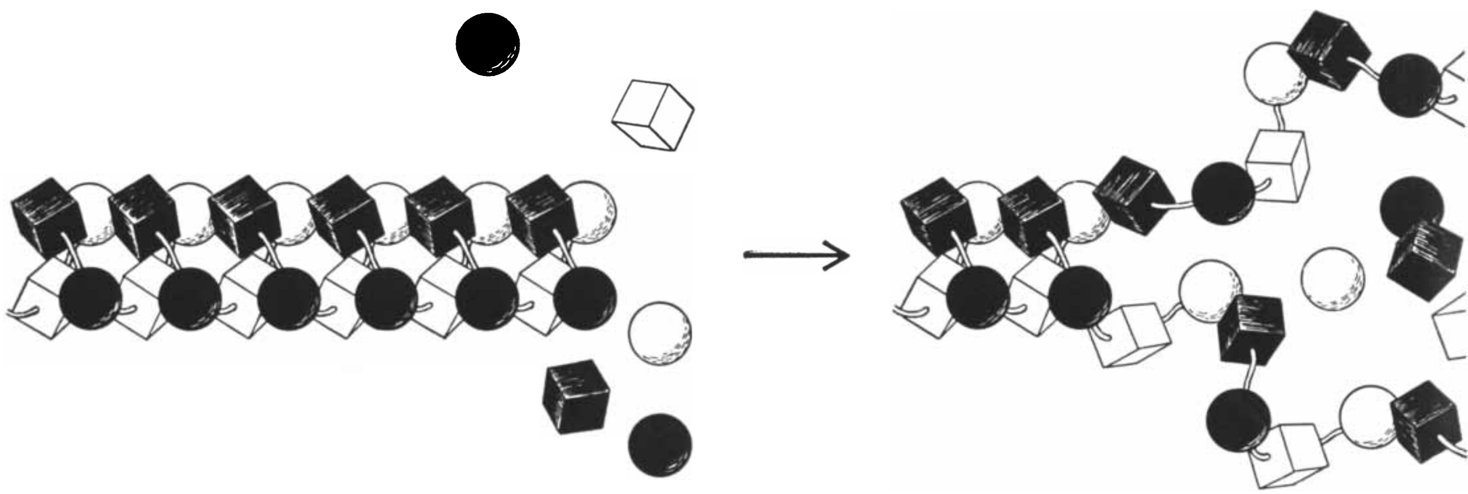
SELF-DUPLICATION OF PEPSIN, an example of autocatalytic reaction in the biosynthesis of proteins, is shown in three steps in this highly schematic diagram. In the first stage (*at left*) a molecule of pepsinogen, the precursor of pepsin, appears at top and a molecule of pepsin below. The beads represent the amino acid units out of which pepsins are made. As indicated, pepsinogen is

interpretation has an important bearing on the possible harmful effects of atomic and other man-made radiations. If the gene is a single molecule, mutable by a single quantum of radiation, then even the smallest exposure to radiation may produce a mutation: in other words, there is no "safe" dose. Experiments bear out this view. Over a wide range of X-ray dosages the frequency of mutation in Drosophila is directly proportional to the number of ionizations, with no indication of a threshold below which mutations are not induced. It is possible that a tolerance level might be found at doses lower than have yet been tested, but such a threshold would be very difficult to detect, because as the dose decreases, we approach the natural, spontaneous rate of mutation, which acts as a background "noise" to obscure the small additional effect of the radiation. Clearly it would be rash to base one's hopes or the national policy on the chance that a threshold exists. The only reasonable course is to assume that no amount of ionizing radiation, however small, is without an effect on the genes. Knowing that gene mutations are irreparable and for the most part harmful, we must weigh this hazard as best we can against the expected benefits of X-rays and other uses of ionizing radiation.

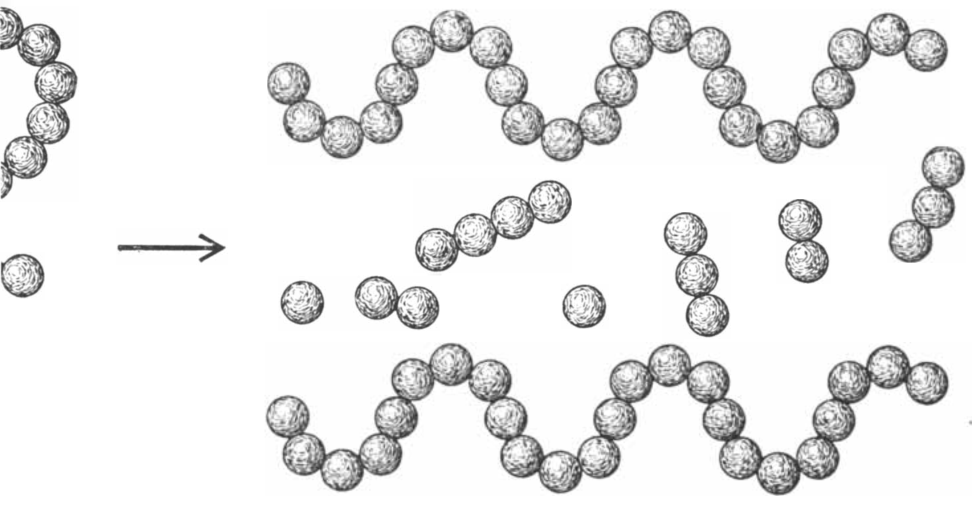
Genes and Enzymes

The sensitivity of genes to radiation brings us to our second question: How do genes act on the cell? A gene mutation can sterilize the cell or permanently alter all of its descendants. Considering that this profound effect is triggered by an almost infinitesimal change in the gene—a single ionization—we must conclude that the genes function in a far-reaching way. That is to say, they act not merely as enzymes (which themselves have profound effects in the cell, determining the rate and direction of its chemical activities) but as catalysts for the production of enzymes.

This idea occurred to the early workers in genetics, but techniques for exploring it have not been available until fairly recently. By now it has won strong support, as the result of the pioneer experiments of George W. Beadle and E.



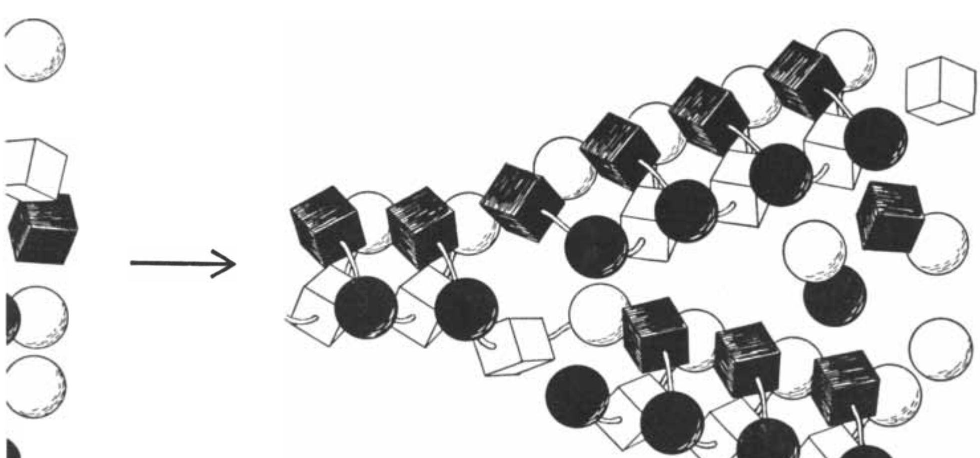
SELF-DUPLICATION OF NUCLEIC ACID, which is thought to be the ultimate genetic material, is shown in three stages in this diagram. In the first stage (*at left*) the nucleic acid is seen as a structure of two helices coiled about one another, with four different nucleotides (represented by cubes and spheres) arranged in complementary order. In the second stage (*center*) the structure



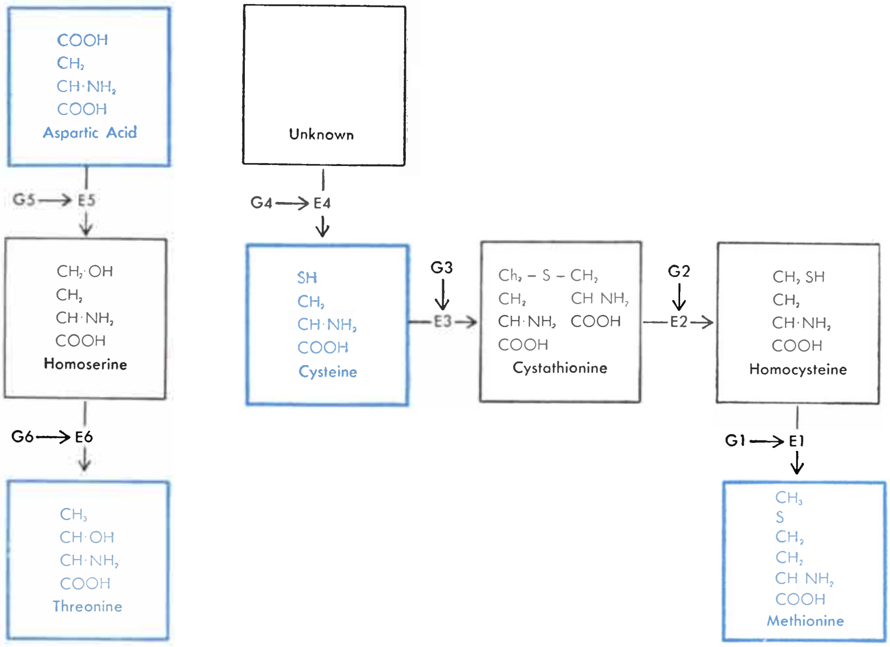
a more complex molecule, incorporating the structure of pepsin itself plus a "tail." In the second stage (*center*) the two molecules enter into reaction with one another. In the third stage the tail has been separated from pepsinogen and there appear two pepsin molecules.

L. Tatum on Neurospora and of many other studies of microorganisms, notably the colon bacillus, *Escherichia coli*. Hundreds of mutations have been produced in these organisms and in each case the effect of the mutation is to abolish the organism's ability to make some essential chemical, for example, a vitamin or an amino acid. The mutation usually blocks just one step in the series of reactions required to make the vitamin or amino acid. It evidently interferes with the production of a single specific enzyme: all the other enzymes involved in catalyzing the series of reactions are apparently unaffected.

In order to account for this selectivity, it is necessary to assume that the structure of the enzyme is related in some way to the structure of the gene. By a logical extension of this idea we arrive at the concept that the gene is a representation—a blueprint, so to speak—of the enzyme molecule, and that the function of the gene is to serve as a source of information regarding the structure of the enzyme. It seems evident that the synthesis of an enzyme—a giant protein molecule consisting of hundreds of amino acid units arranged end-to-end in a specific and unique order—requires a model or set of instructions of some kind. These instructions must be characteristic of the species; they must be automatically transmitted from generation to generation, and they must be constant yet capable of evolutionary change. The only known entity that could perform



uncoils, freeing the components of each helix for attachment to free nucleotide units diffused in the nearby environment. In the third stage (*right*) each helix has bound nucleotide units to itself, thus beginning the formation of two complete new nucleic acid molecules.



SYNTHESIS OF AMINO ACIDS may be mediated by many genes; absence of any one gene will stop the cycle. Each gene (G) catalyzes a specific enzyme (E) which in turn catalyzes one step in the reaction. Compounds boxed in red lines are stable end-product amino acids.

such a function is the gene. There are many reasons for believing that it transmits information by acting as a model, or template.

If the template theory is correct, a mutant gene may produce a mutant enzyme—an enzyme whose structure and properties are changed in some way. A systematic search for mutations of this sort has been started recently, and already several interesting examples have been found.

In our laboratory at the California Institute of Technology we have been studying an enzyme of Neurospora which converts the amino acid tyrosine into melanin—a black pigment widely distributed in nature (it is the black pigment of hair, skin and of the ink of the squid). We find that this enzyme, tyrosinase, may occur in either of two different forms in Neurospora. The forms differ only in their stability toward heat. At a temperature of 138 degrees Fahrenheit, for example, one form is reduced to half of its original activity in three minutes; the other in 70 minutes. Our experiments show that this difference in stability is inherited in a simple Mendelian way—*i.e.*, it is controlled by a single gene. One form of the gene causes the organism to produce tyrosinase which is comparatively stable to heat; the other yields unstable tyrosinase. It is interesting that the forms of the enzyme produced by the two strains of Neurospora are exactly alike in every detail, as far as we have tested them, except in stability to heat. This fact indicates that the genetic control of enzyme structure is exceedingly fine-grained, permitting the separate alteration, as in this case, of a single feature of that structure.

Another example of a gene which influences the structure of a protein is one affecting the hemoglobin of human blood. There is a mutant which is known as the sickle-cell gene, because it leads to production of a form of hemoglobin that causes the red blood cells to take a sickle shape. Linus Pauling and a group of his co-workers at the California Institute of Technology found that the sickle-cell hemoglobin molecule has a different electric charge from normal hemoglobin. A very interesting feature of the sickle-cell mutation, from the evolutionary point of view, is the fact that it apparently confers resistance to malaria [see "Sickle Cells and Evolution," by Anthony C. Allison; SCIENTIFIC AMERICAN, August].

The discovery of structural mutations of proteins is gratifying but is only one step toward a proof of the template theory: to prove conclusively that genes do in fact act as templates, it would have to be demonstrated that every specific property of a protein can be modified by a gene mutation. Experiments along these lines are being pursued actively in several laboratories.

DNA and RNA

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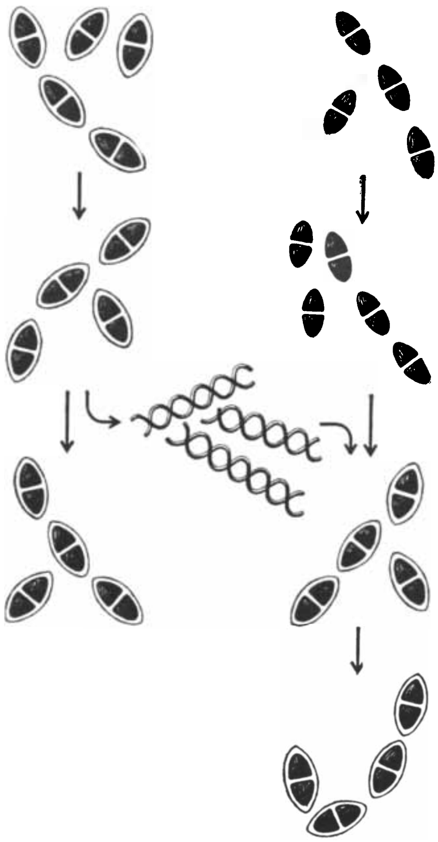
and how they function—will not be obtained until we have found the answer to the third: What are they made of? It may seem strange, considering the great power of modern methods of chemical analysis, that the chemical composition of the genetic material in the chromosomes should still be something of a mystery. The explanation is quite simple: no one has ever isolated a gene from any animal or higher plant—at least so far as anyone is aware, for we have no way so far of recognizing a gene after it has been removed from the cell.

Nevertheless, we do have some definite ideas about the chemical nature of genes. There is very good evidence that the genetic material of some bacteria and viruses consists of nucleic acid, and there is some reason to believe that this is also true in higher organisms. It has been known for a long time that desoxyribonucleic acid (DNA) is a prominent constituent of the chromosomes; this fact marked it for special attention as possible genic material. A number of studies of bacteria and viruses confirm that it does indeed play a genetic role.

Some years ago a substance with gene-like properties was extracted from heat-killed cells of *Pneumococcus*, the pneumonia organism. Strains of Pneumococcus grown in the presence of this substance acquired hereditary characteristics of the particular strain from which it was derived; the characteristics included virulence, resistance to drugs, the ability to synthesize certain enzymes and so on. The transformations were permanent: they were passed on from generation to generation of the bacteria. Moreover, the substance appeared to be subject to mutation. Eventually Oswald T. Avery, Colin M. MacLeod and Maclyn McCarty of the Rockefeller Institute identified the transforming agent as DNA. More recently a new series of transforming agents, also varieties of DNA, has been found in another species of bacteria, *Hemophilus influenzae*.

In the realm of the viruses, there have been two definite identifications of nucleic acid as genetic material. A. D. Hershey and Martha Chase at the Cold Spring Harbor Biological Laboratory have found that DNA plays a genetic role in a bacterial virus which attacks the bacterium *E. coli*. Heinz Fraenkel-Conrat at the University of California identified the genetic substance of the tobacco mosaic virus as ribonucleic acid (RNA).

All the available evidence thus points



PNEUMOCOCCUS is genetically transformed by mixing cells of one strain with nucleic acid from another. The first strain (*right*) thereupon assumes the characteristics which mark the second strain (*left*).

toward nucleic acid as the ultimate genetic material. Naturally its chemical structure has come in for a great deal of attention. F. H. C. Crick and J. D. Watson at the University of Cambridge have proposed a structure for DNA which not only accounts for many of its known physical and chemical properties but also seems capable of accounting for the properties of a gene [see "The Structure of the Hereditary Material," by F. H. C. Crick; SCIENTIFIC AMERICAN, October, 1954]. According to their scheme DNA is composed of two close-fitting, complementary chains, each chain consisting of a long series of nucleotides in linear order. There are only four kinds of nucleotides in DNA, but since the number of nucleotide molecules per chain is of the order of 10,000, the number of possible arrangements is very large indeed. Replication of the molecule is thought to involve separation of the two complementary chains, each of which then acts as a template for the synthesis of a new partner.

The idea of the two-stranded structure seems to have a firm basis. However, it is not easy to see how this model can

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account for template action by genes. The specificity of the Watson-Crick structure rests on the sequence of nucleotides in each chain, suggesting that the genetic information is coded on a linear tape in an alphabet of four symbols. Mutation would consist of the rearrangement, deletion or substitution of parts of this coded message. The difficulty is that whereas the nucleic acid alphabet contains only four symbols (corresponding to the four different nucleotides), the protein alphabet contains 20 or more (corresponding to the 20-odd kinds of amino acids). There is no known mechanism at the present time for translating instructions from the nucleotide code into the amino acid code. But this difficulty may not be insuperable [see "Information Transfer in the Living Cell," by George Gamow; SCIENTIFIC AMERICAN, October, 1955].

Thus for the first time we have a definite working hypothesis as to the structure of the gene. There is, however, a puzzling feature about the present situation. The experiments on the tobacco mosaic virus clearly show that RNA is capable of performing a genetic function. But RNA does not usually act in this way, as far as can be determined. It is found chiefly in the cytoplasm of cells (*i.e.*, outside the nucleus), and genetic experimentation with animals has failed to show any regular mechanism of inheritance in the cytoplasm. Hereditary mechanisms do exist in the cytoplasm of plant cells (for example, in connection with the production of chlorophyll) but they are of minor significance compared to the chromosomal mechanism.

Possibly the RNA that controls heredity in the tobacco mosaic virus (and other plant viruses) is of a different kind from that found in the cytoplasm of animal cells. Such a difference could explain why RNA acts like a gene in one situation and apparently not in the other. But this possibility cannot be tested at the present time, because the chemistry of RNA is still relatively unknown.

The Origin of Life

A general article on the gene ought to make at least some mention of what bearing all this may have on the problem of the origin of life. Probably no question in biology has a wider appeal than this one—especially among nonbiologists. Historically the basic difficulty has been to define "life." Up to the 17th century the most primitive forms of life known were worms, fleas, scorpions and the like, and there was a notion that these creatures originated spontaneously

AB	CD	AD	AC	BA	AC	BD	AC	BA	BC
|	|	|	|	|	|	|	|	|	|
C	H	R	O	M	O	S	O	M	E

FOUR-LETTER CODE suggests one way in which the four nucleotide components of nucleic acid, here designated as A, B, C, D, may control the synthesis of the 20 different amino acids of which proteins are made.

from decaying organic matter. This idea was demolished in 1668 by the Italian physician Francesco Redi, when he showed that no maggots developed in meat shielded from egg-laying insects. But it was reborn at another level when, a few years later, Anton van Leeuwenhoek discovered bacteria. They seemed so small and rudimentary that many people were convinced they must be on the dividing line between living and nonliving matter. Actually bacteria are just as complex as any cell of our own bodies, and their spontaneous origin from nonliving material is not much more likely than the spontaneous generation of scorpions.

Nowadays many biologists and biochemists tend to regard the question of how life started as essentially meaningless. They view living and nonliving matter as forming a continuum, and the drawing of a line between them as arbitrary. Life, on this view, is associated with the complex chemical paraphernalia of the cell—enzymes, membranes, metabolic cycles, etc.—and no one can say at what point it begins. Geneticists are apt to take a different view. If genes are required to produce enzymes, then life began only when they began.

We can imagine the spontaneous origin of some chemical substance capable of reproducing itself, of mutating and of directing the production of specific catalysts in its environment. It would not be long before this substance, trying out new molecular arrangements by blind mutation, began to evolve along lines favored by natural selection. In time all the complexity that is now associated with living matter might well develop.

It may be objected that an unstated assumption is hidden in this theory: namely, that the gene arose in an environment which was already prepared to supply all the materials needed for its multiplication and other chemical activities. But if this is an objection, it holds for any theory which supposes that life began in some accidental combination of chemicals. The material of life as we know it could have come into being only in a complex chemical environment.

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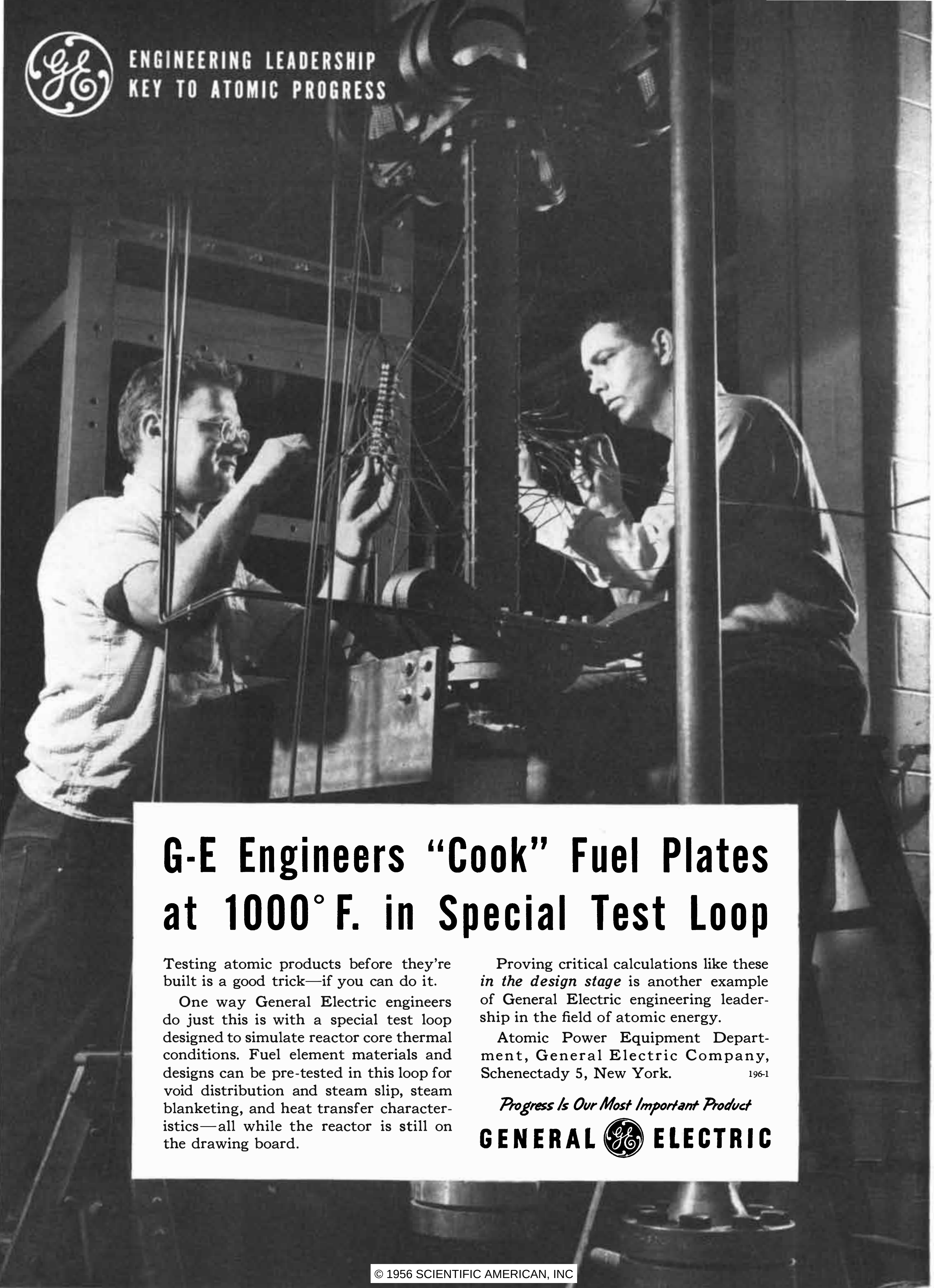

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Mesonic Atoms

For brief instants mesons may spin like electrons on orbits around atomic nuclei. The X-rays they emit, as they jump from orbit to orbit, may illuminate the nature of the nuclear binding forces

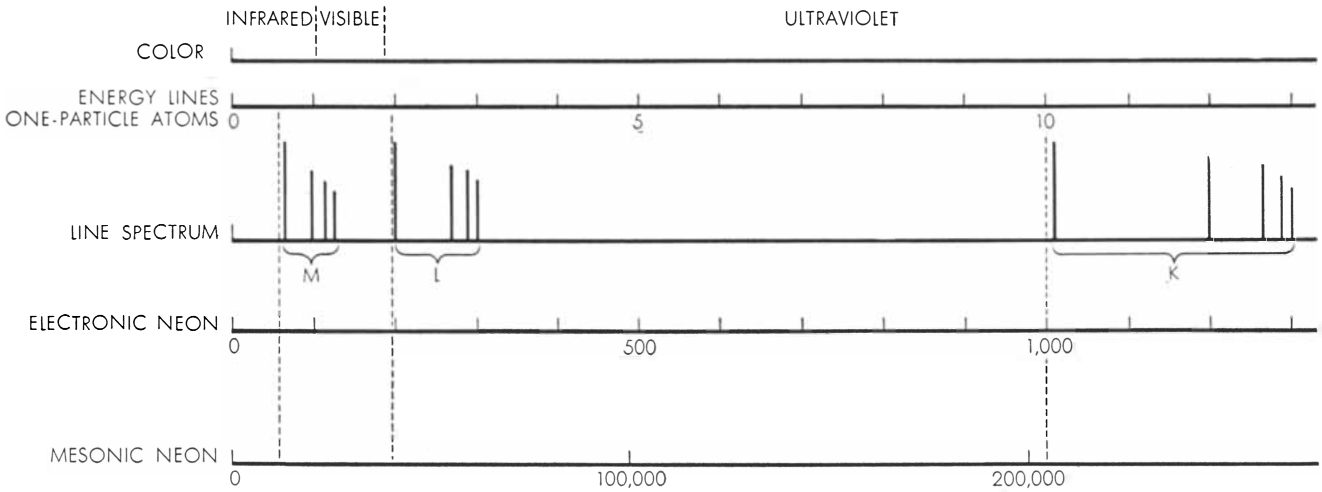
by Sergio DeBenedetti

In the half century since the atom was opened up as a new world to explore, physicists have been busy taking it apart to see what it is made of. It has been a period of violent bombardment and assault, and experimental work in atomic physics has become popularly known as "atom smashing." But the study of the atom is now entering a new phase. Nowadays atoms are so well understood that physicists can undertake to build as well as destroy them. Completely artificial atoms have been forged from some of the newly discovered atomic particles, and these serve as tools for testing theories about the nature of the atomic world.

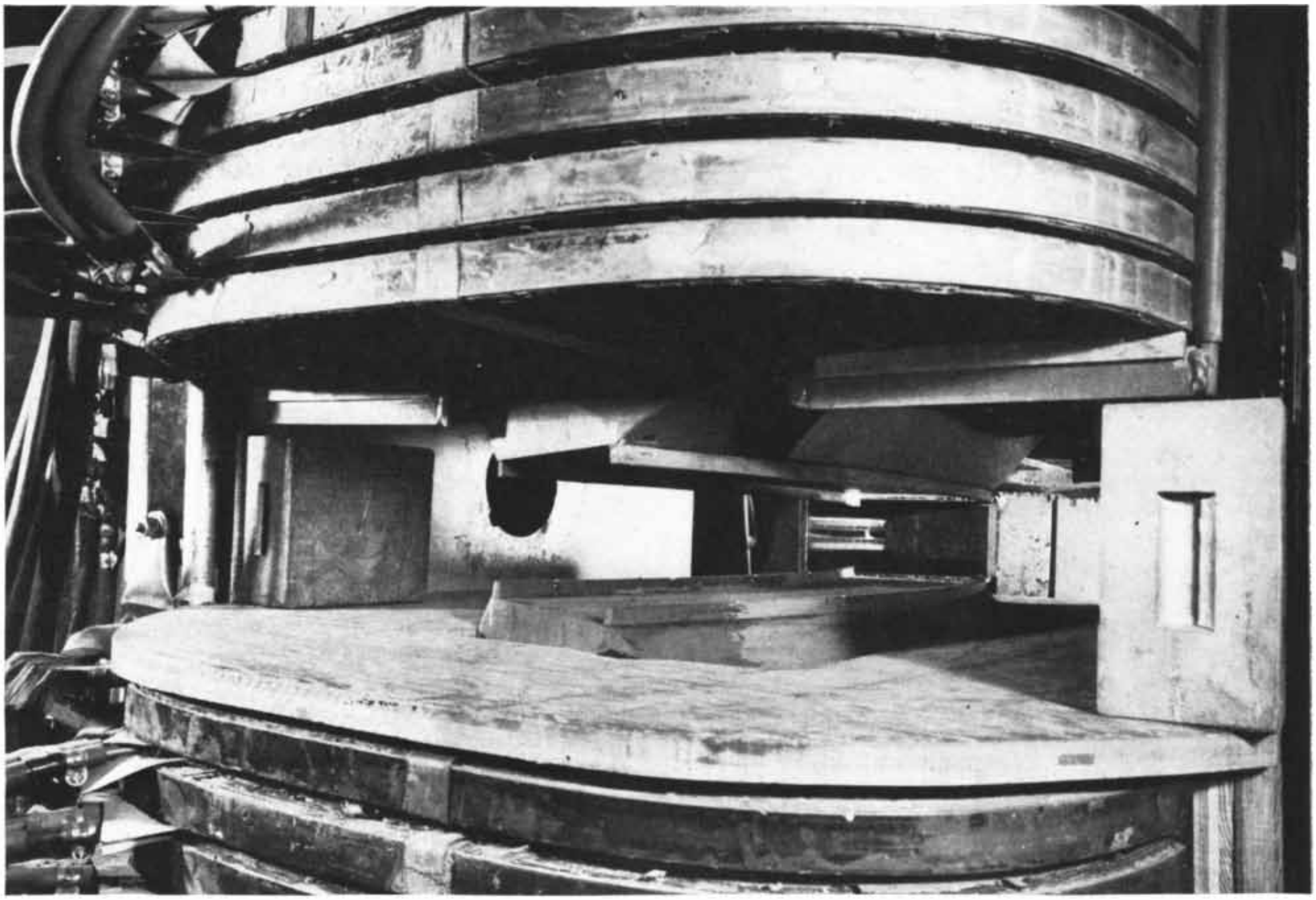
The first such atom to be made was positronium [see "The Ultimate Atom," by H. C. Corben and S. DeBenedetti; SCIENTIFIC AMERICAN, December, 1954]. Positronium is a short-lived, practically weightless atom composed of an electron and a positron—a particle exactly like the electron except that its electric charge is positive instead of negative. The positronium atom is analogous to the simplest ordinary atom, hydrogen, which consists of an electron and a proton; we can consider that in positronium the positron takes the place of the proton.

In this article we shall deal with another type of artificial atom in which we replace an electron with a meson. Here the atom has an ordinary nucleus, consisting of protons and neutrons, but a meson instead of an electron revolves in an orbit around the nucleus. Mesons, as is now well known, are middleweight particles (between the weight of an electron and a proton) which are believed to be connected in some way with the forces inside the atomic nucleus. Since the nature of these forces is the greatest unsolved problem in atomic physics, the mesonic atom is an object of extraordinary interest. What does it tell us about the nucleus?

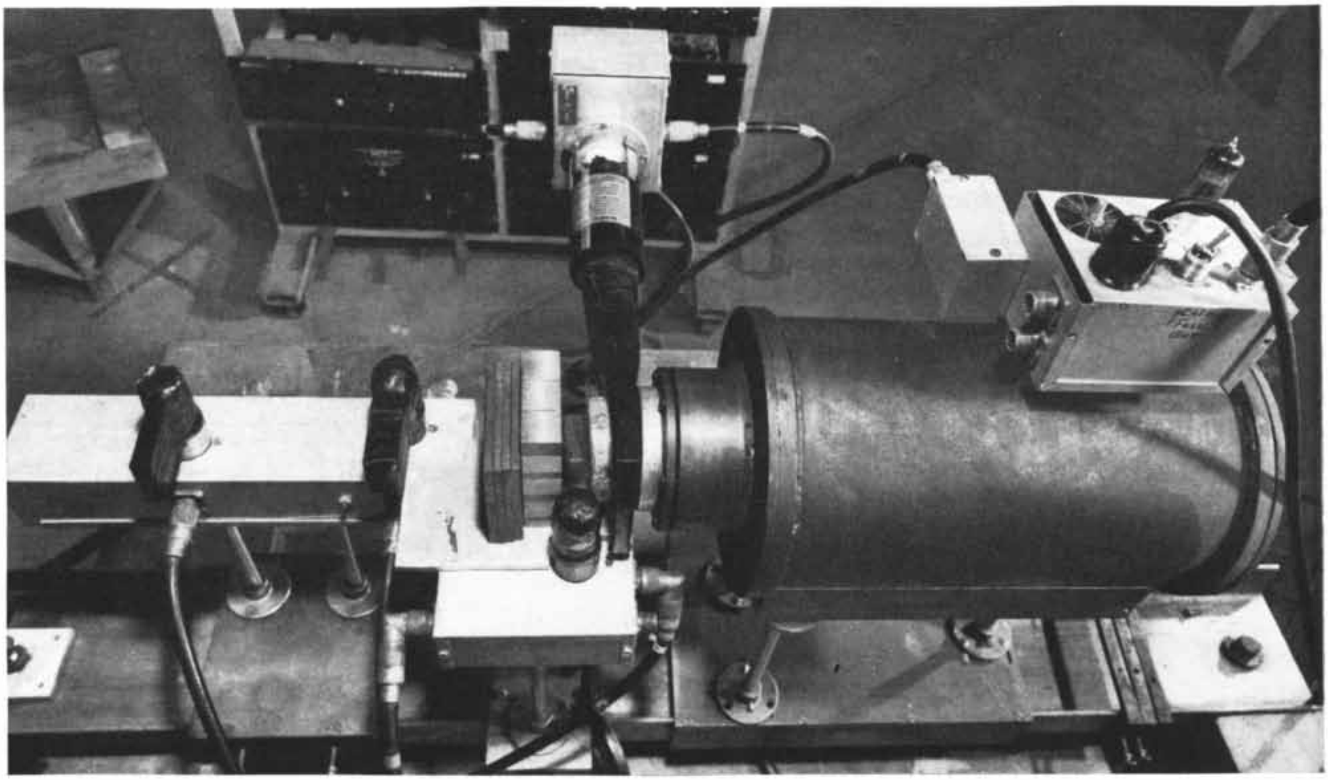
Let us begin by making an inspection tour of the simplest ordinary atom, hydrogen, under the expert guidance of Niels Bohr, who gave us our first idea of its structure. Entering the atom, we find its electron revolving around the heavy positive nucleus, the proton, in a circular orbit about 10^{-8} (a hundred millionth) of a centimeter in diameter. Dr. Bohr points out that if energy is supplied to the atom, the electron may leave this orbit (called the ground state) and jump momentarily to an orbit farther from the nucleus. There is a certain finite number of such orbits available to the electron. It may travel in



ENERGY SPECTRA of electronic and mesonic atoms are compared here. The top three bars locate the emission lines of hydrogen with respect to the visible spectrum (*top*) and to the energy spectrum of hydrogen (*second bar*). The emission lines of electronic neon occur at 100 times the electron voltage of hydrogen. Because the pi meson is 210 times heavier than the electron, the lines of mesonic neon are found at 210 times the electron voltage of electronic neon or 21,000 times the electron voltage of hydrogen.



DEFLECTING MAGNET directs the beam of mesons from the synchrocyclotron to the target. The lucite window of the synchrocyclotron can be seen at right of center through the hole in the 15-foot shielding. The beam travels more than 30 feet in air on its course from the window to the target. The curved metal tracks on the poles of the magnet indicate the deflection of the beam.



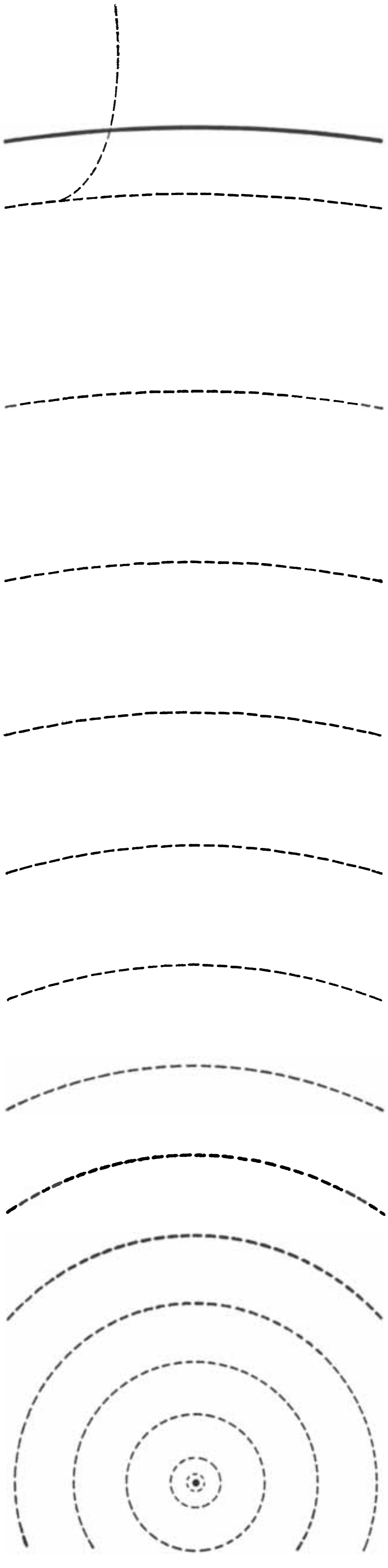
MESON TARGET instrumentation is shown here. The meson beam, traveling from left to right in this picture, is detected first by the two counters at left. Next it is slowed by the slabs of copper and beryllium just to left of center. Then it enters the target wedged between two counters at center. X-rays from the target material are measured in the detector, the large tank at right.

any one of these but is never permitted anywhere else within the atom. Soon after its leap to the higher orbit, the electron, being attracted by the positive charge of the nucleus, jumps back to the ground state, in one or more successive steps. Each jump releases energy which we see as light. A familiar example of this light emission is the tube used for luminous signs, where the atoms are excited to higher orbits by an electric discharge. Every atom emits light of characteristic colors. If we analyze with a spectroscope the light of a tube containing hydrogen atoms, we will see a series of sharp lines of different colors, each corresponding to an electronic jump.

We now ask our guide what would happen if the electron of the hydrogen atom were replaced by a negatively charged meson. Dr. Bohr answers that the meson also will be permitted only certain orbits around the nucleus and will emit characteristic radiation at each jump. If the particle is a mu meson, 210 times heavier than the electron, each of its orbits around the nucleus should be 210 times smaller than the corresponding orbit of an electron, and the wavelength of the emitted radiation should be shorter in the same ratio. If the particle is a pi meson, 273 times heavier than the electron, the orbit and radiation wavelength will be reduced by the factor 273.

This shortening of the wavelength takes the radiation out of the range of visible light and transfers it to the realm of X-rays. Unfortunately the emission from a mesonic hydrogen atom would be soft (*i.e.*, nonpenetrating) X-rays, which are difficult to study. But a heavier mesonic atom will emit shorter-wave (*i.e.*, more energetic) X-rays. Let us take, for example, the case of neon, an atom containing 10 electrons. Its outermost electronic orbit is about as large as the smallest orbit of hydrogen (10^{-8} of a centimeter in diameter). But its innermost orbit is just 10 times smaller than that of hydrogen. Therefore the smallest orbit of a mu meson replacing an electron in the neon atom would be not 210 but 2,100 times smaller than that of the electron in the unexcited hydrogen atom. There is a corresponding reduction in the wavelength of the radiation emitted: the wavelengths of the radiations from the mesonic jumps of neon should be $210 \times 10 \times 10 = 21{,}000$ times smaller than those of normal hydrogen. We should have no difficulty in detecting X-ray emissions of this energy.

Now that, with the guidance of Dr. Bohr, we have an idea of what to expect of mesonic atoms, let us see how



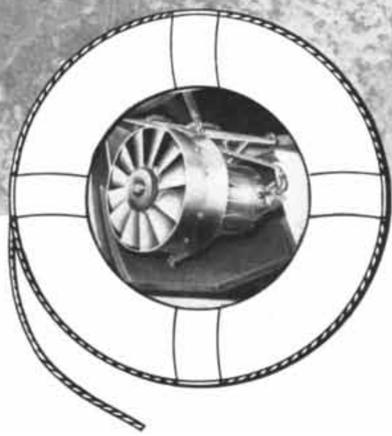
MESONIC ORBITS of carbon are shown here in rough approximation of their relative distances from the nucleus of the atom at bottom. The heavy arc at top of the diagram locates the innermost electron orbit.

well these predictions are borne out by experiments. The experiments require a synchrocyclotron, to produce beams of negative mesons, and an instrument in which the mesons are captured by atoms and the resulting X-ray emissions are recorded: such an instrument was built by Val Fitch and James Rainwater of Columbia University. The fast mesons emerging from the synchrocyclotron are slowed by passage through a block of solid matter; then, reduced to thermal speed (the ordinary speed of atoms' motions), they enter the material whose atoms are to capture them [*see photograph at bottom of page 94*]. While wandering among these atoms, a meson feels the electrostatic attraction of an atom's positive nucleus and is drawn into the inner part of the atom, near the nucleus itself. It jumps from one orbit to the next and emits X-rays. The X-rays are registered by a scintillation counter, and their energy, or wavelength, is found by measuring the size of the pulses in the counter.

The experiments were first conducted with mu mesons. In the case of relatively light atoms, such as neon or carbon, everything went just as Bohr's theory had predicted. The wavelengths of the X-radiation from the mesonic jumps showed the expected ratio to the wavelengths of light during electronic jumps, as computed from the 210-fold difference in mass between the mu meson and the electron. But when it came to heavy atoms, this regular ratio disappeared. The X-rays emitted by a heavy mesonic atom turned out to be considerably less energetic than expected.

What goes wrong? We begin to get some idea when we look at the dimensions with which we are dealing. Let us take the case of an atom of lead, which has 82 electrons. If we substitute a meson for one of these electrons, then according to Bohr's theory the innermost orbit of the meson should be 82×210 times smaller than the diameter of the hydrogen atom: since the hydrogen diameter is 10^{-8} of a centimeter, the diameter of this orbit is 5.8×10^{-13} of a centimeter. This is a small orbit indeed. Let us look up the diameter of the nucleus of the lead atom. In a table prepared before the experiments of Fitch and Rainwater we find that the diameter of the lead nucleus is given as 17×10^{-13} of a centimeter. In short, the meson's orbit is less than half the size of this nucleus, so that according to our calculation the meson should be revolving within the nucleus!

Can this be possible? We have to conclude that, although no such thing is



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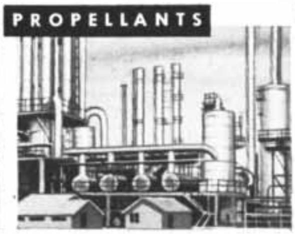

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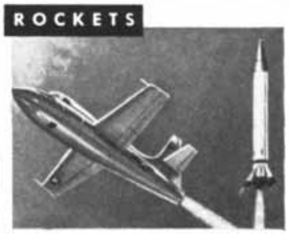

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conceivable in normal atomic physics, it is a possibility in the case of a mesonic atom. While the nucleus of an atom is very dense, density does not necessarily mean opacity, and it is not excluded that the meson may travel freely within the nucleus. The idea of the impenetrability of matter is a macroscopic concept. At the atomic and subatomic level, anything can happen.

And, indeed, it does. The mu meson actually circulates freely within the nucleus (though the pi meson, as we shall see, does not). It makes an enormous number of revolutions—millions of millions—within the nucleus of lead. But all this happens in a hundredth of a millionth of a second, and the meson is then absorbed by the nuclear matter. Upon its absorption the mass of the meson is transformed into energy and the nucleus undergoes a violent explosion.

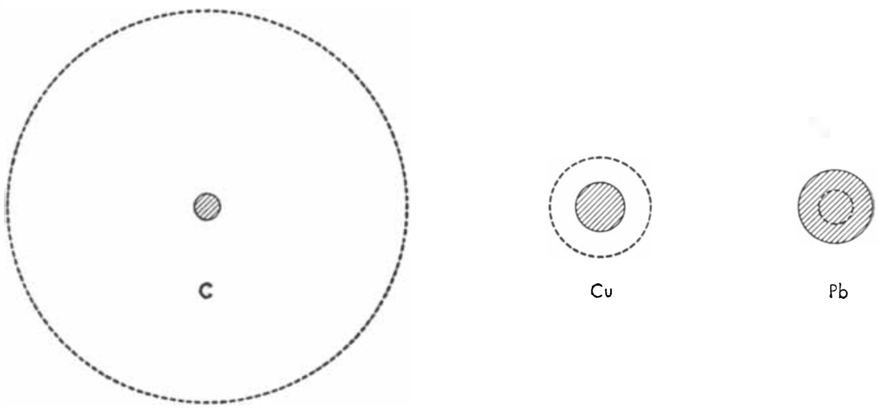
From the wavelengths of the radiations emitted by mesonic atoms, Fitch and Rainwater were able to calculate the sizes of atomic nuclei. The computations are complex and we need not go into them here, but we can say a few words about the assumptions used. The nucleus is pictured as a cloud of charge—dense but nevertheless perfectly fluid, so that it opposes no resistance to the motion of the meson. For the meson we must use a somewhat more refined model than the old theory of Bohr: it is necessary to take into account the uncertainty principle, according to which a particle cannot be localized as a point moving in a definite orbit but is spread out as if it were a diffuse, jelly-like object of finite extent. When the cloud and the jelly—together with a few more ingredients such as relativity and a spin—are introduced in the Los Alamos electronic computer, out comes the result: the dependence of the wavelength of the X-rays on the size of the nucleus.

About the only thing nuclear physicists thought they knew for sure concerning the nucleus of the atom was its size. But the experiments of Fitch and Rainwater proved that they were wrong even in that. According to their measurements, the nucleus of an atom is only about one half as large in volume as had been thought. This is the first very significant contribution of mesonic atoms to our knowledge of nuclei.

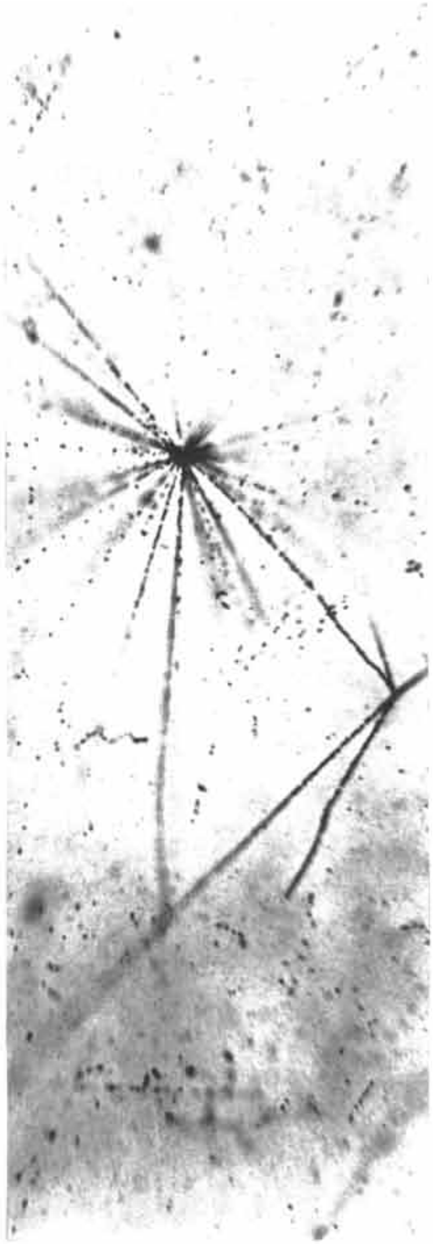
Let us now see what results have been obtained with pi mesons. The pi meson, in contrast to the mu, reacts with nuclear matter very rapidly and much more violently. In a mesonic atom of hydrogen, for instance, the mu meson will revolve peacefully in its orbit around the proton for the comparatively long time (on the atomic scale) of several microseconds; then it decays of its own accord into an electron and neutrinos, just as if the proton were not there at all. On the other hand, a pi meson in such an atom barely reaches the lowest orbit before it is gobbled up by the proton. Its lifetime in the atom is a million times shorter than that of a mu meson. When the negative pi meson reacts with the positive proton, they neutralize each other's electric charge and become neutral particles.

In a heavier atom the phenomenon is even more spectacular. In neon the pi meson does not reach the lowest orbit: it is eaten up by the nucleus when it arrives at the next-to-lowest. The greediness of nuclei for the pi meson is almost incredible. In a heavy atom such as lead—in which the mu meson can travel almost undisturbed within the nucleus—the pi is captured when still in the fifth or sixth orbit away from the nucleus—orbits whose diameter is at least 10 times larger than the nucleus itself. The experimental evidence for this behavior is the absence of the last X-ray lines.

After a pi meson is captured by the



INNERMOST MESONIC ORBITS of carbon, copper and lead are shown here. The nuclei are shown in proportion to size. The innermost orbit of lead is inside the nucleus.



MESON STAR caused by disruption of an atom by a primary cosmic ray appears above center. A pi meson track, traced diagonally to right, terminates in a secondary star.

nucleus, it disappears entirely. As in the case of the mu meson, its mass is transformed into energy: the nucleus explodes and breaks into many pieces. In a photographic emulsion the pieces flying away leave a developable image in the characteristic form of a star.

The fact that the nucleus captures the meson from a faraway orbit does not necessarily mean that they are brought together by a force of attraction. As we have mentioned before, the whole picture of orbits is a convenient oversimplification: the particle which in Bohr's theory is supposed to travel in an orbit is really smeared out over most of the

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atom, and in a sense it touches the nucleus. Thus no special forces are needed to get the meson to the nucleus.

What light can mesonic atoms throw on our main problem—the forces that hold the protons and neutrons together in the nucleus of an atom? Most nuclear physicists now believe that the key to this puzzle lies in the pi meson (which goes under the name of "nuclear glue" even in the daily press). It seems evident that there are strong forces, other than electrostatic, between pi mesons and atomic nuclei. For one thing, a beam of pi mesons behaves differently from one of mu mesons when it bombards matter. The pi mesons will change their direction and scatter much more than the mu: since the electric forces are the same in the two cases, the difference is attributed to specific nuclear forces acting on the pi meson.

The scattering of pi mesons was first studied with some care by the late Enrico Fermi and his collaborators at the University of Chicago. One of the points they could not determine was the sign of the force: whether it was a force of attraction or repulsion. Now, with the mesonic atom, it has been possible to test this question. If the force is attractive, we should expect the pi meson to be brought closer to the nucleus than if it were repulsive, and the issue should be decidable by examination of the wavelengths of X-ray emission. With this in mind, a careful measurement of the X-rays from pi-mesonic atoms was performed at the Carnegie Institute of Technology by Martin and Mary Stearns, Larry Leipuner and the author. The results showed that the nuclear force on the pi meson is repulsive. This conclusion, which has since been verified by certain detailed features of the scattering, need not upset our ideas about the nucleus itself. The forces between the neutron and the proton can still be attractive, and there is no danger that atomic nuclei will come apart!

In spite of its obvious involvement, no quantitative relation between the behavior of the pi meson and the nuclear forces proper has yet been found. Perhaps other mesons and new particles which are continually turning up have something to do with these forces. At any rate, the mesonic atom offers a new approach which is full of promise. As soon as sufficiently intense beams of the newer mesons (tau, k, etc.) become available from the bigger accelerators, we may hope to build new atoms with them and perhaps learn more about the properties of the nucleus.

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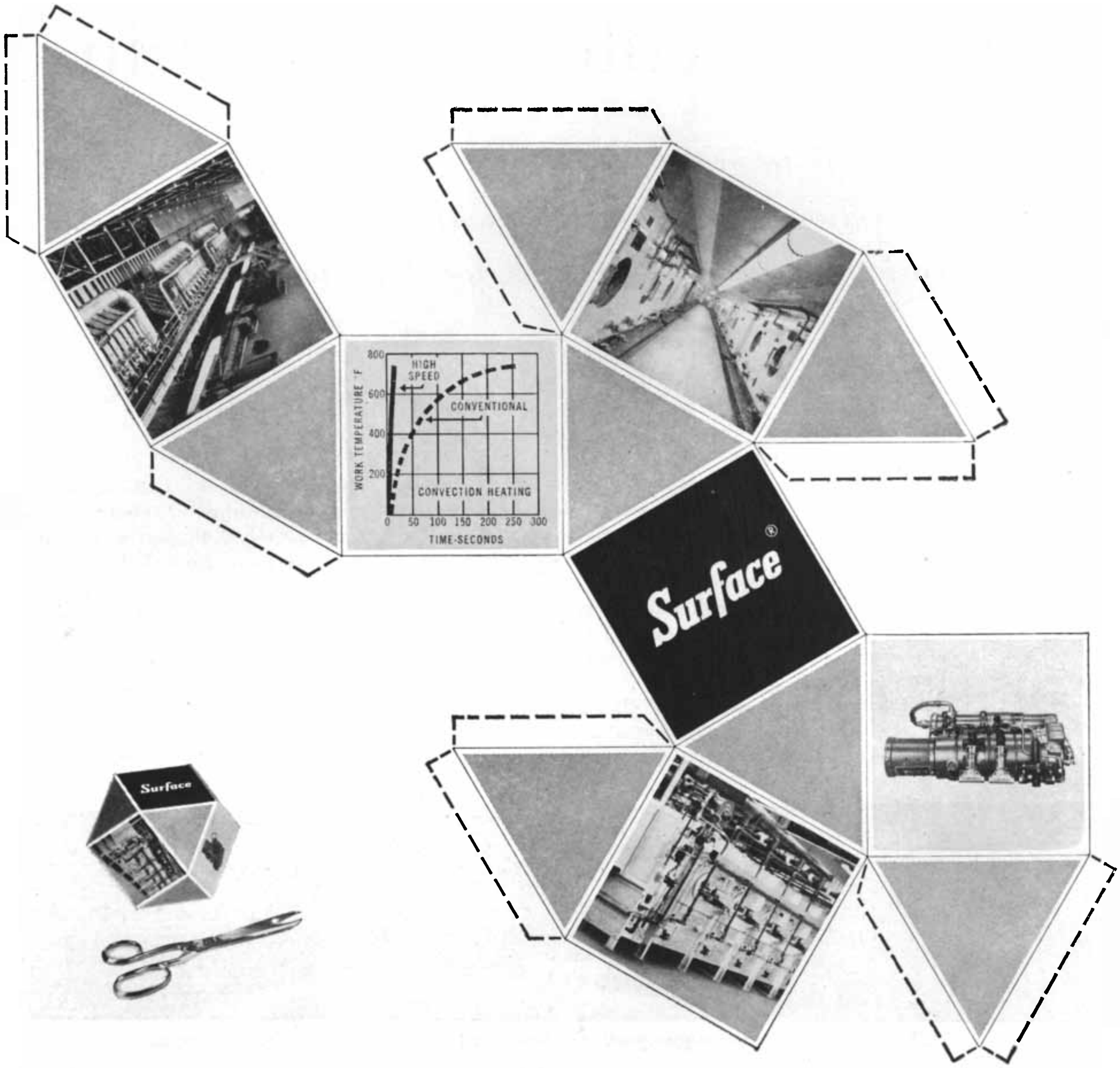

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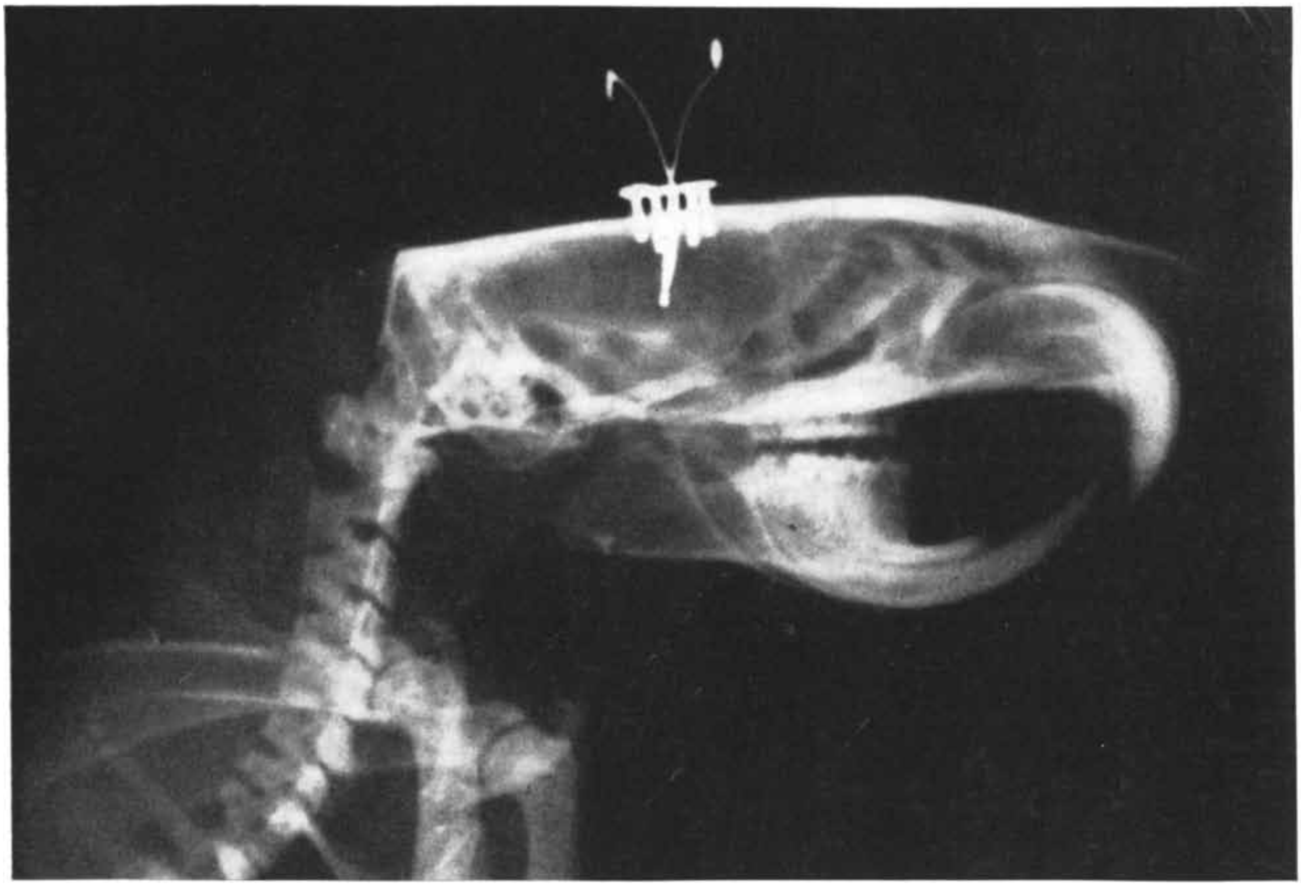
Pleasure Centers in the Brain

Rats can be made to gratify the drives of hunger, thirst and sex by self-stimulation of their brains with electricity. It appears that motivation, like sensation, has local centers in the brain

by James Olds

The brain has been mapped in various ways by modern physiologists. They have located the sensory and motor systems and the seats of many kinds of behavior—centers where messages of sight, sound, touch and action are received and interpreted. Where, then, dwell the "higher feelings," such as love, fear, pain and pleasure? Up to three years ago the notion that the emotions had specific seats in the brain might have been dismissed as naive—akin perhaps to medieval anatomy or phrenology. But recent research has brought a surprising turn of affairs. The brain does seem to have definite loci of pleasure and pain, and we shall review here the experiments which have led to this conclusion.

The classical mapping exploration of the brain ranged mainly over its broad, fissured roof—the cortex—and there localized the sensory and motor systems and other areas which seemed to control most overt behavior. Other areas of the brain remained mostly unexplored, and comparatively little was known about their functions. Particularly mysterious was the series of structures lying along the mid-line of the brain from the roof down to the spinal cord, structures which include the hypothalamus and parts of the thalamus [*see diagram on page 107*]. It was believed that general functions of the brain might reside in these structures. But they were difficult



IMPLANTED ELECTRODES in the brain of a rat are shown in this X-ray photograph. The electrodes are held in a plastic carrier screwed to the skull. They can be used to give an electrical stimulus to the brain or to record electrical impulses generated by the brain.

RAT'S BRAIN in a photomicrographic cross section shows a black spot to left of center, marking the point where electrical stimulus was applied. Such cross sections make it possible to tell exactly which center in the brain was involved in the animal's response.

to investigate, for two reasons. First, the structures were hard to get at. Most of them lie deep in the brain and could not be reached without damaging the brain, whereas the cortex could be explored by electrical stimulators and recording instruments touching the surface. Secondly, there was a lack of psychological tools for measuring the more general responses of an animal. It is easy to test an animal's reaction to stimulation of a motor center in the brain, for it takes the simple form of flexing a muscle, but how is one to measure an animal's feeling of pleasure?

The first difficulty was overcome by the development of an instrument for probing the brain. Basically the instrument is a very fine needle electrode which can be inserted to any point of the brain without damage. In the early experiments the brain of an animal could be probed only with some of its skull removed and while it was under anesthesia. But W. R. Hess in Zurich developed a method of studying the brain for longer periods and under more normal circumstances. The electrodes were inserted through the skull, fixed in position and left there; after the skin healed over the wound, the animal could be studied in its ordinary activities.

Using the earlier technique, H. W. Magoun and his collaborators at Northwestern University explored the region known as the "reticular system" in the lower part of the mid-brain [*see opposite page*]. They showed that this system controls the sleep and wakefulness of animals. Stimulation of the system produced an "alert" electrical pattern, even from an anesthetized animal, and injury to nerve cells there produced more or less continuous sleep.

Hess, with his new technique, examined the hypothalamus and the region around the septum (the dividing membrane at the mid-line), which lie forward of the reticular system. He found that these parts of the brain play an important part in an animal's automatic protective behavior. In the rear section of the hypothalamus is a system which controls emergency responses that prepare the animal for fight or flight. Another system in the front part of the hypothalamus and in the septal area apparently controls rest, recovery, digestion and elimination. In short, these studies seemed to localize the animal's brain responses in situations provoking fear, rage, escape or certain needs.

There remained an important part of the mid-line region of the brain which had not been explored and whose functions were still almost completely unknown. This area, comprising the upper portion of the middle system, seemed to be connected with smell, and to this day it is called the rhinencephalon, or "smell-brain." But the area appeared to receive messages from many organs of the body, and there were various other reasons to believe it was not concerned exclusively or even primarily with smell. As early as 1937 James W. Papez of Cornell University suggested that the rhinencephalon might control emotional experience and behavior. He based this speculation partly on the observation that rabies, which produces profound emotional upset, seems to attack parts of the rhinencephalon.

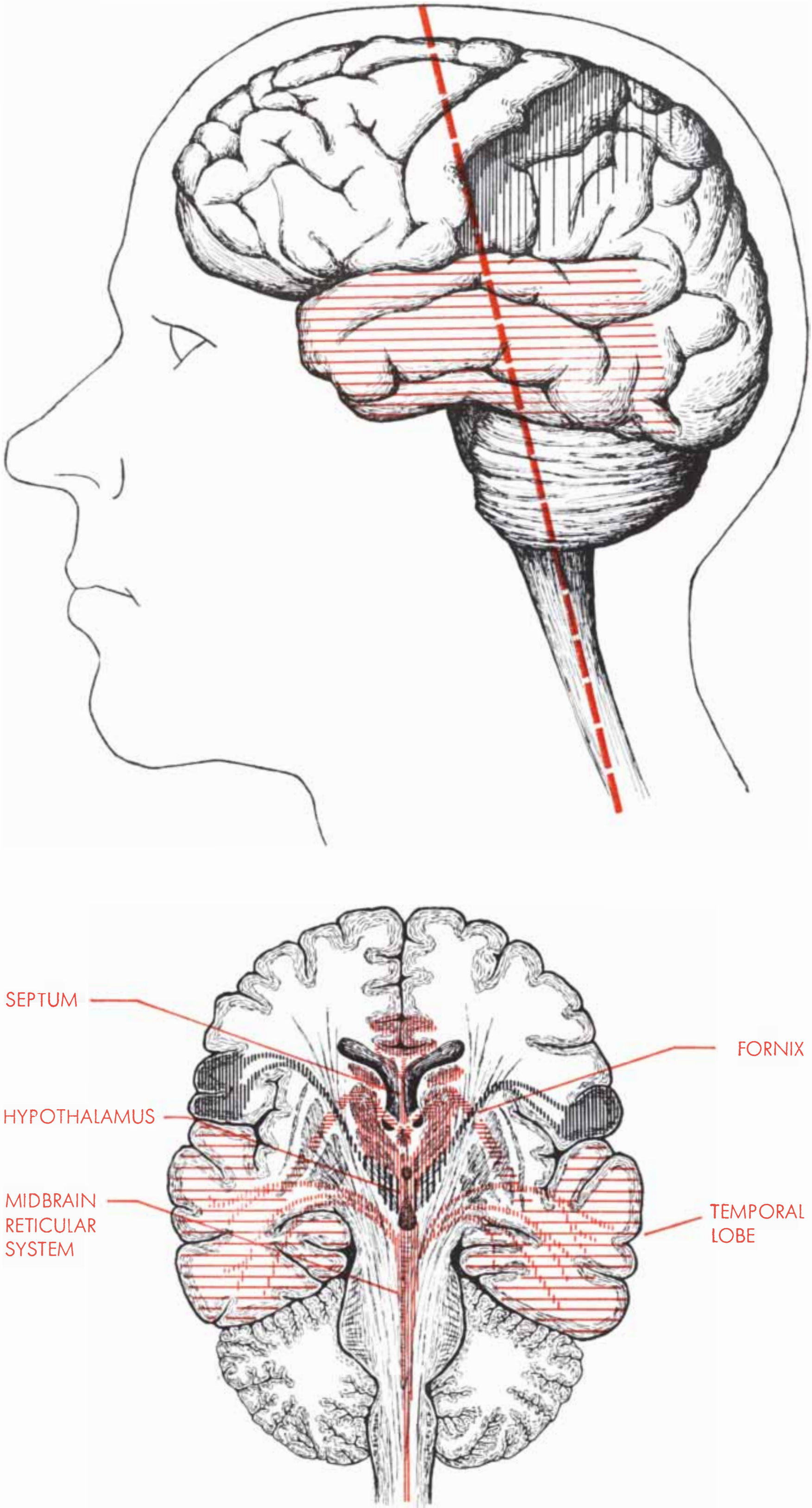
Such observations, then, constituted our knowledge of the areas of the brain until recently. Certain areas had been found to be involved in various kinds of emotional behavior, but the evidence was only of a general nature. The prevailing view still held that the basic motivations—pain, pleasure and so on—probably involved excitation or activity of the whole brain.

Investigation of these matters in more detail became possible only after psychologists had developed methods for detecting and measuring positive emotional behavior—pleasure and the satisfaction of specific "wants." It was B. F. Skinner, the Harvard University experimental psychologist, who produced the needed refinement. He worked out a technique for measuring the rewarding effect of a stimulus (or the degree of satisfaction) in terms of the frequency with which an animal would perform an act which led to the reward. For example, the animal was placed in a bare box containing a lever it could manipulate. If it received no reward when it pressed the lever, the animal might perform this act perhaps five to 10 times an hour. But if it was rewarded with a pellet of food every time it worked the lever, then its rate of performing the act would rise to 100 or more times per hour. This increase in response frequency from five or 10 to 100 per hour provided a measure of the rewarding effect of the food. Other stimuli produce different response rates, and in each case the rise in rate seems to be a quite accurate measure of the reward value of the given stimulus.

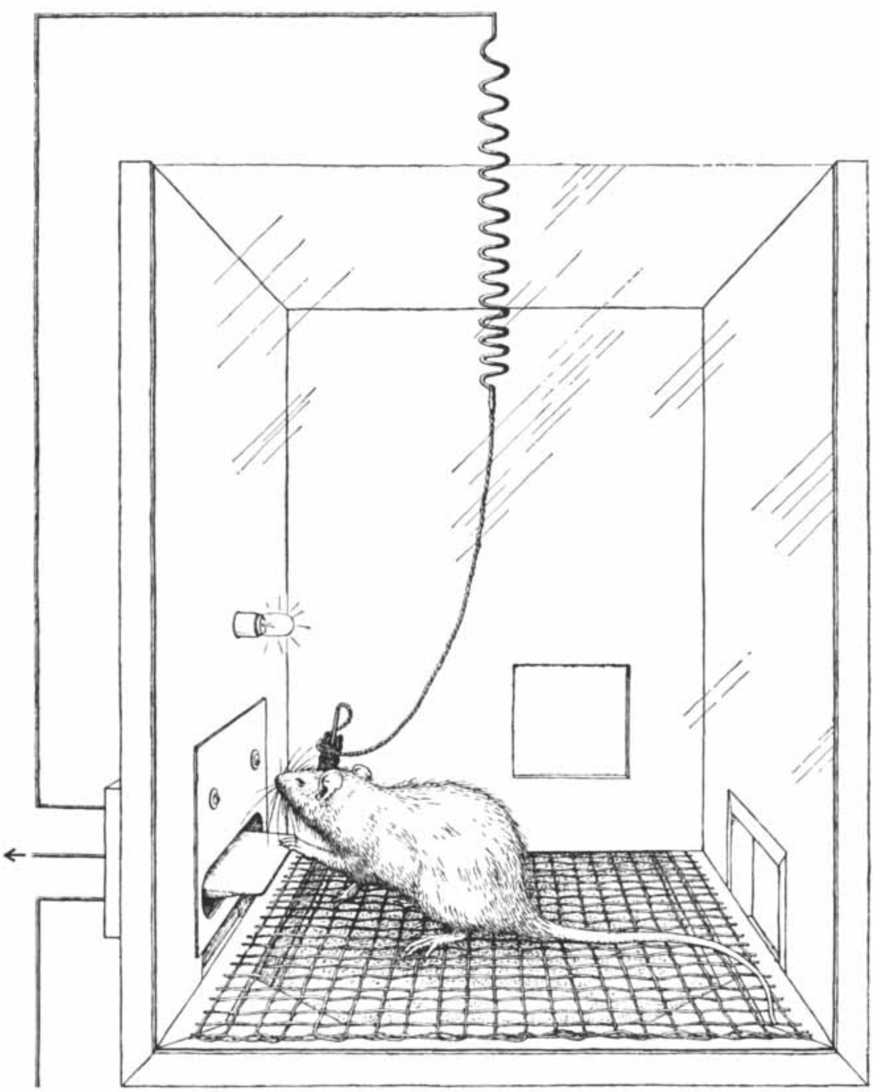
With the help of Hess's technique for probing the brain and Skinner's for measuring motivation, we have been engaged in a series of experiments which began three years ago under the guidance of the psychologist D. O. Hebb at McGill University. At the beginning we planned to explore particularly the midbrain reticular system—the sleep-control area that had been investigated by Magoun.

Just before we began our own work, H. R. Delgado, W. W. Roberts and N. E. Miller at Yale University had undertaken a similar study. They had located an area in the lower part of the mid-line system where stimulation caused the animal to avoid the behavior that provoked the electrical stimulus. We wished to investigate positive as well as negative effects—that is, to learn whether stimulation of some areas might be sought rather than avoided by the animal.

We were not at first concerned to hit very specific points in the brain, and in fact in our early tests the electrodes did not always go to the particular areas in



LOCATIONS OF FUNCTION in the human brain are mapped in these two diagrams. The white areas in both diagrams comprise the motor system; the black crosshatched areas, the sensory system. Crosshatched in color are the "nonspecific" regions now found to be involved in motivation of behavior. The diagram at bottom shows the brain from behind, dissected along the heavy dashed line at top. The labels here identify the centers which correspond to those investigated in the rat. The fornix and parts of the temporal lobes, plus associated structures not labeled, together constitute the rhinencephalon or "smell-brain."



SELF-STIMULATION CIRCUIT is diagrammed here. When the rat presses on treadle it triggers an electric stimulus to its brain and simultaneously records action via wire at left.

the mid-line system at which they were aimed. Our lack of aim turned out to be a fortunate happening for us. In one animal the electrode missed its target and landed not in the mid-brain reticular system but in a nerve pathway from the rhinencephalon. This led to an unexpected discovery.

In the test experiment we were using, the animal was placed in a large box with corners labeled A, B, C and D. Whenever the animal went to corner A, its brain was given a mild electric shock by the experimenter. When the test was performed on the animal with the electrode in the rhinencephalic nerve, it kept returning to corner A. After several such returns on the first day, it finally went to a different place and fell asleep. The next day, however, it seemed even more interested in corner A.

At this point we assumed that the stimulus must provoke curiosity; we did not yet think of it as a reward. Further experimentation on the same animal soon indicated, to our surprise, that its response to the stimulus was more than curiosity. On the second day, after the animal had acquired the habit of returning to corner A to be stimulated, we began trying to draw it away to corner B, giving it an electric shock whenever it took a step in that direction. Within a matter of five minutes the animal was in corner B. After this, the animal could be directed to almost any spot in the box at the will of the experimenter. Every step in the right direction was paid with a small shock; on arrival at the appointed place the animal received a longer series of shocks.

Next the animal was put on a T-shaped platform and stimulated if it turned right at the crossing of the T but

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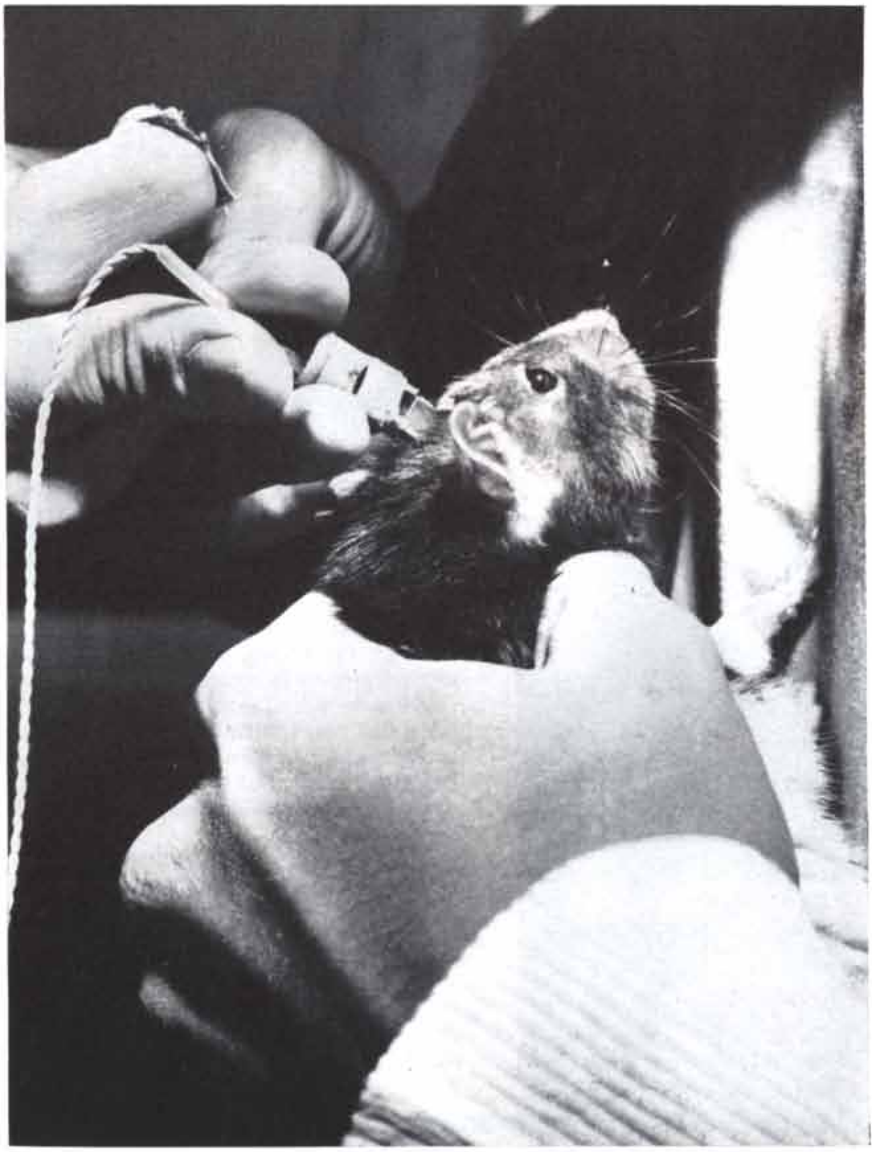
not if it turned left. It soon learned to turn right every time. At this point we reversed the procedure, and the animal had to turn left in order to get a shock. With some guidance from the experimenter it eventually switched from the right to the left. We followed up with a test of the animal's response when it was hungry. Food was withheld for 24 hours. Then the animal was placed in a T both arms of which were baited with mash. The animal would receive the electric stimulus at a point halfway down the right arm. It learned to go there, and it always stopped at this point, never going on to the food at all!

After confirming this powerful effect of stimulation of brain areas by experiments with a series of animals, we set out to map the places in the brain where such an effect could be obtained. We wanted to measure the strength of the effect in each place. Here Skinner's technique provided the means. By putting the animal in the "do-it-yourself" situation (*i.e.*, pressing a lever to stimulate its own brain) we could translate the animal's strength of "desire" into response frequency, which can be seen and measured.

The first animal in the Skinner box ended all doubts in our minds that electric stimulation applied to some parts of the brain could indeed provide reward for behavior. The test displayed the phenomenon in bold relief where anyone who wanted to look could see it. Left to itself in the apparatus, the animal (after about two to five minutes of learning) stimulated its own brain regularly about once every five seconds, taking a



RAT IS CONNECTED to electrical circuit by a plug which can be disconnected to free the animal during rest periods. Presence of electrodes does not pain or discommode the rat.

Dr. Robert L. Fullman, B. Eng., D. Eng., Yale University, joined the staff of the General Electric Research Laboratory in 1948. His fields of specialization include studies of microstructure in metals and alloys, recrystallization, and grain growth. Since 1955 he has been manager of the *Materials and Processes Studies Section.*

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The most direct way to make a metal object in a desired shape is simply to melt the metal and then "freeze" it in a mold. And scientists now believe there is *no fundamental reason* why castings should not be as strong and ductile as wrought metal.

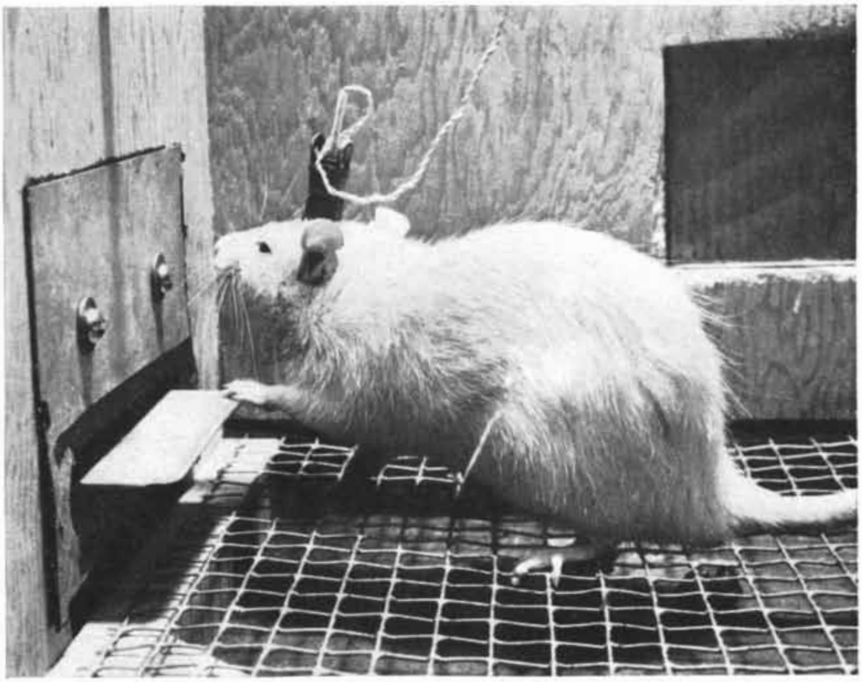
Dr. Robert L. Fullman of the General Electric Research Laboratory is the leader of a group that is relating *microstructure* to the properties of metals — and then seeking processing methods to produce the desired structure. The basic mechanism by which molten metals *begin* to "freeze" — nucleation — has been modified through the application of recently developed theories; work in this area already has resulted in practical new materials whose improved properties are attributed to smaller grain size.

Dr. Fullman believes that when it is possible to control the *growth* as well as the *nucleation* of crystals, many of tomorrow's superior metals — for applications ranging from appliances to aircraft — will be made by methods as simple as those now used for cast iron.

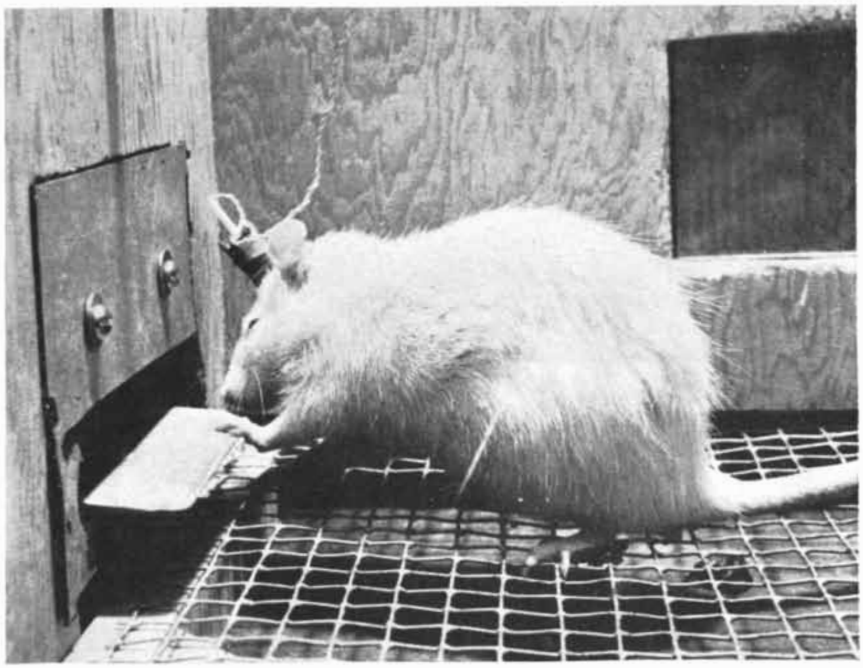
As we see it, providing scientists with freedom and incentive to extend the frontiers of knowledge is fundamental to the creation of better products, better jobs, and more opportunities for human satisfactions.

Progress Is Our Most Important Product

GENERAL ELECTRIC



RAT SEEKS STIMULUS as it places its paw on the treadle. Some of the animals have been seen to stimulate themselves for 24 hours without rest and as often as 5,000 times an hour.



RAT FEELS STIMULUS as it presses on treadle. Pulse lasts less than a second; the current is less than .0005 ampere. The animal must release lever and press again to renew the stimulus.

stimulus of a second or so every time. After 30 minutes the experimenter turned off the current, so that the animal's pressing of the lever no longer stimulated the brain. Under these conditions the animal pressed it about seven times and then went to sleep. We found that the test was repeatable as often as we cared to apply it. When the current was turned on and the animal was given one shock as an *hors d'oeuvre*, it would begin stimulating its brain again. When the electricity was turned off, it would try a few times and then go to sleep.

The current used to stimulate was ordinary house current reduced by a small transformer and then regulated between one and five volts by means of

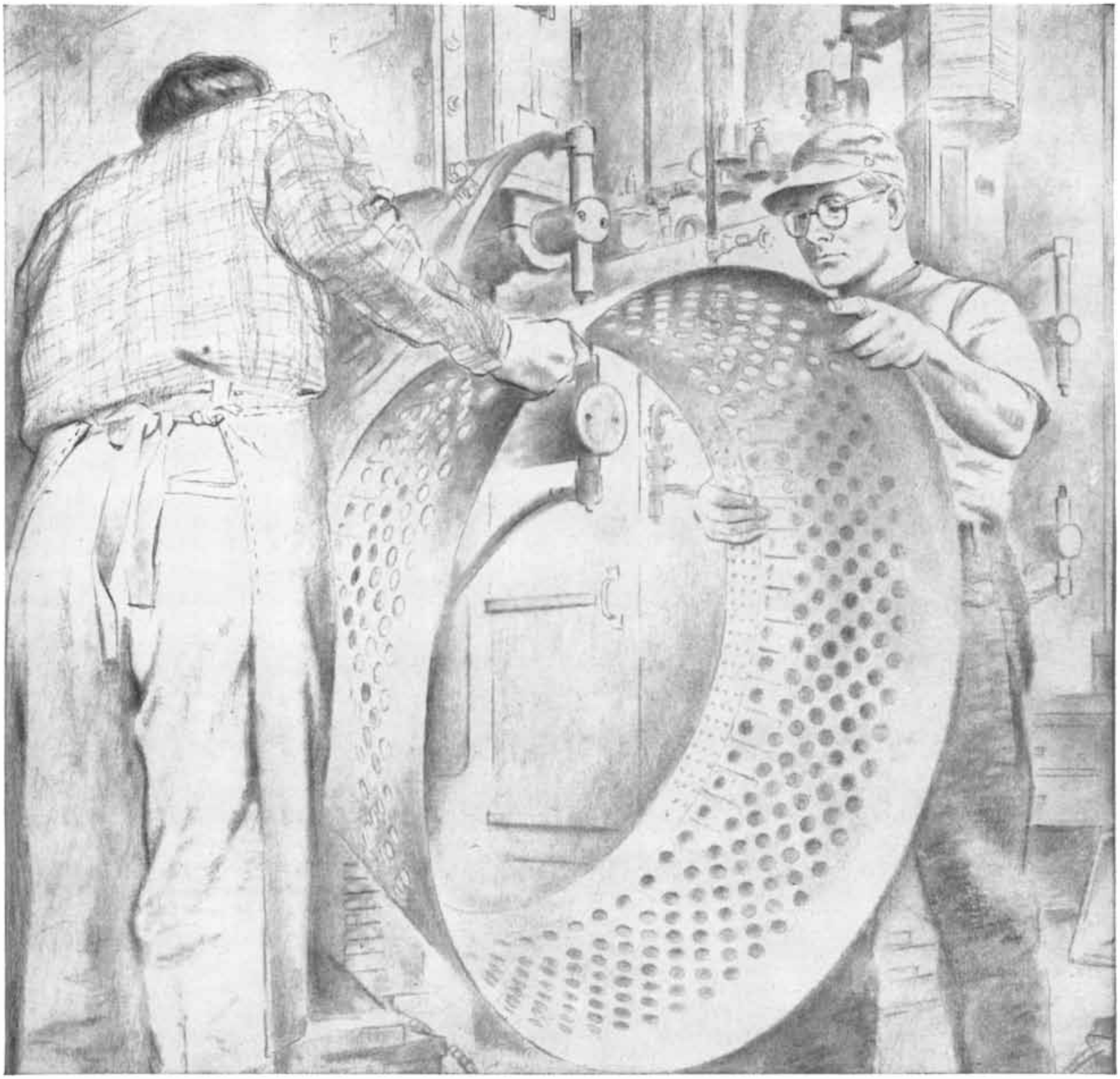
a potentiometer (a radio volume control). As the resistance in the brain was approximately 12,000 ohms, the current ranged from about .000083 to .000420 of an ampere. The shock lasted up to about a second, and the animal had to release the lever and press again to get more.

We now started to localize and quantify the rewarding effect in the brain by planting electrodes in all parts of the brain in large numbers of rats. Each rat had a pair of electrodes consisting of insulated silver wires a hundredth of an inch in diameter. The two stimulating tips were only about one 500th of an inch apart. During a test the animal was placed in a Skinner box designed to produce a chance response rate of about 10 to 25 bar-presses per hour. Each animal was given about six hours of testing with the electric current turned on and one hour with the current off. All responses were recorded automatically, and the animal was given a score on the basis of the amount of time it spent stimulating its brain.

When electrodes were implanted in the classical sensory and motor systems, response rates stayed at the chance level of 10 to 25 an hour. In most parts of the mid-line system, the response rates rose to levels of from 200 to 5,000 an hour, definitely indicative of a rewarding effect of the electric stimulus. But in some of the lower parts of the mid-line system there was an opposite effect: the animal would press the lever once and never go back. This indicated a punishing effect in those areas. They appeared to be the same areas where Delgado, Roberts and Miller at Yale also had discovered the avoidance effect—and where Hess and others had found responses of rage and escape.

The animals seemed to experience the strongest reward, or pleasure, from stimulation of areas of the hypothalamus and certain mid-brain nuclei—regions which Hess and others had found to be centers for control of digestive, sexual, excretory and similar processes. Animals with electrodes in these areas would stimulate themselves from 500 to 5,000 times per hour. In the rhinencephalon the effects were milder, producing self-stimulation at rates around 200 times per hour.

Electric stimulation in some of these regions actually appeared to be far more rewarding to the animals than an ordinary satisfier such as food. For example, hungry rats ran faster to reach an electric stimulator than they did to reach food. Indeed, a hungry animal often ignored available food in favor of the pleasure of stimulating itself elec-



Spot welding titanium aircraft assembly at Solar-Des Moines trically. Some rats with electrodes in these places stimulated their brains more than 2,000 times per hour for 24 consecutive hours!

Why is the electric stimulation so rewarding? We are currently exploring this question, working on the hypothesis that brain stimulation in these regions must excite some of the nerve cells that would be excited by satisfaction of the basic drives—hunger, sex, thirst and so forth. We have looked to see whether some parts of the "reward system" of the brain are specialized; that is, there may be one part for the hunger drive, another for the sex drive, etc.

In experiments on hunger, we have found that an animal's appetite for electric stimulation in some brain regions increases as hunger increases: the animal will respond much faster when hungry than when full. We are performing similar tests in other places in the brain with variations of thirst and sex hormones. We have already found that there are areas where the rewarding effects of a brain stimulus can be abolished by castration and restored by injections of testosterone.

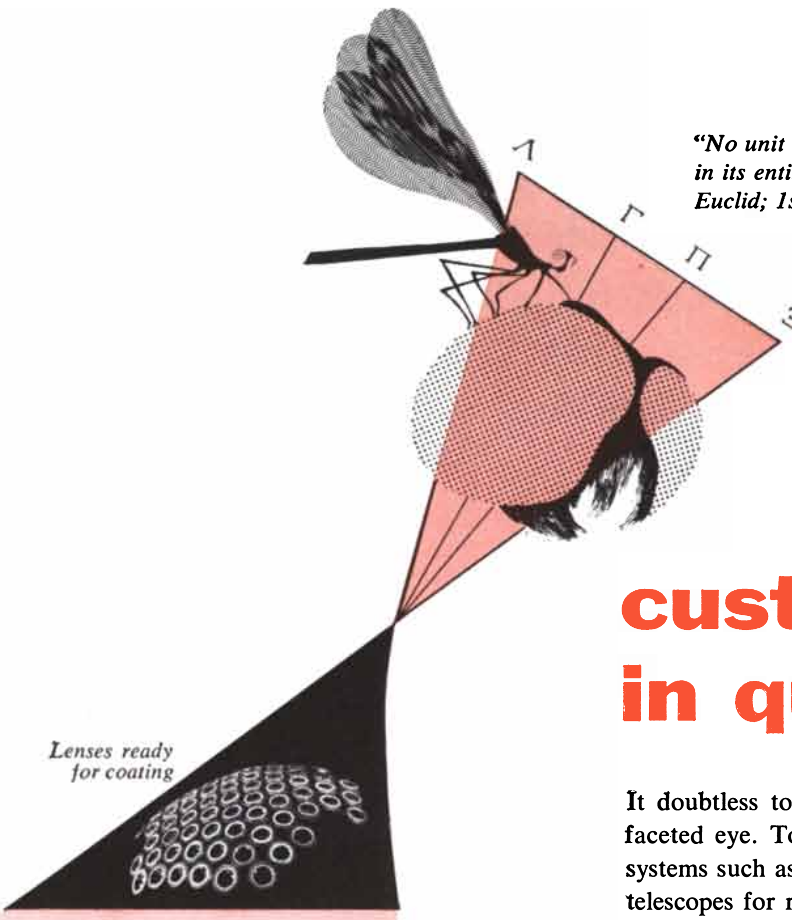
Our present tentative conclusion is that emotional and motivational mechanisms can indeed be localized in the brain; that certain portions of the brain are sensitive to each of the basic drives. Strong electrical stimulation of these areas seems to be even more satisfying than the usual rewards of food, etc. This finding contradicts the long-held theory that strong excitation in the brain means punishment. In some areas of the brain it means reward.

The main question for future research is to determine how the excited "reward" cells act upon the specific sensory-motor systems to intensify the rewarded behavior.

At the moment we are using the self-stimulating technique to learn whether drugs will selectively affect the various motivational centers of the brain. We hope, for example, that we may eventually find one drug that will raise or lower thresholds in the hunger system, another for the sex-drive system, and so forth. Such drugs would allow control of psychological disorders caused by surfeits or deficits in motivational conditions.

Enough of the brain-stimulating work has been repeated on monkeys by J. V. Brady and J. C. Lilly (who work in different laboratories in Washington, D. C.) to indicate that our general conclusions can very likely be generalized eventually to human beings—with modifications, of course.

"No unit can be seen simultaneously in its entirety."
Euclid; 1st. theorem of optics.



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ARTIFICIAL LIVING PLANTS

Proposed here is a design for self-reproducing machines that would be harvested for the materials from which they construct themselves. They might prove more feasible than spaceships and more profitable

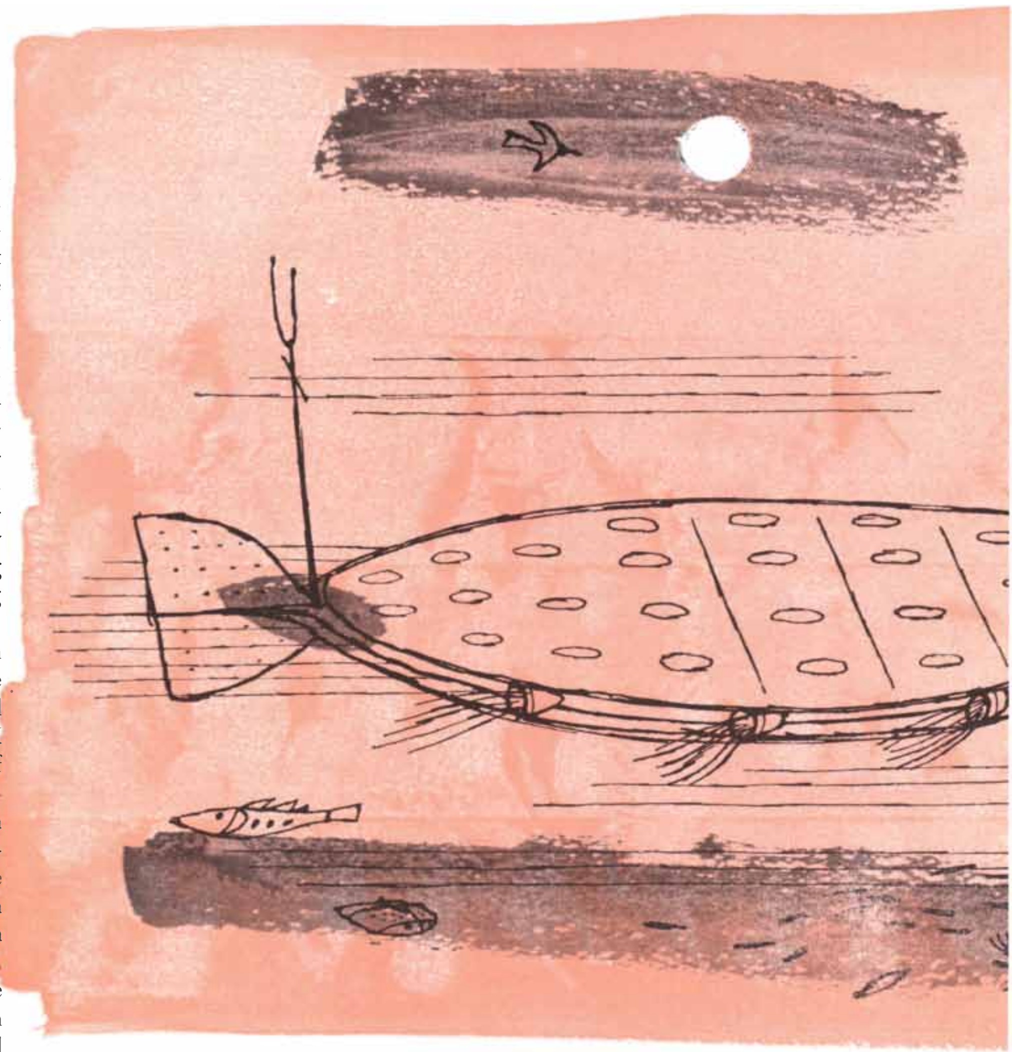
by Edward F. Moore

In the growing profession of designers of automatic machines, discussion goes on at two levels. One is the immediate business of building machines for given purposes. The other is the more theoretical, but in some ways more enjoyable, occupation of speculating about machines of the future. These visions sometimes seem fantastic, but they rest on something more solid than fantasy. Engineers join with philosophers in the speculation. Even practical men know that it is from such dreams that the machines of tomorrow will spring.

Several years ago the mathematician John Von Neumann, who has been a pioneer in designing computers, demonstrated as a proposition in logic that it would be possible to build a machine which could reproduce itself [see "Man Viewed as a Machine," by John G. Kemeny; Scientific American, April, 1955]. Von Neumann's machine would be made of wires, relays, batteries, devices for doing mechanical manipulation, and so on. Set up in a stock room well supplied with these parts, the machine would assemble them into a copy of itself. The machine and its offspring could go on building duplicates as long as the supply of parts lasted.

It is unlikely that the machine Von Neumann described will ever actually be built, because it would have no useful purpose except as a demonstration. I would like to propose another type of self-reproducing machine, more complicated and more expensive than Von Neumann's, which could be of considerable economic value. It would make copies of itself not from artificial parts in a stock room but from materials in nature. I call it an artificial living plant. Like a botanical plant, the machine would have the ability to extract its own raw materials from the air, water and soil. It would obtain energy from sunlight—probably by a solar battery or a steam engine. It would use this energy to refine and purify the materials and to manufacture them into parts. Then, like Von Neumann's self-reproducing machine, it would assemble these parts to make a duplicate of itself.

For the first model of such a machine, a good location would be the seashore, where it could draw on a large variety of available materials. The air would provide nitrogen, oxygen and argon; the sea water would provide hydrogen, chlorine, sodium, magnesium, sulfur, calcium,



This artificial living plant is jet-propelled, on the model of the squid.

potassium, bromine and carbon; the beach would provide silicon and possibly aluminum and iron. Other elements would be available in smaller quantities. From these elements the machine would make wires, solenoids, gears, screws, relays, pipes, tanks and other parts, and then assemble them into a machine like itself, which in turn could make more copies. If the model designed for the seashore proved a success, the next step would be to tackle the harder problems of designing artificial living plants for the ocean surface, for desert regions or for any other locality having much sunlight but not now under cultivation. Even the unused continent of Antarctica might be brought into production.

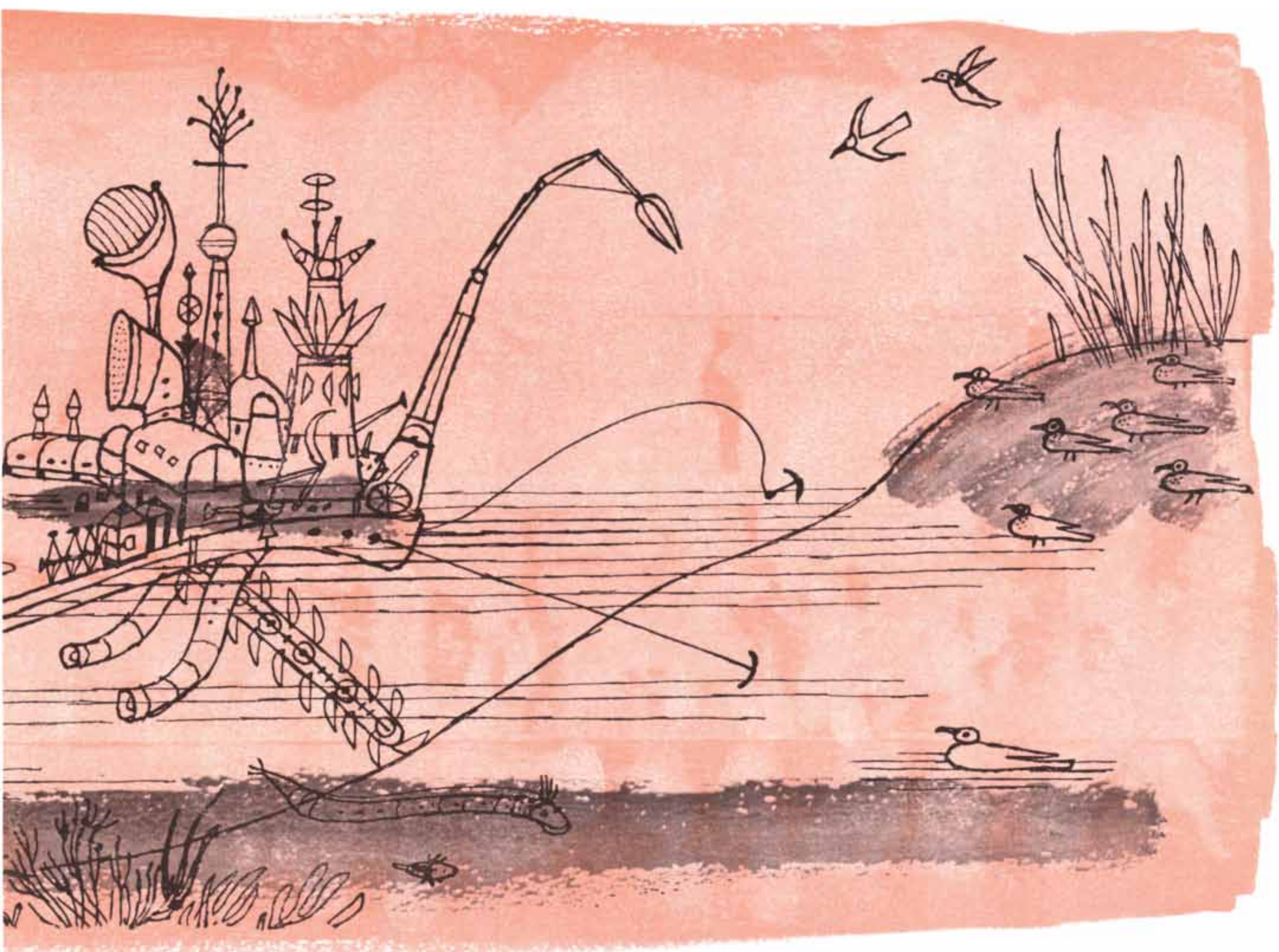
It is easy to see that a plant of this kind could have considerable economic value. It could be harvested for a material it extracted or synthesized, just as cotton, mahogany and sugar cane are now harvested from plants in nature. Thus an artificial plant which used magnesium as its chief structural material could be harvested for its magnesium.

The problems to be solved in the design of such a plant would be problems in logic, electrical engineering, mechanical engineering, chemistry and chemical engineering. The main problem in logic has already been solved by Von Neumann, and the additional tasks in logic posed by this machine would be no more difficult than those solved regularly by the designers of digital computers, automatic elevator controls and telephone central offices. In electrical and mechanical engineering the problems would be somewhat more complex than those handled so far in automatic factories, but they could certainly be solved by the expenditure of enough time and money. Most difficult of all would be the problems in chemistry and chemical engineering; their solution might not be possible without advances over present-day technology.

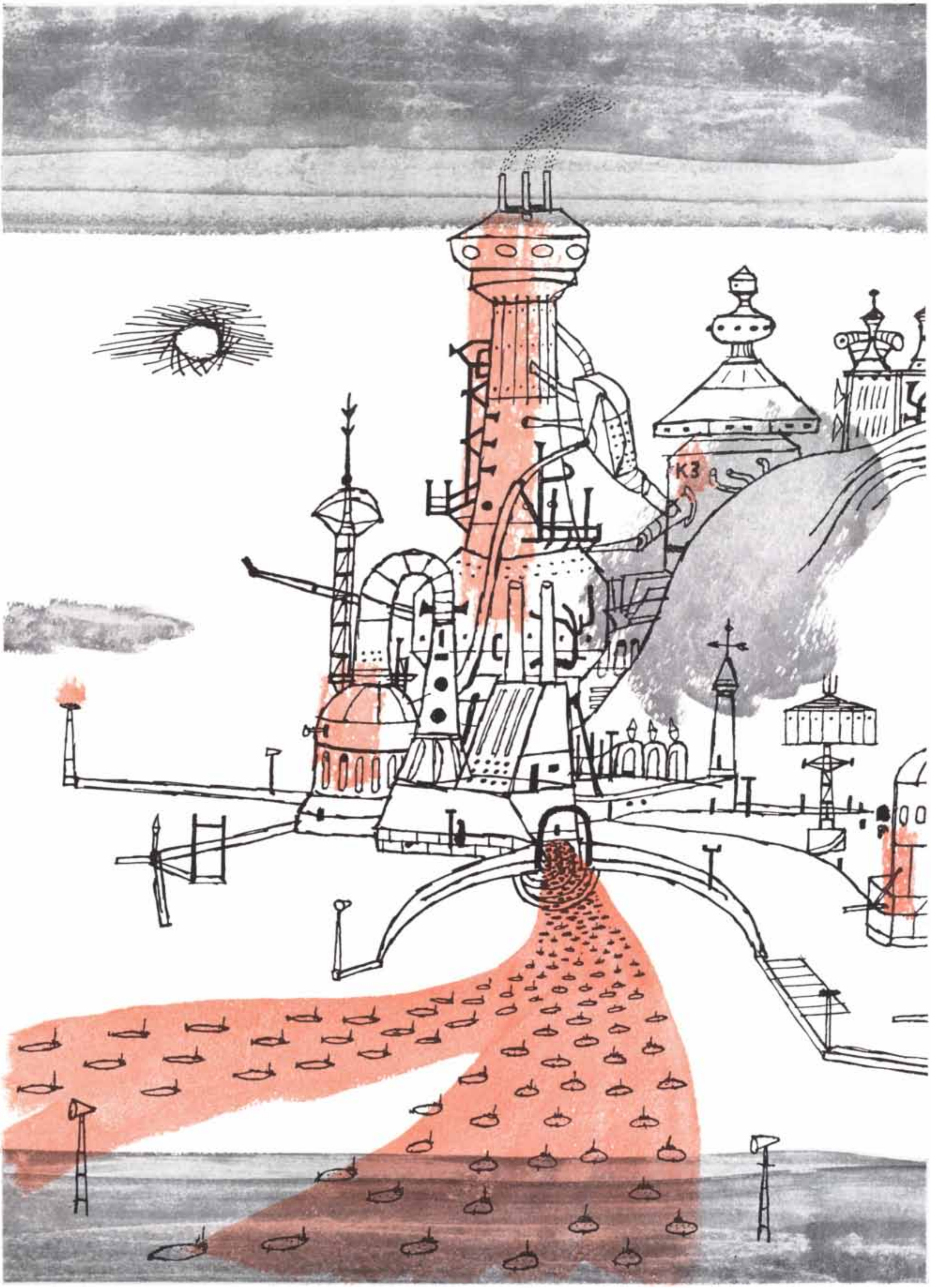
The first chemical problem is to decide what materials would be required for the plant. For the electrical part of the machine they would have to include a conducting material, an insulating material and a ferromagnetic material. For containers in which to carry out the necessary chemical operations and processes, the machine would need refractory materials—to line a smelter if metal smelting is one of the operations, or to resist sulfuric acid if the manufacture of sulfuric acid is one of the processes.

Once the list of needed materials was chosen, engineers would have to design a flow scheme for the automatic manufacture of all of them. It would be very desirable to keep the list of materials as short as possible, and the manufacturing operations and processes as simple as possible. Since not all the materials would have to be made at once, much of the apparatus could be used for different purposes at different stages.

The operations chosen would not



When securely moored, it will begin the process of reproduction.



Like lemmings, a school of artificial living plants swims into the maw of the harvesting factory.

necessarily be the most economical ones available, for it might be advisable to use somewhat inefficient methods to cut down the complexity of the machine and maximize its over-all effectiveness. In designing such a machine it would simplify matters to adopt some criterion as a general guide for choosing between possible processes or materials. The most reasonable general criterion is the time factor—how long it would take, say, for a population of artificial living plants to double itself. If this time could be made as short as six months or a year, the artificial living plants would be very successful, but if it were as long as the time it takes for money to double at compound interest, the machine would be a poor investment.

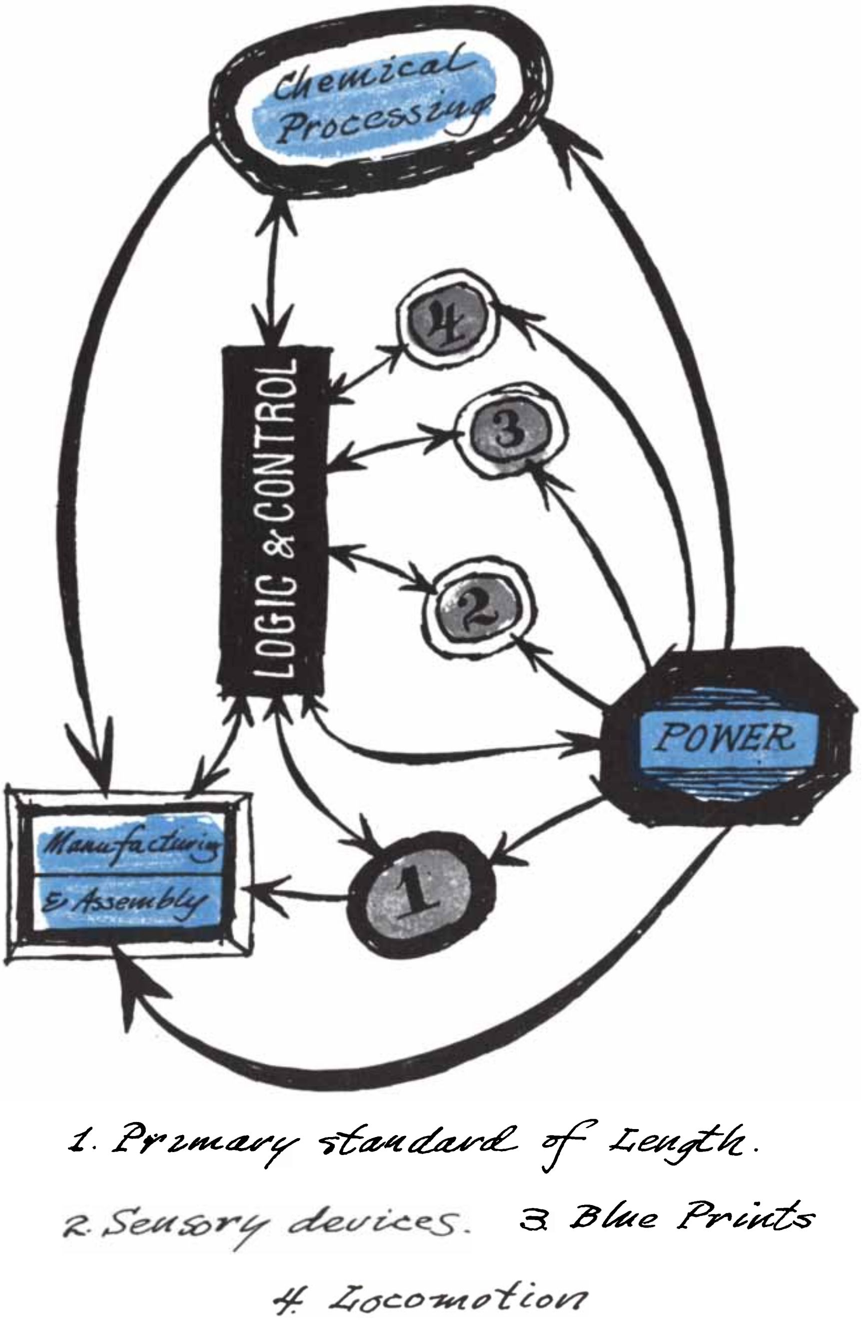
The calculation of net reproduction time of course would have to take account of mortality among the artificial living plants: a certain fraction of each generation would "die" because of internal failures, degeneration or natural catastrophes such as earthquakes or hurricanes.

To use energy effectively and reproduce itself in a reasonable time the machine should be small, or at least very thin. The energy required to manufacture materials would be proportional to their mass (*i.e.*, roughly the cube of the linear dimension), but the machine would receive energy from sunlight only in proportion to area, or the square of linear dimension. A population of algae, spread on the surface of a pond or tank, takes less than a week to double itself, but a sequoia tree may take centuries.

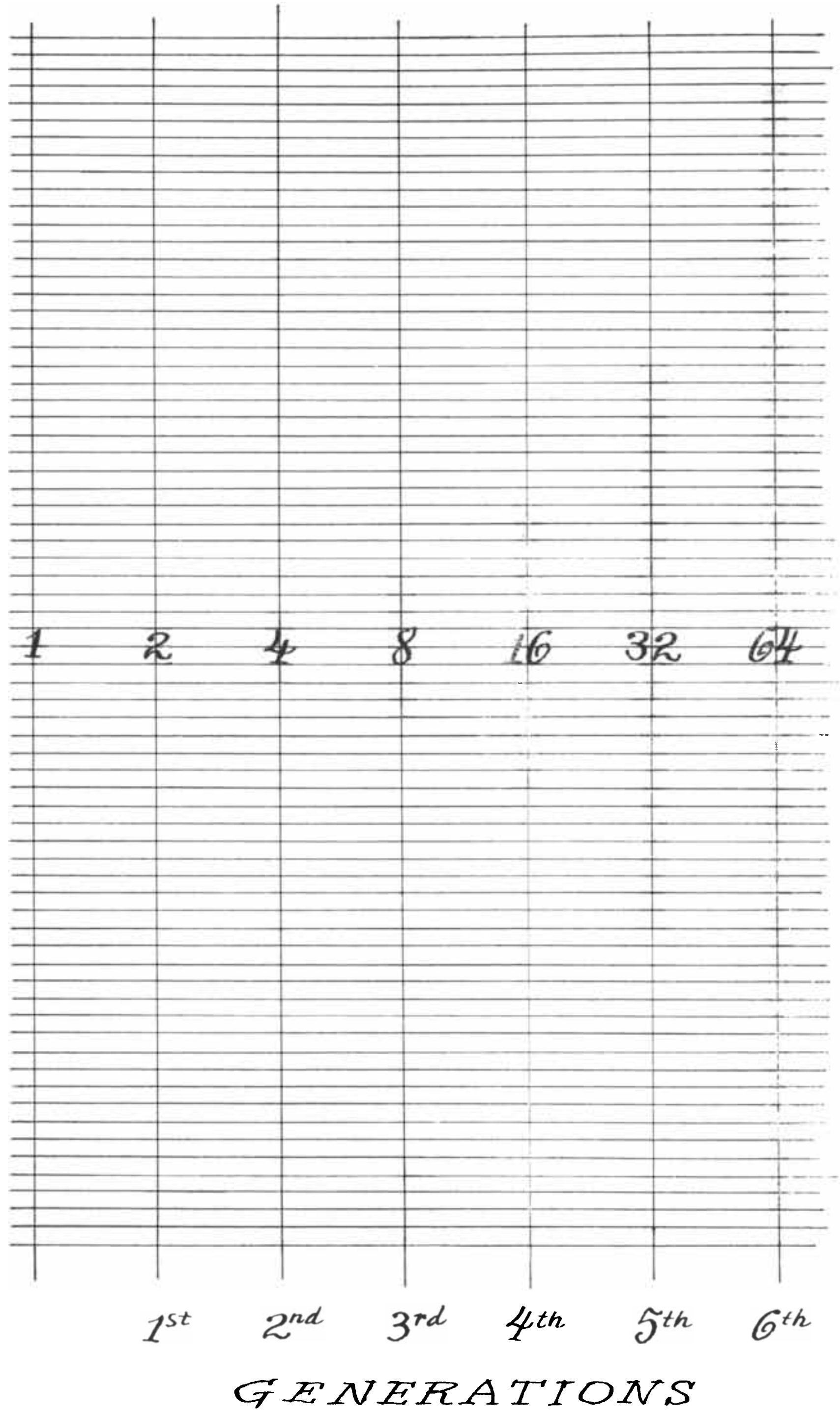
Why make an artificial plant out of ferromagnetic materials, electric motors, machine tools, gears, screws, wires, valves and lubricating oil? Why not make it of organic materials, such as amino acids and chlorophyll? The answer, of course, is that we do not yet understand organic chemistry well enough. Biochemists have not even identified all of the chemical substances in the simple blue-green alga. They are still far from being able to synthesize substances such as chlorophyll. On the other hand, the chemistry of electrical insulators, ferromagnetic materials, lubricating oils and so on are so well known that they can easily be synthesized from materials in nature. Moreover, engineers are on familiar ground in operating machinery by electrical and mechanical methods, but we would not know how to begin to design a system operated by hormones and enzymes.

Similarly we would have to be content with a plant that reproduced itself from the same blueprints, or "genes," in every generation. We have a somewhat better understanding of theoretical genetics and evolution than we do of biochemistry, but it is still not complete enough to enable us to endow a machine with evolutionary abilities. In any case, the ability to mutate would be a doubtful benefit: it seems safer, at least at the beginning, to let the plant reproduce itself exactly in successive generations, lest it take on undesirable characteristics.

If the object is to manufacture a specific product, would it not be much simpler to design an automatic factory to make it, rather than to go to all the trouble of creating an artificial living plant? It would indeed be simpler, but obviously the returns would not be as great. Where a factory turns out products at a constant rate, the production of the artificial living plant would grow exponentially. If its net reproduction time were one year, after 30 years there would be more than a billion of these



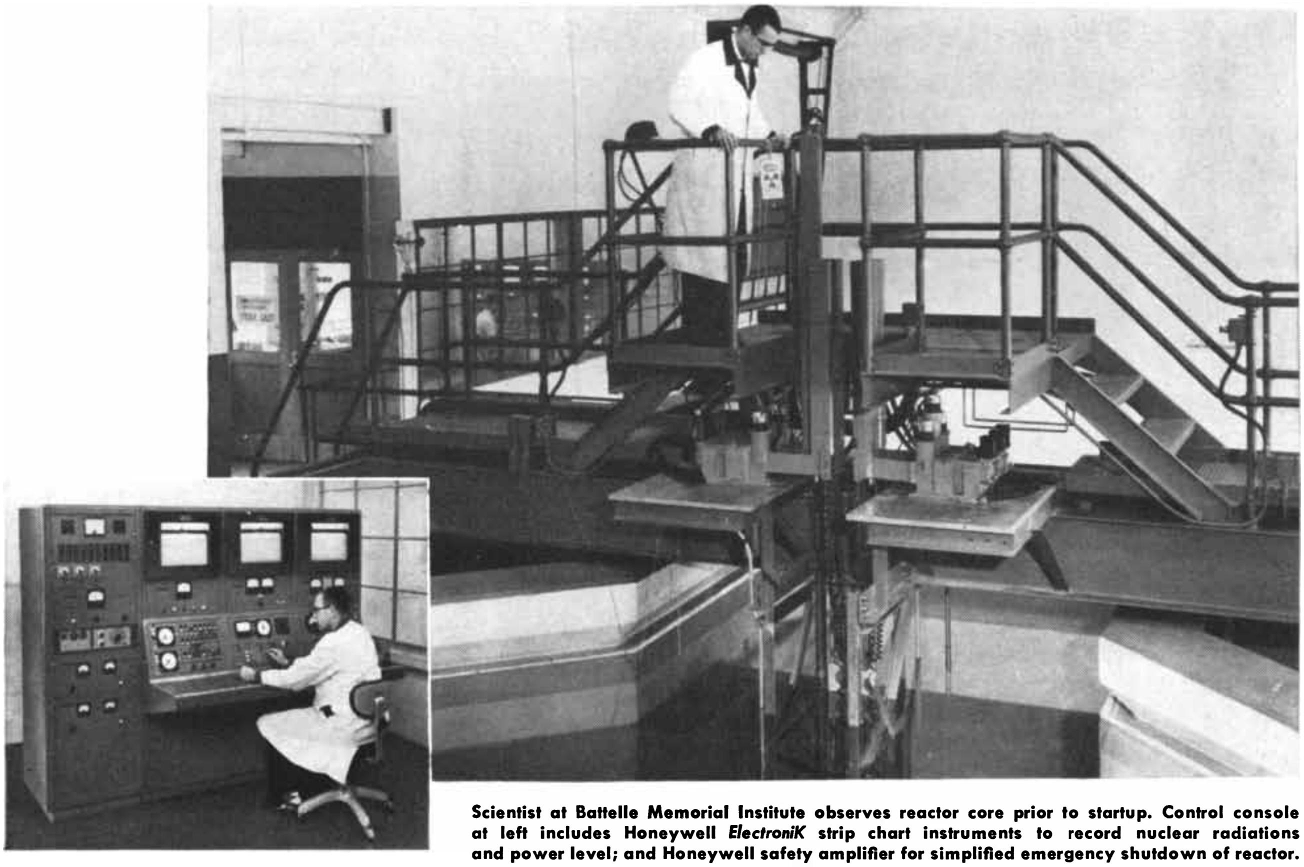
Feedback circuits (double-pointed arrows) *ensure coordination of principal organs.*



In six generations one plant would have 63 descendants and 1,048,575 in 20.

plants! Needless to say, they could not be allowed to reproduce indefinitely, for they would soon fill up the oceans and the continents. And the artificial plant would have to be provided with a means of locomotion to move out of the way as it was produced; if not, the multiplying population would cut off sunlight and choke itself to death. As the counterpart of the seed-dispersing mechanisms whereby plants are distributed in nature, the artificial plant would need wheels or a propeller. It might be worth while to build into these plants a tendency to migrate, like lemmings, to preassigned locations where they could be harvested conveniently.

Clearly there would be need for international controls and allocation of areas for production and harvesting. This



Scientist at Battelle Memorial Institute observes reactor core prior to startup. Control console at left includes Honeywell *ElectroniK* strip chart instruments to record nuclear radiations and power level; and Honeywell safety amplifier for simplified emergency shutdown of reactor.

Honeywell packaged control console

operates new swimming pool reactor

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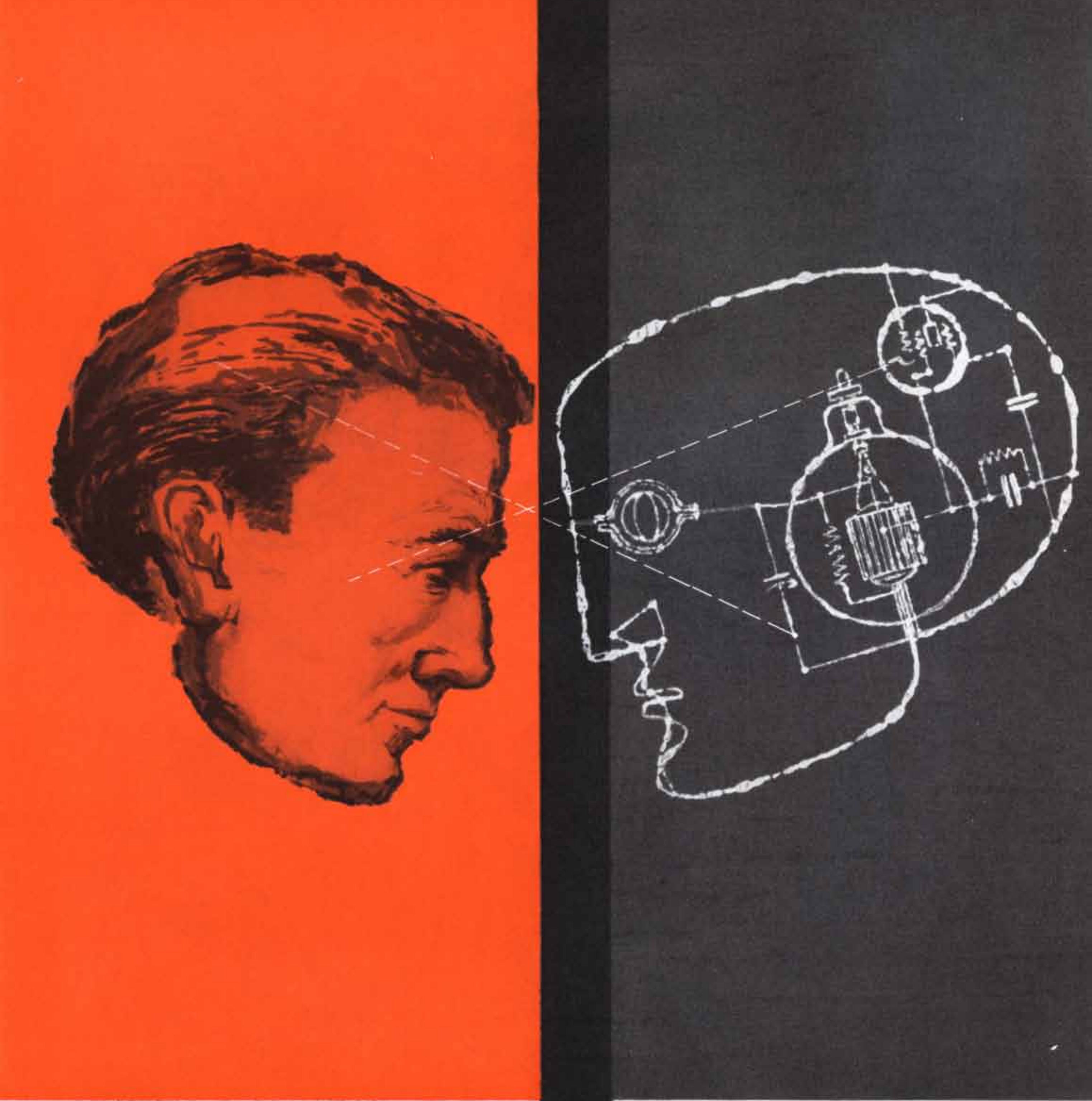
would involve not only the political rights of nations but also questions of natural conservation. Ecologists would be concerned about the artificial plant's competition with natural plants for sunlight and the possibility that it might upset the balance of nature in the areas where it was allowed to multiply.

Social problems would also arise in connection with the selection of products to be manufactured. An artificial plant might be designed to make a product which was not useful to the plant itself. For instance, it might extract gold from sea water, refine it and cast it into an ingot, which would be harvested as the crop from the plant. But it would certainly be shortsighted to select this crop for manufacture. Multiplying at an exponential rate, the gold-making plant would soon produce so much of it that gold would lose its scarcity value and probably end up being worth very little, for gold does not directly fulfill any essential human need. On the other hand, an example of an excellent candidate for production by an artificial plant is fresh water, which is needed in great quantities in various parts of the world.

In short, the artificial living plant has tremendous possibilities, if we can solve the problems in designing it. Such machines would free mankind's agriculture from dependence on the natural characteristics of plants. They would make it possible to produce any desired crop, instead of only those that nature happens to have provided. They would be a long step forward in man's control of his environment.

How much would such a project cost, and how soon could it be successful? That depends on the difficulties encountered in chemistry and chemical engineering. My guess is that if, on the basis of present-day chemical knowledge, a scheme could be found for a machine to reproduce itself from a short list of materials made by simple and efficient processes, the whole design problem could probably be solved in five or 10 years, for as little as $50 million to $75 million. But if new chemical processes must first be found, and if the machine would require a long list of materials producible only at low yield in complicated fashion, it might cost hundreds of millions of dollars and take decades to develop such a machine. I think the achievement would be more easily attainable than human flight to other planets in a spaceship, but it is obviously not going to be accomplished by a lone inventor working in his basement.



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DEFENSE ACTION of small birds against a predator takes two forms, which require different types of audible message. When the enemy is perched in a tree (*upper drawing*) the small birds may practice "mobbing." They swarm around the larger bird, uttering sharp, easily located "chinks" to advertise its presence. Against a hawk on the wing (*lower drawing*) the little birds take cover under foliage, and their warning cry is now the high-pitched, drawn-out "seeet" which is difficult to trace (*see diagrams on opposite page*).

The Language of Birds

The songs and other calls of birds are not merely joyous outbursts. They make up a complex communications system, with the various sounds suited to various types of message

by W. H. Thorpe

If birds were suddenly eliminated from the world, the absence of their song would at once change the whole aspect of nature out of doors. The reasons why we appreciate bird song so keenly are several. We are attracted by its beauty, by its association with spring and all the promise which that time of the year suggests. Perhaps strongest of all is the feeling expressed by W. H. Davies in the lines:

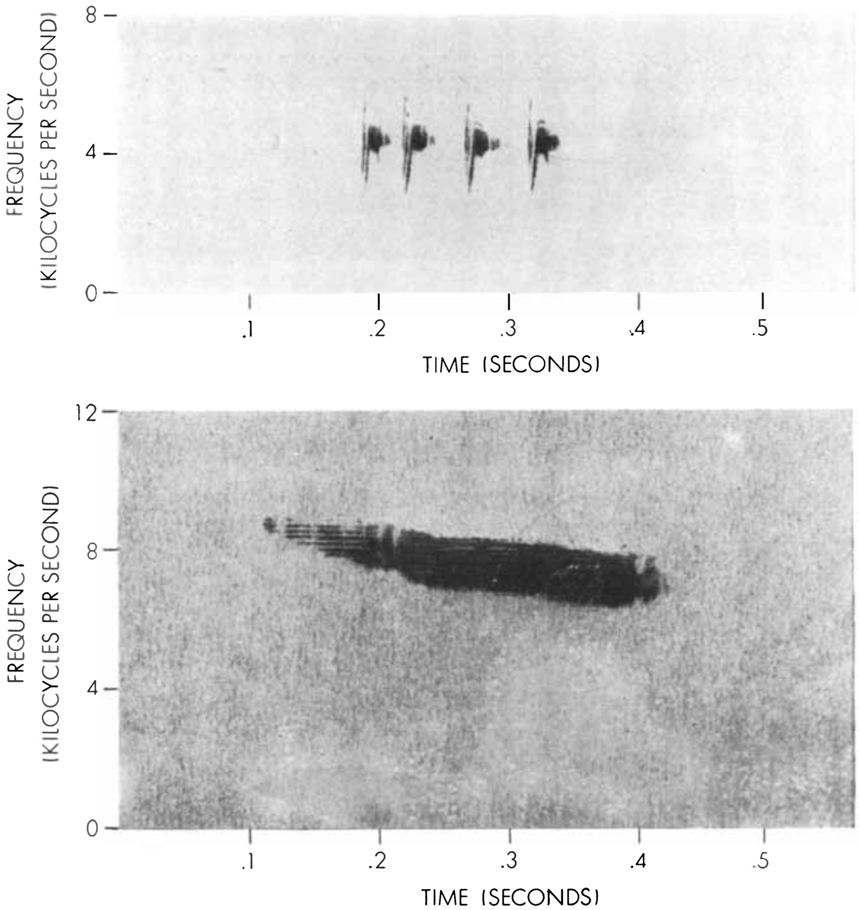
I could not sleep again, for such
wild cries,
And went out early into their green
world:
And then I saw what set their little
tongues
To scream for joy—they saw the
East in gold.

The idea that bird song is often an expression of irrepressible joy actually has some scientific justification. But we are apt to overlook the fact that bird songs and calls are not merely a spontaneous emotional outlet, that they are in fact the language in which the chirpers communicate with one another.

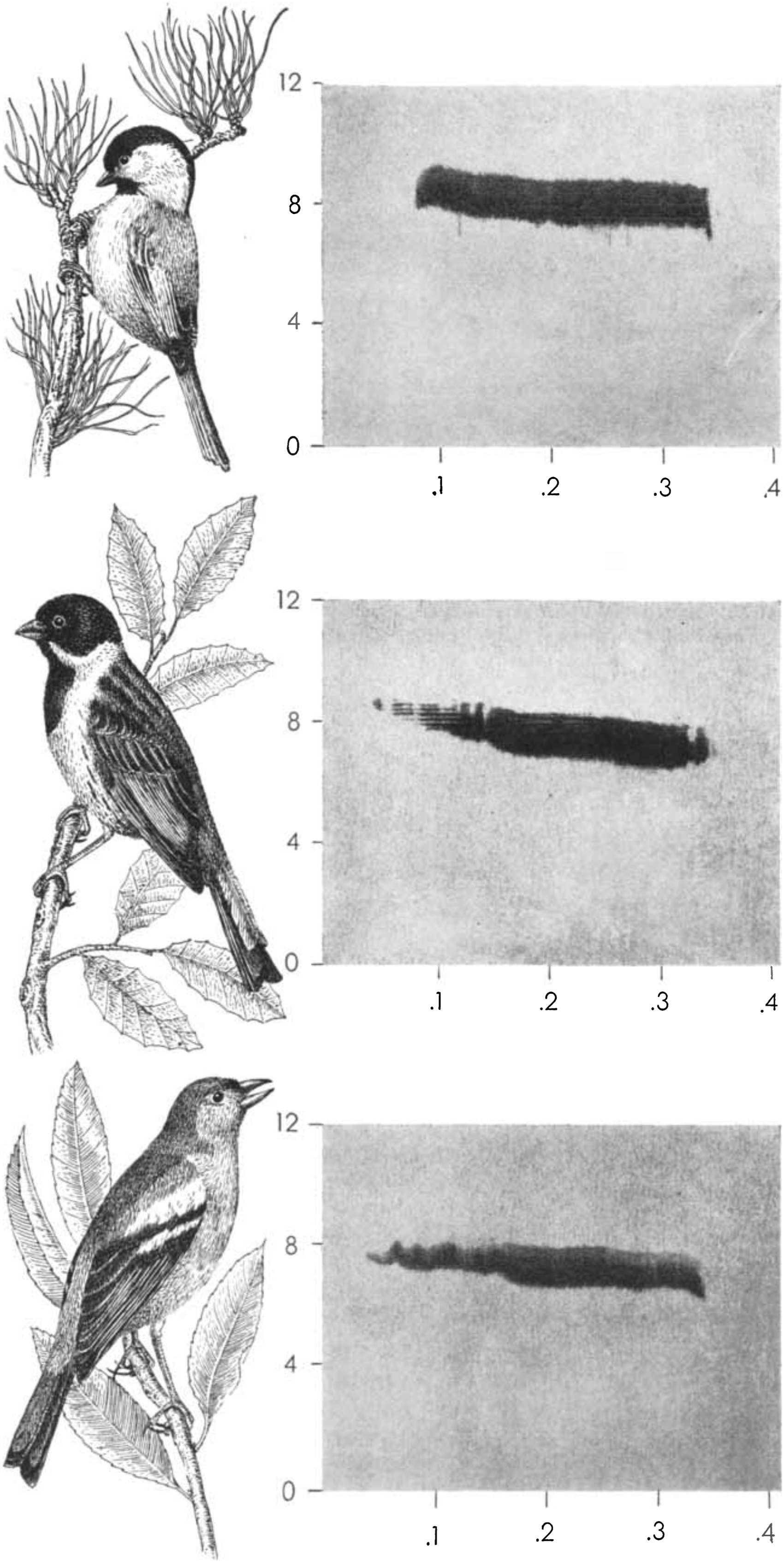
The sounds that birds make have two main functions: to arouse an emotional state (by way of warning, wooing, etc.) and to convey precise information. The sounds themselves can conveniently be divided into two categories: call notes and true song. In general the characteristic call notes of a species are inherited, whereas the true songs may be either entirely inherited, partly inherited and partly learned or almost entirely learned.

We have been making a detailed study of bird songs and calls for several years at the Madingley Ornithological Field Station of the University of Cambridge. In this investigation we have enlisted the help of tape recorders and electronic equipment for analyzing sound. The chief bird partner in our study has been the common English chaffinch (*Fringilla coelebs*). The calls and the songs of the chaffinch illustrate very beautifully some of the chief generalizations we are now able to draw concerning the musical language of birds.

A bird's call note, in contrast to its song, is a brief sound with a relatively simple acoustic structure. Its main function, in the case of small birds, is to sound a warning of the presence of a dangerous enemy, such as a hawk or



WARNING CALLS differ according to the circumstances of their use (*see drawing opposite*). "Chink" (*top oscillogram*) is easy to locate because of its long wavelength, brief duration and abrupt beginning and end. "Seeet" (*bottom oscillogram*) has short wavelength, long duration and begins and ends imperceptibly, making its direction difficult to trace.



CALLS OF DIFFERENT SPECIES are sometimes remarkably alike. Above are sketches of three small birds (the blue tit, a close relative of the American chickadee, top, the bunting, center, and the chaffinch, bottom) together with oscillograms of their "seeet" calls. The oscillograms show time in seconds horizontally and kilocycles per second on the vertical axis.

owl. If the bird of prey is perched conspicuously in a tree, the small birds will often make themselves conspicuous too by behavior known as "mobbing." They set up a chorus of cries which points out the predator, so to speak, to all and sundry. If the bird of prey is in flight, on the other hand, the small birds race to the nearest bush or other cover, and utter their warning cries from that haven. Now the calls are very different in the two cases. Chaffinches mobbing a perched predator give forth relatively low-pitched sounds known as "chink" calls. But when they have fled to cover, the males give a high, thin note designated as the "seeet" call, the effect of which is to cause other chaffinches also to dash for the nearest shelter, and to peer cautiously upward looking for the hawk in the sky.

The significant difference between the two calls is that the "chink" note is easy to locate whereas the "seeet" is extremely difficult. The low frequencies of the "chink" sound are of a wavelength which allows the two ears of a hawk (or a man) to detect phase differences; the call also gives clues to its direction in the form of intensity and time of arrival of the sound at the two ears—the latter because the sound comes as clicklike pulses. On the other hand, the "seeet" call is composed of certain high frequencies which probably permit no clues to its location by phase or intensity difference, and it probably also fails to give a time clue, because it begins and ends imperceptibly, instead of coming as a sharp click [*see spectrograms on page 129*]. So it seems that the "seeet" call is admirably adjusted to avoid giving positional clues of any kind to predators. Yet it is just as effective as any other sound would be in warning neighboring chaffinches.

The full song of the male chaffinch performs the function of keeping other males from its territory and attracting unmated females. It is not too inadequately described by the mnemonic jingle *chip-chip-chip; tell-tell-tell; cherry-erry-erry; tissy-chee-wee-oo.* As sound spectrograms show [*see page 132*], the chaffinch song is sufficiently complex not only to identify the species but also to allow wide individual variation, so that individual birds are recognizable, even by human beings, by their personal signature tune.

Study of these songs is extremely interesting from the standpoint of heredity and learning. We have found evidence that even complex songs may depend primarily on the inherited make-up of a bird. For example, the spectro-

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Flame-Plated coatings of aluminum oxide provide resistance to wear, and to chemical action in high temperature applications. Applications are found in thrust bearings, pump plungers, thermocouple tubes, gas turbines, guided missiles, and other devices. Either aluminum oxide or tungsten carbide can be Flame-Plated on most metals. If you have a special wear problem, LINDE's Flame-Plating Department will gladly help you to reach a solution. Write to "Flame-Plating Department R-10."

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A Division of Union Carbide and Carbon Corporation

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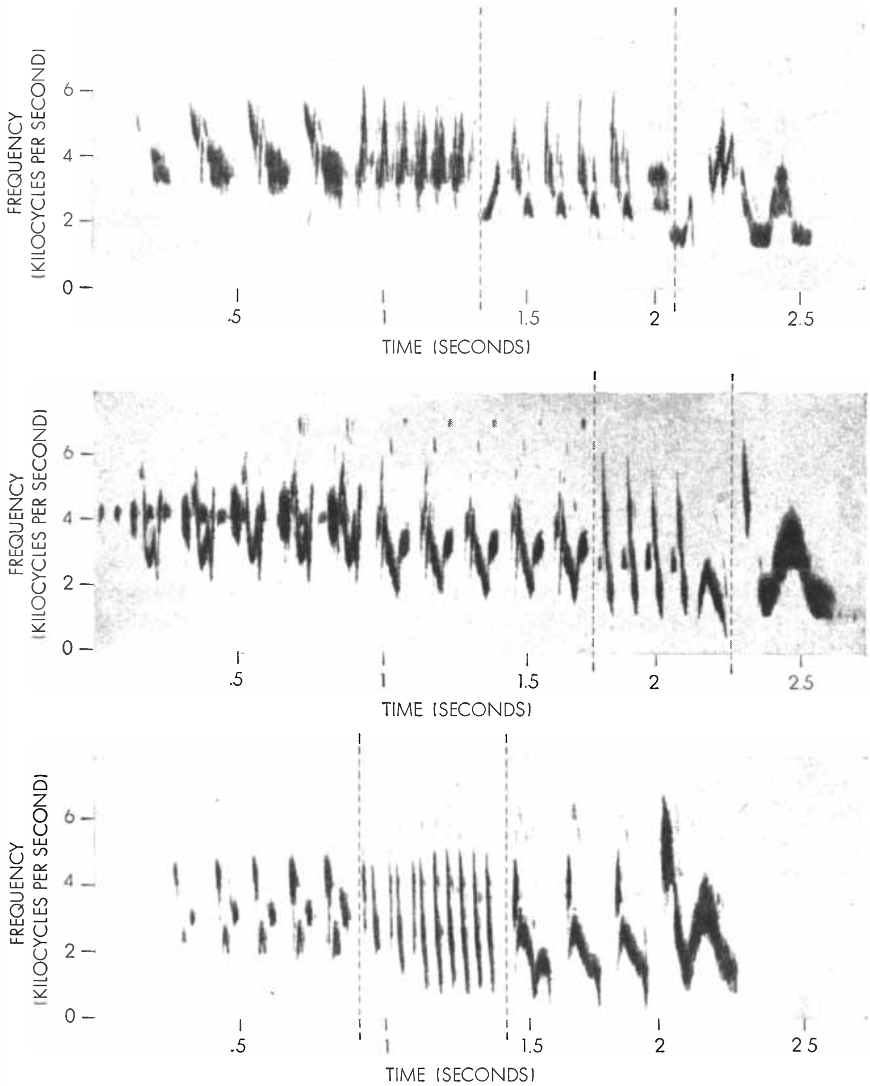
Flame-Plating by Linde

grams of the songs of the European wren and of the American winter wren are remarkably alike. It appears that the song pattern of some birds must rest upon an inborn pattern of activity in the central nervous system.

On the other hand, everyone who has listened to bird songs attentively and with a trained ear has detected individual differences. We have lately proved, by experiments with chaffinches, that these individual differences are not the expression of genetic differences but develop by learning during the early life of the bird. This problem fascinated field ornithologists in England and Germany as far back as the early 18th century, but its precise study has become possible only within the last few years, when apparatus for the accurate analysis of sounds became available.

When a young chaffinch is taken from the nest and reared separately out of hearing of all chaffinch song, its song development is greatly restricted. The bird eventually produces a song of about the normal length (two to three seconds), but it fails to divide the first part of the song into phrases, as a normally reared chaffinch does, or to end its song with the elaborate flourish—the *tissy-chee-wee-oo*—which is one of the most striking characteristics of the chaffinch song in the wild.

The simple, restricted song of the isolated bird can be taken to represent the inherited basis of a chaffinch's performance. Now if after babyhood two or more such birds are put together in a room, but still with no opportunity to hear experienced chaffinches, they develop more complex songs. The attempt to sing in company provides mutual stimulation which encourages the pro-



SONGS OF DIFFERENT BIRDS of the same species have similar over-all patterns but may show striking individual differences. Above are oscillograms of the songs of three different chaffinches. The phrases into which the songs are divided are marked off by dotted lines.

CORNING GLASS BULLETIN

FOR PEOPLE WHO MAKE THINGS

Microwaves in the kitchen

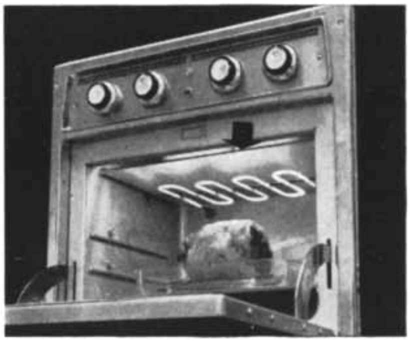
Tappan's latest electronic range lets you cook a 5-pound roast in 30 minutes, bake a potato in 4, broil bacon in $1\frac{1}{2}$, heat a jar of baby food in 45 seconds.

Key to this microwave magic is a magnetron supplied by Raytheon. It generates waves of 2450 megacycles, a frequency that requires licensing by the Federal Communications Commission.

These waves do the cooking. They are fed into the oven cavity by a guide mounted at the top and properly diffused by a slowly revolving fan and a sheet of glass.

This glass, as you might imagine, is no ordinary piece of window pane. It has to pass the high-frequency waves and help in their even distribution. It also must protect the electronic elements and fan from hot, spattering grease.

Handling the task nicely is Corning's VYCOR brand glass No. 7900, one of a group of 96% silica glasses exhibiting some quite unusual performance characteristics.



Tubing below VYCOR glass shield (arrow) is an infrared unit to give a pleasant "browning" effect to food.

For example, you can heat an object made of No. 7900 glass to 900° C., then plunge it into ice water. You'll get *no* cracking, crazing, breaking, or changing in shape or structure even after such terrific thermal shocks.

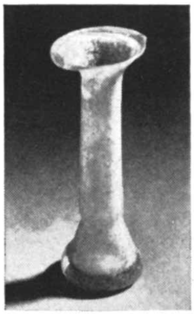
Continuous use at 900° C. is standard operation; and intermittent use to 1200° C. is both possible and practical.

VYCOR brand glass also does a fine job of transmitting ultraviolet at wave lengths of 365 millimicrons and higher, and short-wave infrared up to 3.5 microns.

Details on seven of the VYCOR brand glasses (including facts on manufacturing, physical properties, uses and forms) are summed up in B-91: "VYCOR brand Industrial Glassware by Corning." A copy awaits your request.

Lachrymal lesson

Legend has it that ancient Romans grieving their departed collected their tears in small vases and buried the vases with the deceased.



Such vases go back to the Rome of about 300 A.D. Yet, despite this antiquity, so many are *still* in such perfect shape that a tourist can own one for the outlay of a mere 50 cents.

Lesson? Oh, yes, —these long-lasting vessels for lachrymal liquid were made of *glass*. And glass, as made *today*, offers the designer a host of useful qualities, in addition to durability.

Take as a starter, PYREX brand glass No. 7740. It's the choice of those whose products must cope with corrosive environments, thermal shock, and rough handling in general.

Among the literally thousands of useful items fashioned from this particular Corning glass you'll find precision labware; piping for the food, chemical and drug industries; broiler shields; oven windows; oven cooking ware; dental and medical products; vapor chambers; coffee makers and servers; and sundry lamp globes.

No. 7740 is just *one* of a wide array of glasses by Corning available in commercial quantities . . . which brings us to a standing offer:

You can tap the data files on some 50,000-odd formulas for glass in quest of an answer to your materials problems. What we've learned about the advantages (and limitations) of glass we'd like to share with you.

Or, if more background data on what you can do with today's *engineered* glasses seems in order, send for any or all of the free literature listed in the coupon.

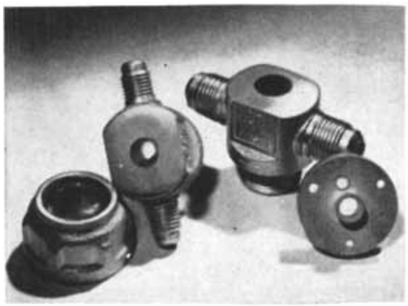
Look, no gasket!

Troubles—that's what most of us have come to expect with sight glasses used in pipelines or other strategic locations.

Causes are not hard to pinpoint—innocent tampering, heat and vibration that cause failure in soldered joints, various forces that result in gaskets degenerating.

'Til now most of us have quietly accepted the inevitable disruptions. But, there's no need to any longer.

Working with a prominent supplier of refrigeration equipment, we've come up with a real innovation—a gasketless, solderless, sight-glass assembly.



Glass fused directly to metal provides unusually rugged service in these sight glass assemblies.

In this new Corning development, the glass and metal are fused directly together. Result? A hermetically-sealed, tamperproof arrangement that stands up to moderate heats and high pressures.

A number of variations are available, with diameters ranging from $\frac{3}{16}''$ to 1″, with glasses from $\frac{1}{16}''$ to $\frac{1}{4}''$ thick.

Typical performance—$\frac{3}{8}''$ diameter and a $\frac{1}{8}''$-thick glass withstood pressures in excess of 5,000 p.s.i.

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Corning means research in Glass

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Please send me the following material: Bulletin B-91, "VYCOR brand Industrial Glassware by Corning" ☐; Bulletin IZ-1, "Glass . . . its increasing importance in product design" ☐; Bulletin B-84, "Manufacturing and Design of Commercial Glass" ☐; Illustrated booklet, "Glass and You" ☐; Information on sight glasses ☐.

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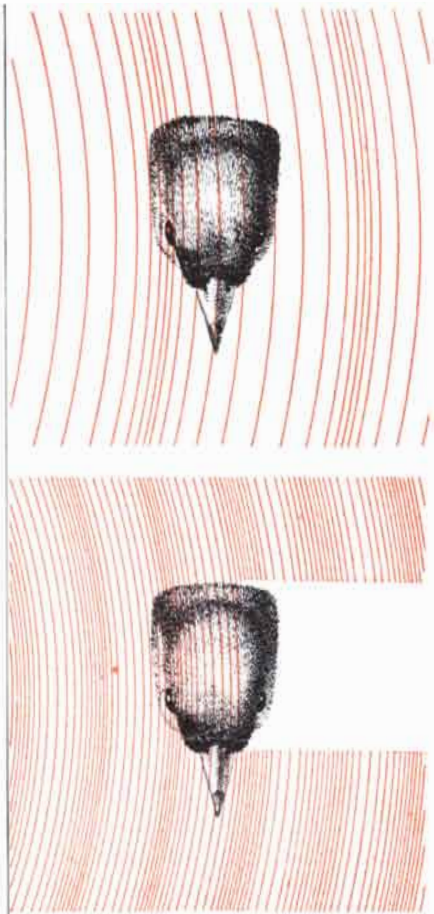
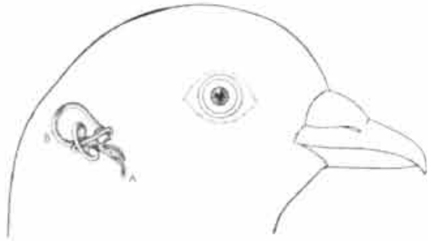


DIRECTION from which a sound is coming may be judged in various ways. Wavelengths comparable to the width of the bird's head give phase differences at its two ears (*top*). Shorter waves may be blocked by the head so that the more distant ear is in a "sound shadow" and receives little energy (*bottom*).

duction of complexity. The group of birds will, by mutual imitation, build up a distinctive community pattern. The members of the group conform so closely to this pattern that it is barely possible to distinguish the songs one from another, even by the most minute electronic analysis. Their song may be quite as complex as that of a normal wild chaffinch. But it bears practically no resemblance to the characteristic chaffinch song!

There is a short and critical six-week period, at about the 11th month of life, during which the chaffinch develops its song pattern. Once this critical learning period is over, the song is fixed for life: no matter how much a bird is exposed to other chaffinch songs afterward, it continues year after year to sing only the song or songs it worked out as a youngster.

Such experiments make clear what is happening in the wild. In nature young chaffinches must certainly learn some



INNER EAR of a bird contains the cochlea (A), or organ of hearing, and the highly developed semicircular canals (B) which provide acute sense of balance needed for flight.

details of song from their parents or from other adults in the first few weeks of life. At this stage a young bird absorbs the general pattern of division of the song into two or three phrases with a flourish at the end. But not until the critical learning period, during the following spring, does the bird develop the finer details of its song. This is the time when the young wild chaffinch first sings in a territory in competition with neighboring birds of the same species, and there is good evidence that it learns details of song from these neighbors. It may learn two or three different songs, sometimes even more, from neighbors on different sides of its territory. Many field naturalists have observed local dialects of the song of a given species.

So the full chaffinch song is a simple integration of inborn and learned song patterns, the former constituting the basis for the latter. While isolated chaffinches can, as we have seen, work out for themselves very strange songs, those in the wild are circumscribed by the general pattern of the chaffinch song characteristic of the locality, though they may develop individual variations in detail.

The chaffinch, like many other small birds, has a subsong consisting of an irregular sequence of chirps and rattles. This subsong, in contrast to the full song, is usually uttered from dense cover and appears to have little or no communicatory function. Heard in the early spring, it seems to be associated in some degree with rising production of sex hormones by the gonads. The subsong in a sense constitutes the raw material out of which the true song is constructed. It contains a much bigger range of frequencies than does the full song, and the bird drops some of these frequencies in the full song. This suggests a similarity with the way in which human children learn to speak. A baby will produce at random almost every conceivable sound

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its vocal mechanisms are capable of making, but as it grows it ceases to produce those sounds which it does not hear uttered by its parents and others around it.

Everyone knows that many birds are good mimics: besides the proverbial parrot there are the mockingbird in the U. S. and the starling and other species in Europe. To its own innate song such a bird adds notes and phrases from a wide variety of other species, and sometimes even sounds of inanimate origin. (The biological function of this imitation is still obscure: if the song of the starling, for instance, is a territorial proclamation like that of the chaffinch, to imitate many other species would seem merely to lead to confusion.) We have recently found that a chaffinch caged with, say, canaries may introduce a very good imitation of a phrase of canary song into its subsong, but never into its full song. How this restriction is maintained, we do not know. It is being studied, however, and we hope that its investigation will in due course throw light on the relationship between subsongs and full songs.

We have just commenced a very interesting study of the songs of hybrid birds—born of two different species. A curious and puzzling first result is that the hybrid is sometimes more imitative than either parent bird. For example, the song of a hybrid offspring from a goldfinch and a greenfinch is a virtually perfect imitation of a chaffinch song which the bird heard in its aviary.

It was said at the beginning that most people tend to think of bird song as a sort of emotional release rather than the process of communication that it usually is. Actually the possibility of birds singing for pleasure is by no means ruled out. The evidence is far from negligible that the songs of some thrushes, the warblers and the nightingale exhibit elaborate esthetic improvement far beyond what strict biological necessity requires. To be sure, the purity of tone which characterizes the best singers is potentially advantageous to them, for it helps to provide an additional dimension for distinctiveness. On the other hand, we have seen that in birds' imitation of song there seems to be no immediate or obvious biological reward, and that often the matching of sound patterns must itself constitute the reward. Much of it, of course, may be merely part of the trial-and-error process of learning, but in those cases of vocal imitation where new phrases are produced only after long delay and apparently without specific practice, another influence must be at work.

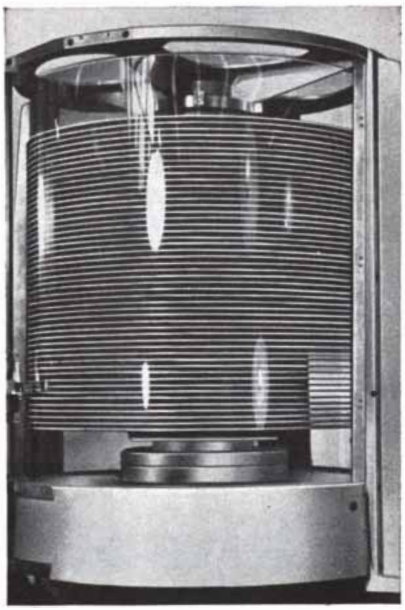
putting IDEAS to work—research at IBM

- **Random Access Memory Accounting: RAMAC®, magnetic-disk memory storage, gives fast access to 5,000,000 characters. IBM Bulletin No. 400.**
- **Slanting Rain: "Shadows" created on a surface by its irregularities and discontinuities magnified 200,000 times through electron microscopy.**

Random Access Memory Accounting

RAMAC, IBM's newest data processing system, needed a unique memory storage system. Ordinary methods of memory storage—magnetic tape, drums, ferrite cores—couldn't store enough "bits" of information. It took a research team of ours, with Trigg Noyes and Wes Dickinson as key men at IBM's San Jose Research Labs, to find the answer. The heart of this new idea: magnetic disks, played and replayed like the records in coin-operated music machines!

Here's how it works: Information is stored, magnetically, on fifty disks which rotate at 1200 rpm. These disks are mounted so as to rotate about a vertical axis, with a spacing of three tenths of an inch between disks. This spacing permits two magnetic heads to be positioned to any one of the 100 concentric tracks which are available on each side of each disk. Each track contains 500 alphanumeric characters. Total storage capacity: 5,000,000 characters. The two recording heads are mounted in a pair of arms which are moved, by a feed-back control system, in a radial direction to straddle a selected disk.



RAMAC's memory

This new system promises memory storage possibilities never before accomplished. If you'd like to read more about the engineering design of this magnetic-disk, random access memory system, write for IBM Bulletin No. 400.

Slanting Rain

All of us have stood on a tall building on a cloudy day and looked down at the street—pretty difficult to judge relative heights of objects that far below, wasn't it? But during late afternoon on a sunny day the lengths of shadows made your estimates of height as easy as apple pie.

Blown-up shadows

The 100,000-volt Electron Microscope at our Poughkeepsie Research Laboratory allows us to study the topography of surfaces in just the same way. Instead of relying upon the obstruction of light by objects on a surface, we cause them to obstruct a slanting rain of metal vapor. Where the rain falls on a thin collodion coating previously put on the surface, the transmissibility of electrons through the coating is altered when it is put into the Electron Microscope; the "shadows" can be magnified and recorded on photographic film. A photographic enlargement made from the film can result in magnification of 200,000 times, thus making it possible to clearly observe an object less than one ten-millionth of an inch in diameter; or, this dash, —, magnified to the extent that it would appear to be about ¼ mile long. This magnification is about 200 times greater than practical in light microscopy, primarily because of the greater resolution possible in the EM, due to the short effective wave length of electrons.

Poughkeepsie's EM

We regard the electron microscope as one of our most important research tools. It has in some cases provided the missing data needed to understand the inter-relation of the variables in a problem; has in other cases allowed us to confirm a proposed new theory.

- RESEARCH at IBM means IDEAS at work. For bulletins mentioned above, write International Business Machines Corp., Dept. SA-10, 590 Madison Ave., New York 22, N.Y.

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If your salary reflects lack of opportunity for promotion, why not look into opportunities presented by Lockheed diversification. It's worth discussing. Write or phone collect, if you possess an engineering degree or actual engineering experience. Address written inquiries to E. W. Des Lauriers or use the brief resumé form below. If you phone, call STanley 7-1241, Extension 6-2134.

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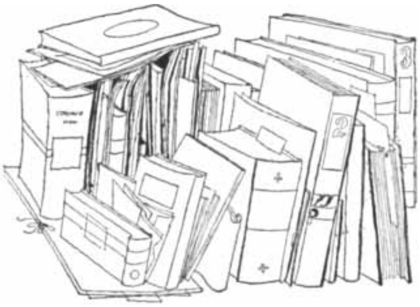


BOOKS

The natural philosophers of 18th-century America

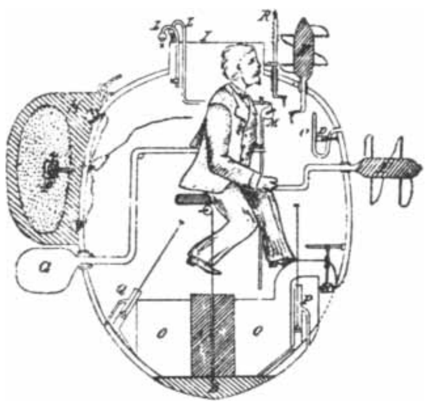
by James R. Newman

THE PURSUIT OF SCIENCE IN REVOLUTIONARY AMERICA, by Brooke Hindle. The University of North Carolina Press ($7.50).

Brooke Hindle's highly informative chronicle of the beginnings of science in this country opens with the period around 1735, when a climate in which science could flourish began to be established in the New World. It was the period in which the influence of the Age of Enlightenment, whose apostles were Isaac Newton and John Locke, "flooded into the colonies," and Benjamin Franklin voiced "exalted aspirations" for science in America. "The first drudgery of settling new colonies which confines the attention of people to mere necessaries," he announced, "is now pretty well over; and there are many in every province in circumstances that set them at ease, and afford leisure to cultivate the finer arts and improve the common stock of knowledge." Franklin outlined a plan for the "cooperative promotion of science on an intercolonial basis." With the methods of the new science, the spirit of the new philosophy, the liberty of the new society, who could assign limits to the achievements of the new civilization? A book appeared in Constantinople with a picture of the American "wakwak" tree, which "bore women rather than the more usual type of fruit." The wonders of the land were incalculable; imagination soared; the future was bright.

Franklin was a practical man but inclined to optimism. The fact was the future had not yet arrived. The concerted effort necessary for the advancement of science in the colonies did not blossom overnight. The intellectual atmosphere was favorable in New England, in Philadelphia, in Charleston and in a few other centers, but the general picture was less promising. The colonies were divided and sprawled over a large territory. The effects of physical isolation were aggravated by jealousies and rivalries. The population was small. For the support of scientific work both wealth and leisure were needed, but these were so widely distributed "that there were only a few to act in the capacity of patrons even if they would." The botanist John Bartram wrote in 1745: "I sometimes observe that the major part of our inhabitants may be ranked in three Classes, the first Class are those whose thought and study is intirely upon getting and laying up large estates and any other attainment that dont turn immediately upon that hinge they think is not worth thair notice, the second class are those that are for spending in Luxury all they can come at and are often the children of avaritious Parents, the third class are those that nessesity obliges to hard labour and Cares for a moderate and happy maintenance of thair family and these are many times the most curious tho deprived mostly of time and matereals to pursue thair . . . inclinations."

But ties among the colonies were being strengthened by trade, correspondence, improved roads, more dependable postal service and the circulation of newspapers. The colonists had a common bond in being Englishmen, but they also had a common bond in being Americans. While their institutions were basically European in conception, the circumstances of the new country demanded modifications of the European heritage. The end result was a "variant of European civilization" in which men shared both their legacy and their exertions to adapt it to new problems and conditions. Military exertions played their part in promoting rapport among the colonists. The capture of the French fortress of Louisburg by a New England force in 1745 "provided occasion for the most unrestrained celebration of a common patriotism in Maryland as well as Massachusetts." Patriotism spurred a cultural nationalism, which was bound to stimulate the pursuit of science. It is not often in history that one can see so clearly the interdependence of a growing interest in knowledge and social change, of the life of science and the life of the community. Dr. Hindle's book enriches our understanding of this interdependency.



David Bushnell's 1776 submarine

The first part of his survey deals with the years 1735 to 1765. Three groups during this period contributed to scientific knowledge: naturalists, physicians and college teachers. America was a paradise for those who followed botany or zoology, who collected stones, who were passionate classifiers, who cultivated exquisite gardens or were grubbily concerned with seeds and crops. Venturesome Europeans made the trip across the Atlantic to sample the wonders of natural history. Sea captains and itinerants brought back to Europe specimens of flowers, trees, animals, birds and minerals that had never been seen in the Old World. Among the foremost collectors and patrons was Sir Hans Sloane, a wealthy physician and president of the Royal Society of London, whose collection of books and curiosities was to become the nucleus of the British Museum. With financial backing provided by him and others, regional studies of flora and fauna were made in America: one of the products was Mark Catesby's influential *Natural History of Carolina, Florida and the Bahama Islands.*

By the middle of the 18th century, says Hindle, an international circle occupied with natural history had been formed among the naturalists of America, England, France, Holland, Sweden, Germany and Italy. The American partnership in this effort owed a great deal to a London Quaker merchant, Peter Collinson. Collinson was not a scientist, but he loved flowers, trees and rare plants and he wanted to be remembered for the many species he had introduced into England. His great counting house in London became a "clearing house from which specimens and communications received from America were redirected to Linnaeus in Sweden, Dillenius at Oxford, Gronovius at Leyden, and other members of the circle." He was a leading member of the Royal Society and was on friendly terms with scientists throughout Europe. His enthusiasm and intelligent patronage gave "coherence and direction" to the labors of American naturalists.

Among the Americans who benefited most from Collinson's patronage was the botanist Bartram. Described by a contemporary as a "down right plain Country Man," Bartram had little formal education, but he made up for this lack in zeal and natural skill. His work in botany attracted the support of James Logan, a wealthy Pennsylvania Quaker merchant who made important contributions of his own to science: Hindle credits him with being the first to demonstrate the functions of the various organs in sexual reproduction of plants by experiments with corn. With Logan's help, and later Collinson's, Bartram was able to travel the colonies from New England to Florida collecting specimens and broadening his knowledge. For the *Philosophical Transactions of the Royal Society* he wrote papers on insects, aurora borealis, snake teeth and mollusks; he also worked out a plan for a geological survey of the colonies to uncover their mineral wealth. Bartram remained throughout his long life "basically a noble nurseryman," but he was a remarkable observer and gave substantial impetus to the development of American science.

John Clayton, a Virginian, was another devoted collector who became widely known. His collections formed the basis of Gronovius' *Flora Virginica*, which for many years was the best systematic treatise on American botany. Among others who promoted the science of plants were Abraham Redwood of Rhode Island, Henry Laurens of South Carolina, William Byrd of Virginia, Charles Read of New Jersey, William Allen of Pennsylvania and even several governors of the colonies.

Amid all this activity, it is striking how little concentrated effort was expended on the improvement of agriculture. Jared Eliot of Connecticut recorded observations on cultivation, plowing, use of fertilizers and other techniques. A few gentlemen farmers shared this interest. But the preponderant motive of the early students was curiosity about the flora and fauna of the New World, rather than improvement in the arts of husbandry.

In America, as in England and on the Continent, physicians played a prominent part in the pursuit of natural history. American doctors trained at the University of Edinburgh, a leading medical center of the time, returned to the colonies imbued with the lore of vegetable remedies and ardently devoted to botany. Cadwallader Colden of New York and Alexander Garden of Charleston were pre-eminent in this group. Colden, a man with a widely ranging mind, composed *The History of the Five Indian Nations*, had a plant named after him by Linnaeus, wrote articles on yellow fever, pokeweed and cancer, and was the author of a grandiose pamphlet on matter, motion, ether and gravity. Colden firmly believed in his theories, but admitted that he had applied "himself to Physics and Mathematics, only by way of amusement, to fill up a vacant hour."

A flower named for Franklin

Garden discovered many new genera of plants which Linnaeus incorporated in his *Systema Naturae*. He also collected specimens of Carolinian fish, reptiles and insects, and experimented with the electric eel, thus elegantly wedding physics to zoology. Other physicians deserving mention are William Douglass of Boston, who pursued botany, minerology and meteorology (recording the state of

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THE PURSUIT OF SCIENCE IN REVOLUTIONARY AMERICA
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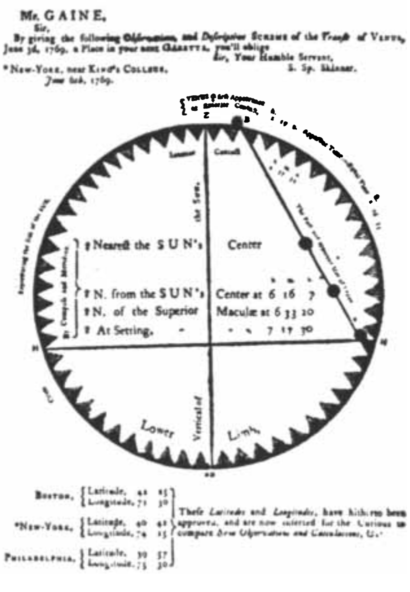
The World of NATURAL HISTORY
ENGINEERING IN HISTORY

the weather in Boston as well as he could without a thermometer or barometer); John Lining of Charleston, who did work in botany, studied the relation of weather to disease and performed experiments in metabolism, weighing the intake and outgo of his body for one year; John Mitchell of Virginia, a botanist, zoologist and author of an essay which ascribed the "Different Colours of People in Different Climates" to environmental factors.

Gradually the "thinness of the intellectual environment" in America began to be enriched by libraries, publications and scientific societies, where the learned could foregather and converse amiably as well as peck at each other. The Library Company of Philadelphia was one of the first. Financed on the subscription principle, it soon held the finest collection of scientific books in the country. The Library was also a museum and repository of scientific apparatus. Collectors were given shares in the company for contributions of curiosities: stuffed snakes, a dead pelican, Indian chiefs' robes, a set of fossils. John Penn, a proprietor of Pennsylvania, presented a "costly Air-Pump"; his family also donated a pair of 16-inch globes, a telescope and an electric machine.

Philadelphia's growing population and wealth were the underpinning for a steady increase in cultural activities. Ben Franklin had retired from his printing business with a fortune and turned his overflowing energy to everything from organizing fire companies and inventing a fireplace to experimenting with electricity. Bartram, to whom he always dis-



Newspaper report of a transit of Venus

played warm affection, interested Franklin in establishing a scientific academy. Franklin drew the plan for the American Philosophical Society, which was to concern itself with botany, medicine, geology, geography, agriculture, mathematics, chemistry and the crafts. But the initial enthusiasm soon flagged, and by 1747 the Society was quite dead. Scientific societies need patrons and yearners as well as scientists. In its first incarnation the American Philosophical Society was short of merchants and gentlemen; it failed while the Royal Society, which had the support of the London mercantile community, succeeded. The American Society, however, was to have a rebirth under more favorable auspices in 1767.

Shortly after the collapse of the Society, Collinson sent to the Library Company of Philadelphia a glass tube for conducting electrical experiments and directions for repeating certain German work in electricity. Under the spur of these gifts Franklin became "totally engrossed" in the subject. The famous "Philadelphia experiments" followed. Franklin communicated his results in letters to Collinson, some of which found their way into the *Philosophical Transactions,* some into the *Gentleman's Magazine* of London. Then in 1751 a collection of the letters were published under the title *Experiments and Observations on Electricity.*

Franklin's work in electricity was the supreme scientific achievement in America during the colonial period. The response to it was overwhelming. The book passed through five English and three French editions and was translated into German and Italian. The Royal Society awarded Franklin its highest honor, the Copley medal, and went to unheard-of lengths in admitting him to fellowship without payment of the usual fees. "Mr. Franklin of Pennsylvania" received the personal thanks of the King of France, membership in the Académie des Sciences and honorary degrees from Harvard, Yale and William and Mary. He passed "from the little world of Philadelphia to the great world of London and Paris." His literary, political and scientific reputation steadily rose, until he became, Hindle observes, the very symbol of the learned philosopher.

Franklin's electrical researches gave an immense stimulus to American science. Except for astronomy, the physical sciences and mathematics had not been pursued with anything like the vigor devoted to natural history. But thanks to Franklin's achievements and to the work of a few gifted teachers—notably John

Winthrop, Hollis professor of mathematics and natural philosophy at Harvard—interest in natural philosophy and mathematics grew among students, and by the 1760s these subjects were chosen for the majority of college theses.

As the colonies grew and took up common cause against England, their emerging nationalism took form in cultural as well as political activities. Learned academies and societies for the encouragement of the arts, manufacture and commerce sprang up in profusion. Prizes were offered for inventions. "Buy-American" movements got under way. Physicians organized to raise the standards of the profession. The American Philosophical Society was reborn. Hindle devotes a chapter to its rebirth and another to the colonies' first major cooperative project in science—observation of the transit of Venus in 1769. A new generation of scientists and inventors began to appear on the American scene, among them David Rittenhouse, the gifted Pennsylvania clockmaker who built a famous orrery which represented the motions of the planets about the sun with unprecedented accuracy; young Benjamin Thompson of Concord (later Count Rumford); Benjamin Rush, the noted physician and vigorous supporter of science in all its branches; David Bushnell, the Yale student who built an oak-cask submarine to "pulverize the British Navy"; John Fitch, the Connecticut craftsman who dreamed of building a steamboat and turned his dream into a successful reality.

The Revolution brought first a sharp decline and then an even sharper recovery in the affairs of learning. By the early 1780s the vigorous new cultural flowering was producing books in unprecedented numbers, new societies, colleges and universities, new daily newspapers, libraries, museums and hospitals. Researches were pursued in subjects ranging from agriculture and optics to ballooning and statistics. Inventions proliferated. Great canals were planned and fine bridges built.

Yet all was not light and glory. There was a tremendous huffing and puffing and patriotic self-inflation. The intellectual environment was still thin, and the practice of the basic sciences in the new republic was not in a class with that of Western Europe. It was perhaps true that America was the greatest theater for the improvement of mankind and for the realization of the highest hopes of the Enlightenment, but the actors were still novices. Nevertheless, the men who made the American Revolution were justified, as Hindle says, in their confidence that the pursuit of science would flourish in the U. S. When the Continental Congress assembled, Rittenhouse declared that to it were entrusted "the Future Liberties, and Consequently the Virtue, Improvement in Science and Happiness, of America." Today we may be less certain that a legislative body can be depended upon to assure these blessings, or that improvement in science and happiness are inseparable twins, but it will not be denied that the material well-being of the U. S. vindicates "the faith of the Revolutionary generation" in what science, beneficently used, can achieve.

Dr. Hindle has made an able contribution to scholarship. His book is not always lively; at times the details are burdensome and one feels one is reading a learned catalogue. Interpretation of facts is no less important than the facts themselves. Where Hindle offers his views they are invariably enlightening and the story moves; too often, however, he dwells on minutiae and restricts his function to scrupulous reporting. But his study, for all its long-windedness and other academic faults, is a pioneering achievement—a solid entry into an important phase of the history of science and its relation to social and political events.

Short Reviews

The Changing Universe, by John Pfeiffer. Random House ($4.75). Twenty-five years ago a young Bell Telephone Laboratories radio engineer, Karl Jansky, erected on what had once been a potato farm in New Jersey a radio aerial which was 100 feet long, resembled the skeleton of a large airplane wing and, driven by a motor at the center, rotated slowly on four wheels taken from a Model-T Ford. This ungainly contraption was the first research instrument to investigate the celestial sources of radio static. It served to found the science of radio astronomy. In the quarter century that has elapsed since Jansky, with earphones clamped to his head, first heard the distant universe hissing at him, much progress has been made in identifying the radiations emitted by the sun, by far-off stars, by the spiral arms of the Milky Way, by remote galaxies. Radio astronomy has vindicated Kepler's vision of the music of the spheres—though not quite as he would have expected. In England, the Netherlands, France, Australia and the U. S. radio telescopes of many designs have been built, some so sensitive that they

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can pick up the radio signals from a man's stomach more than four miles away. The cooperative assault of radio and optical astronomy promises to deepen our understanding of the structure of the sky, of the dimensions of the universe, of the processes by which stars are made. A popular account of what has already been achieved and of future programs of research is presented in this book. The author, who spent two years visiting radio astronomy installations and interviewing investigators in the U. S. and abroad, presents his information clearly and unpretentiously.

PHRENOLOGY: FAD AND SCIENCE, by John D. Davies. Yale University Press ($3.75). Phrenology today is only a boardwalk and carnival discipline, but it once stood higher in the world. In the 19th century, according to this interesting book, it was a dignified science, a humanitarian philosophy, a cult, a crusade, a popular system of psychology "hailed as a panacea for social ills." Its founder was the German physician Franz Joseph Gall, still remembered for his many discoveries in cerebral physiology. His first disciple was Johann Gaspar Spurzheim, who gave a great impetus to the popularization of phrenology. After Spurzheim's death (during a U. S. lecture tour), his mantle fell upon a brilliant young Edinburgh barrister, George Combe, who wrote the best known and most inspirational of all phrenological books, *The Constitution of Man* (1828). Combe spent three years in the U. S. spreading the gospel among the learned and the fashionable. As Gall conceived it, phrenology was an experimental science reared on the assumption that mental phenomena are linked to anatomical and physiological features of the brain. His theory postulated four basic physiological types: the "nervous" (large brain, delicate health, emaciation), the "bilious" (harsh features and firm muscles), the "sanguine" (large chest and moderate plumpness), the "lymphatic" (rounded form and heavy countenance). The mind is composed of 37 independent and ascertainable faculties, each occupying a little plot in the head. Destructiveness is over the left ear—bordering, most appropriately, on secretiveness, alimentiveness and combativeness. Behind this ear are evitativeness, amativeness and conjugality. Sublimity, cautiousness and adhesiveness are well inside the skull. There is a small lozenge for murder; this is better developed in some men than in others. Self-esteem is on top of the head and obviously vulnerable unless the bone is thick. Mirthfulness is over the sinuses, and among its neighbors are causality, time, tune, locality and imitation. These various faculties compete for space and affect the size and contour of the cranium. Thus a trained person can make a character analysis by studying the shape of a subject's head in conjunction with his temperament. W. S. Gilbert's policeman sang of his captured felon:

Observe his various bumps
His head as I uncover it
His morals lie in lumps
All round about and over it.

But even a criminal can be reformed, for it is basic phrenological doctrine that while faculties and propensities are inherited, they can be altered and improved by methods ranging from hygienic living to kind treatment. Phrenology found its first roots in the U. S. among the educated classes and the medical profession. Spurzheim's and Combe's lectures were spectacularly successful. Newspapers and magazines were full of the subject; phrenological associations sprang up in many cities; in Philadelphia, a Biddle added the essential "éclat" to the enterprise; at Yale, Professor Benjamin Silliman conferred his enthusiastic blessing. There were, of course, those who regarded the whole business as a fraud and trumpery. But controversy helped to spread the doctrine. When the interest of the upper classes waned, clever men took over phrenology as a nostrum for the crowd. Orson Squire Fowler, a brilliant promoter, peddled phrenology to the masses, made a fortune and built himself an octagonal house. Phrenological books, charts and manuals were sold by the hundreds of thousands; phrenological readings were obtainable by mail if one sent in a daguerrotype; employers advertised for apprentices who carried good phrenological recommendations. The craze lasted through the 1840s; by the Civil War it was dead. Davies' lively and thoughtful study assesses the influence of phrenology on education, the treatment of the insane, penology, health, literature, medicine, religion. Notwithstanding its absurdities and racketeering aspects, phrenology as a philosophy was humane and idealistic. Alexis de Tocqueville, seeking to explain its special popularity in America, suggested that it appealed to some of the best qualities of a young and growing democratic society. E. G. Boring, the Harvard psychologist, observes that "it is almost correct to say that scientific psychology was born out of phrenology,

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out of wedlock with science." Davies' book is a most readable and instructive essay.

Engineering in History, by Richard Shelton Kirby, Sidney Withington, Arthur Burr Darling and Frederick Gridley Kilgour. McGraw-Hill Book Company, Inc. ($8.50). Two engineers and two historians have collaborated to produce this attractive introduction to engineering history. They begin their account with building in Mesopotamia, ancient hydraulic and sanitary engineering, the construction of roads, bridges, ships, pyramids and temples, and carry it up to modern times in the development of certain principal branches of civil, mechanical, electrical and metallurgical engineering. The presentation is clear and nontechnical, and an attempt is made to relate engineering achievements to the underlying advances in basic science and to tell their impact on civilization. However, the latter, an enormous subject in itself, is given little more than perfunctory treatment in this book. Moreover, the historical account is more satisfying for certain periods and topics than for others. Architecture, the raising of great structures, the building of canals and bridges, the evolution of steam power are very ably discussed, while electrical engineering and transportation are treated more hurriedly. The authors have enriched their history with many colorful asides and vivid details. Among the absorbing episodes are those dealing with the Brooklyn Bridge, with James B. Eads's famous ferrous span across the Mississippi at St. Louis and with Domenico Fontana's celebrated removal in 1586 of Caligula's obelisk from the Circus of Nero in Rome to the plaza before St. Peter's. During this hair-raising operation punishment by death was threatened for anyone who should "speak, spit, or make any loud noise." As a sound, well-written chronicle of engineering for the student and general reader, this book is most welcome.

Voyage to the Amorous Islands, by Newton A. Rowe. Essential Books, Inc. ($5). In 1766 Captain Samuel Wallis set sail from Plymouth in a 511-ton, copper-bottomed ship called the *Dolphin*. His orders from the Admiralty were to enter the Pacific through the Straits of Magellan and, if possible, find the "Southern Continent." Geographers of the time believed there must be an enormous land mass in the southern hemisphere to balance the northern land masses; otherwise, it seemed clear, the world would turn upside down. This *Terra Australis Incognita* (not Australia, whose existence was already known) had for centuries roused the appetites and ambitions of the major European powers, which dreamed of gold and other treasures to be gained from seizing it. En route to the unknown continent Captain Wallis planned to stop at Patagonia, whose southern coast was reported to be inhabited by a race of giants; the captain, a practical man, took along a measuring rod. The Patagonians turned out to be not quite 11 feet tall, as certain European navigators had averred. And the *Dolphin* sighted no Southern Continent. But after much dangerous and wearisome wandering the voyagers did discover a delightful and enchanting land—Tahiti. The natives were first unfriendly, but after some sharp skirmishes in which the ship replied to their stones with musket fire and grapeshot, hostilities came to a quick end. The weary sailors found the island a "paradise—Calypso's Island, the Hesperides, the Fortunate Isle, the Isle of the Blessed, the Happy Island, the Amorous Island—where nearly all their dreams came true." The climate was alluring, the harbor snug; there were firewood, fresh water, meat, fruit and beautiful "and accessible" girls. The *Dolphin*'s five-week stay at Tahiti came as close to a sojourn in Heaven as the crew, or anyone for that matter, would ever experience. The author of this book has captivatingly reconstructed the voyage and visit of the *Dolphin* from many accounts and journals, published and unpublished. Rowe describes the habits, customs, legends and fascinating ceremonials of the Tahitians. The aristocratic ruling cult of the island practiced free love and strangled at birth any child who lacked a male sponsor. Rowe portrays vividly the handsome Queen Purea, a middle-aged lady of enormous stature, whose name means the "Wished-for." She wished for Captain Wallis, but in vain. The Polynesian girls were happy to grant their favors to the *Dolphin*'s crew. They acted out of love, without wantonness or vulgarity, but in a communal spirit felt they should be paid in nails—a coin which the men of the island could convert to useful tools. (The author remarks that in the 20th century South Sea Island girls prefer to be paid with dynamite, with which "fish can be killed in the shallow lagoons for the benefit of the whole community.") Rowe's book, "largely compiled from the actual words" of the visitors to Tahiti, is a contribution to the history of discovery and an admirable description of a people whose innate goodness matched the beauty of their land.

ECONOMIC NEEDS OF OLDER PEOPLE, by John J. Corson and John W. McConnell. The Twentieth Century Fund ($4.50). Since 1900 the number of persons 65 and over in the U. S. has quadrupled, while the total population has doubled. In 1900 only one person in 25 was aged 65 years or older; in 1950, one in 12. This study deals with the economic problems resulting from the change in the nation's age structure. It draws the broad picture of the aged in our society: how many can work, their health and the medical and nursing care they get, where and how they live, what they live on, the ways of life among retired old people. The survey then considers in detail such matters as employment and retirement, savings in relation to old age, the political aspects of security programs, old age assistance and social insurance, private and public pension plans. The volume concludes with a report of the Fund's Committee on the Economic Needs of Older People.

OXFORD REGIONAL ECONOMIC ATLAS: THE U.S.S.R. AND EASTERN EUROPE. Oxford University Press ($10). This is the first atlas of what promises to be an excellent series. The maps are clear and well executed; together with the supporting text and statistical tables they convey an immense amount of information about a region of the world regarding which even well-read persons are usually ignorant.

THE FEARS MEN LIVE BY, by Selma G. Hirsh. Harper & Brothers ($2.75). In the early 1940s the American Jewish Committee undertook to support a series of investigations into racial and religious prejudice. The findings have been reported in detail in five volumes, of which the best known is *The Authoritarian Personality*. This book is a popular summary and interpretation of them. Prejudice, like delinquency, is an especially pernicious kind of social pathology. People who suffer from it tend to look upon the world as cruel and threatening, to fear individuality in themselves and others and to find safety in subservience to authority. These personality patterns were common among all highly prejudiced persons examined in the study—including Jewish anti-Semites. It is good to have the studies of the specialists presented in a nontechnical way, but the author has a tendency to lapse into a kind of singing prose which more often obscures than illuminates the facts.

An Open Interview with an Engineer

at Westinghouse Electronic Tube Division, Elmira, N. Y.

Today's engineering applicants are interested not only in their opportunities for growth and advancement in their chosen fields, but they also carefully consider the community and its facilities for pleasant living.

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Here is part of a typical interview as we see it at the Westinghouse Electronic Tube Division, Elmira, N. Y.

(Interviewer) "We're glad you could arrange to come to Elmira to talk over our professional openings."

(Applicant) "I've enjoyed it so far."

(I.) "Good! Looking over your resume, I see that you've been primarily concerned with circuit design problems since you got your degree in '52."

(A.) "That's right. While the work has been quite interesting, I feel that I'd like to get into something a little different—something that will make use of my circuit experience and also broaden my background."

(I.) "Do you want to stay in the equipment design field?"

(A.) "Well, no, not necessarily. I'd like to explore some aspects of tube design if you think I might fit in."

(I.) "I think so. It's been our experience that anyone with an E.E. degree has the background for learning design rapidly. This is even more true of those engineers who have taken our fundamentals of vacuum tubes course, here in Elmira. This, along with your experience, should make you highly competent rather quickly."

(A.) "Where would I fit into the Tube Division, then?"

(I.) "There's a possibility in each of several sections—Camera Tube Design, Application Engineering, Receiving Tube Design, and Equipment Development where our own manufacturing and test equipment is designed, to mention only a few. We will arrange interviews with the heads of those sections so you can go into detail of our work in each. Is that okay?"

(A.) "Sounds good."

(I.) "Do you have any other questions that can be answered while the interviews are being arranged?"

(A.) "Is there a Pension and Insurance plan?"

(I.) "You bet! Two of the best plans I've seen. Here are short, quickly read booklets describing them. You will find that they cover most every contingency. Incidentally, the life insurance and pension plan goes into effect the day you start to work."

(A.) "How about housing?"

(I.) "It's pretty good. We've been able to find suitable quarters fairly quickly in the past year or so. To help you get located, we'll run an ad in the local papers for you—Elmirans have found that Westinghouse engineers make desirable tenants. There are some good real estate buys available too. Do you go in for outdoor activities?"

(A.) "Whenever possible. Fishing and golf are my favorites. Haven't had much time for either since living in the big city."

(I.) "There's good trout and bass fishing here—both in the streams and the lakes. And $30 pays your annual greens fees at the 18 hole course about a mile from the plant. There are lots of other activities that might be of interest—chess, little theatre, hiking, bridge, soft ball teams, management club, bowling, bird watching, sailing, community concerts, and others—lot of choice."

(A.) "How about churches?"

(I.) "I don't know your choice, but I'll bet you'll find it! We have more than 50 churches within a radius of 5 miles. There are excellent Sunday Schools, too."

(A.) "How about the schools here?"

(I.) "Several beautiful schools have been completed recently to take care of the increasing school population. Your youngsters would get the benefit of fine modern schools—and both the public and parochial schools maintain high scholastic standards."

(A.) "Sounds good so far—now about pay."

(I.) "A very important item! After you have had your interviews, I'll get together with those men you talked with and the Wage and Salary Administrator. The contributions we can expect from you, your estimated potential and your relative spot in the organization will be translated into a monthly salary. That will be included in our offer-letter which you will receive soon after your visit. You will find our salaries are very competitive."

(A.) "Any reasonable chance of getting more?"

(I.) "Naturally. There'll be at least a 3% general increase each Fall for the next three years, quarterly cost of living adjustments and periodic performance reviews to determine merit increases. There is nothing 'hit or miss' about our salary program. Promotions are very possible too, in a growing, dynamic organization like Westinghouse."

(A.) "Well—that sounds encouraging—and quite challenging too. It seems to me you've covered all my questions very well."

(I.) "Here, let me pin this identification badge on your lapel—and we'll go through the plant and offices on the way to your talks with each of the men with whom appointments have been made. I'll take you to the first one, and he'll 'pass you along' the chain. After the last interview, you will come back to my office for any further questions. We're aware of your travel arrangements—so we shall see that you make your plane home. Let's go meet the Engineering Manager."

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At present we have opportunities for engineers in Tube Design and Development for Microwave Tubes, Receiving Tubes, Pickup Devices, Power Tubes, Cathode Ray Tubes; Application Engineering, Electrical Equipment Design, Manufacturing Engineering, and in Glass Engineering.

In submitting information concerning your background, phone collect to Westinghouse Electronic Tube Division, Elmira 9-3611 and ask for Robert M. Jarrett in Department W21. (After 5 p.m. or weekends phone collect Elmira 9-2360.) If you prefer, write a letter attention above person and Dept., giving basic information, and ask any questions you wish.

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THE AMATEUR SCIENTIST

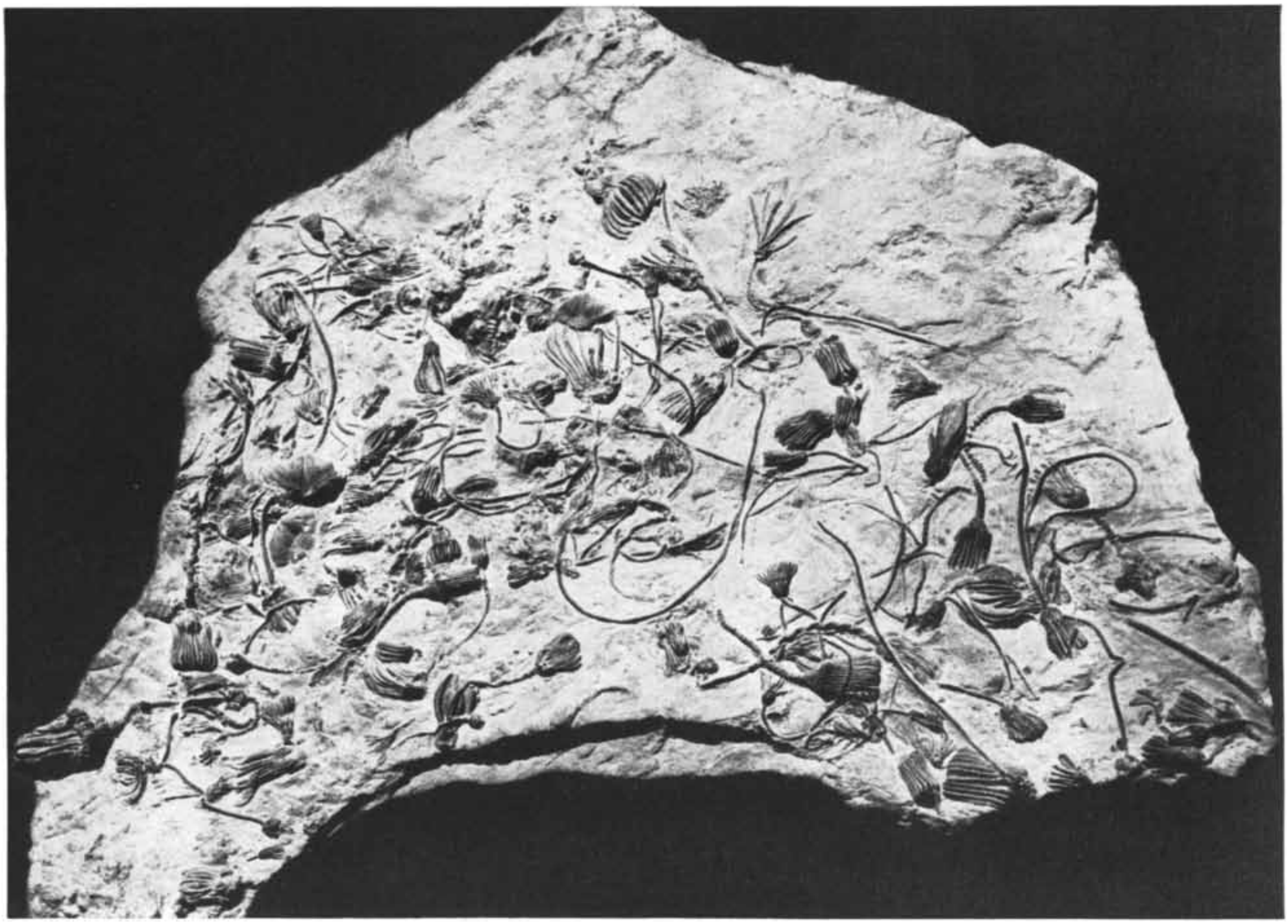
Fossil Starfish from Iowa and a British Van de Graaff

Long after bookworms have devoured the last trace of Blue Boy, the wonder hog of Phil Stong's *State Fair*, the fame of certain other native animals of Iowa will live on in museums all over the world. And they will give a touch of immortality to a small village whose name is unknown even to most Iowans, as well as to a farmer whose name is similarly unsung in his own state, though it is already recognized in museums of London, Paris, New York and Capetown. The village is LeGrand, population 396. The farmer is B. H. Beane, an amateur paleontologist. His distinction is that from a rock quarry near LeGrand he has unearthed fossils of echinoderms, 300 million years old, which constitute one of the world's prized collections of ancient sea animals.

Echinoderms flourish in warm, shallow seas. They include sea urchins, starfish, sea lilies, sand dollars and related animals with external skeletons composed of small, limy plates held together by soft tissue. Echinoderms evolved some 400 million years ago and reached the zenith of their biological vigor about 100 million years later.

During that period Iowa was an ooze at the bottom of a vast inland sea. The sea has washed over much of the U. S. midwest on at least eight occasions during the past billion years. Geologists do not agree on the precise cause of the periodic flooding. But many details concerning its frequency, extent, duration and associated climate have been explained by analysis of the sediments laid down by the water and fossils trapped in the resulting rock.

In general each period of flooding followed an interval of crustal unrest during which the earth was disturbed by volcanic action and mountain building accompanied by the accumulation of



Limestone slab from Iowa quarry contains fossil crinoids of several varieties glacial ice on the land. In the period of upheaval the midwest stood above sea level. Gradually the crust settled down, erosion rounded off the mountains, the glacial belt retreated to the north and eventually the planed-down midwest area fell below the sea level again. Then for millions of years life teemed in the balmy climate. So each of these cyclic periods in the history of our continent is marked in the rocks by the fossil remains of plants and animals which rose to dominance and flourished until buried by a new upheaval.

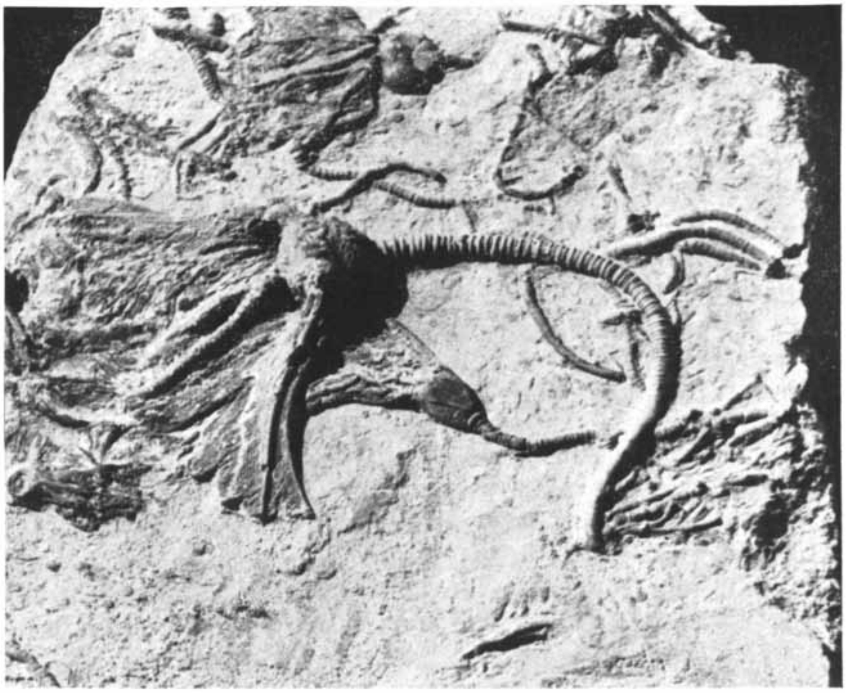
Half a billion years ago trilobites, primitive three-lobed marine animals resembling the modern horseshoe crab, populated the waters on Iowa in immense numbers. The fishes followed 200 million years later. Another 200 million years saw the rise of dinosaurs. Other organisms similarly held the center of the stage at other periods. One of these was a representative of Mr. Beane's echinoderms: the sea lily, or crinoid. The echinoderms, immediate successors in the evolutionary chain to the coelenterates (which include jellyfish, sea anemones and hydra), developed a remarkable skeleton, a nervous system, a vascular system, a digestive tube distinct from the body cavity and a sexual mode of reproduction.

Echinoderms typically have a radially symmetrical form, as in the starfish. In addition to the rayed structure, sea lilies are provided with a stalk which extends down from the center of the body to a rootlike structure at the lower end which enables the animal to grasp the bottom. Its petal-like arms wave continuously in search of food, and any particles encountered are conveyed down a groove to the mouth at the center.

After death the soft tissues binding the skeleton disintegrate, and water currents scatter the minute plates over the bottom, where they are usually crushed beyond recognition by the weight of accumulating debris. During the mid-Mississippian period some 300 million years ago, often called "the age of echinoderms," a great deal of limestone was formed by this process, and in some midwestern localities the beds are nearly half a mile thick, interrupted only occasionally by veins of shale or sandstone marking intervals when the inland sea temporarily withdrew.

Until the discovery of the LeGrand

B. H. Beane's prize discovery: The largest colony of fossil echinoderms ever found



A complete fossil crinoid, one of the rarest specimens of its kind

fossils, few paleontologists had ever seen a complete fossil specimen of a crinoid. But under certain conditions—*e.g.*, quick burial under a thin layer of silt which excludes oxygen and bacterial invasion—the soft tissue of a crinoid may be replaced by deposits of calcium and magnesium compounds. These conditions were met in a remarkable way in a small area of what is now a rock quarry about a half-mile north of LeGrand. There the first major deposit of crinoids was discovered 75 years ago.

"This quarry," writes Beane, "has served for more than a century as a major source of stone used in the construction of the Iowa buildings and highways. The Kinderhook beds at LeGrand are an outcrop of the Hampton formation. Descriptions of crinoid fossils discovered here have appeared in geological literature since 1890. Fragments of individual fossils were discovered in the vicinity by James Hall, a New York State geologist, in 1858. But the first really productive deposit was uncovered 40 years later, when workmen operating on one of the rock ledges near the Iowa River in the south half of the quarry came upon a circular colony of echinoderms, mostly crinoids, at a depth of about 20 feet. Crinoids are gregarious animals, and hundreds were recovered from the deposit in excellent preservation. Evidently the colony was killed quickly—perhaps a slide of some sort roiled the bottom and they suffocated—because all of the specimens are found in a single zone of the rock. The stems lie in random directions, indicating that the colony lived in still water.

"This discovery created quite a stir among scientists of the day, and during the next decade several of the nation's foremost paleontologists and geologists visited LeGrand. They were the idols of my boyhood. I pestered them with endless questions and they answered with inexhaustible patience. I became a fossil collector and have been at it ever since."

After the first deposit was picked clean of fossils, pickings were lean for 40 years. "You locate crinoids," says Beane, "by examining the edge of the rock for a fossil outcrop. From the turn of the century until 1931 I must have examined a thousand tons of loose rock as well as keeping a close eye on the entire quarry face. About one rock in 500 would turn out to be fossiliferous, and not more than 1 or 2 per cent of these yielded interesting specimens.

"Then one day in 1931 a blast uncovered the edge of a spectacular colony of crinoids about 100 feet from the initial find. It was somewhat smaller, a lens-shaped deposit about 15 feet across, but the specimens were in a state of almost perfect preservation. Doubtless many choice fragments loosened by the blast went to the rock crusher before I got on the job. But even so, scores of museums now own beautiful specimens from this deposit. From then on I kept continuous watch of every square inch of quarry face in the near vicinity as it was un-

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Los Alamos Scientific Laboratory has completed arrangements with the University of New Mexico for the establishment of a Graduate Residence Center at Los Alamos. This program will provide the opportunity for employees and residents to meet all of the requirements for the master's degree in the physical sciences and engineering (including Nuclear Engineering) by attendance at evening classes. Some of these courses are taught by Laboratory personnel outstanding in their fields.

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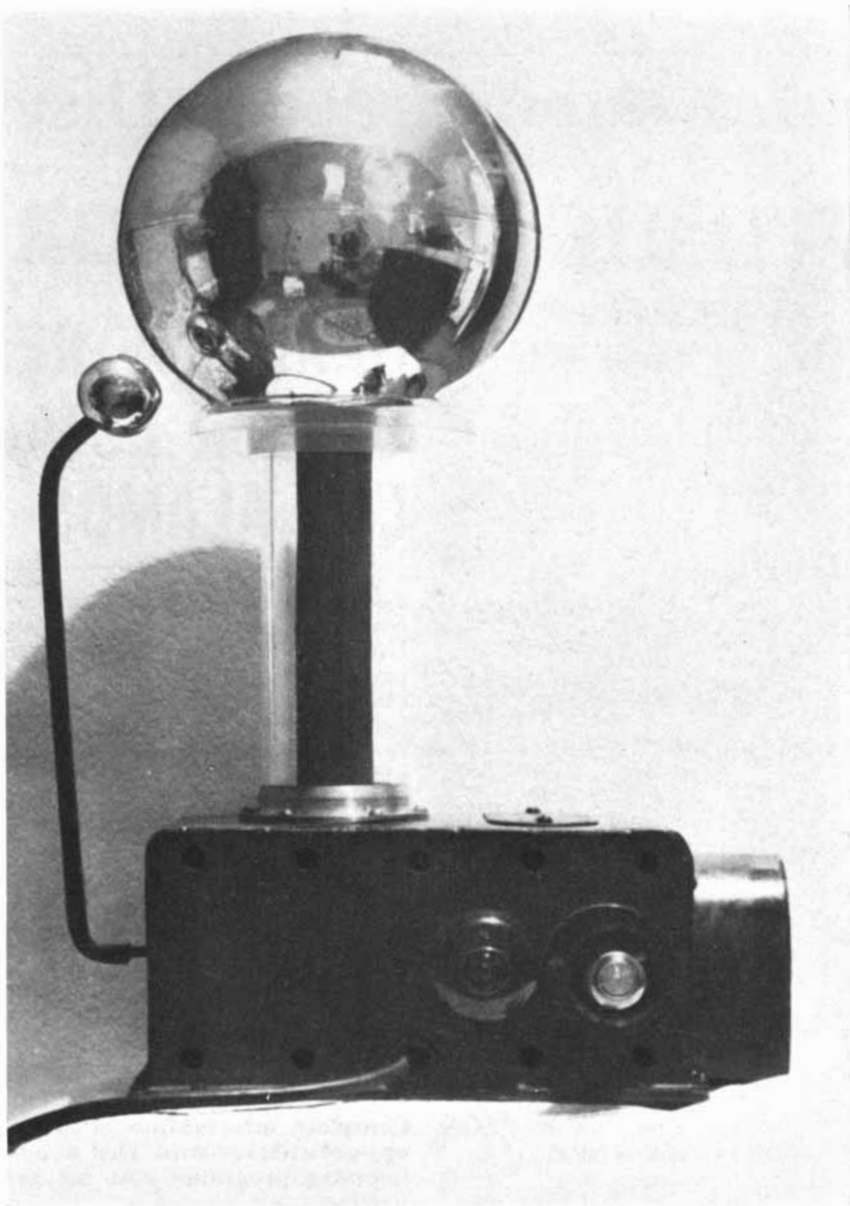

Van de Graaff generator built by F. J. Hedley of Lancaster, England

covered. The scrutiny paid off in 1933 with a truly big discovery. Evidence of specimens appeared in the familiar zone at a point about 50 feet from the colony discovered in 1931.

"The quarry owner generously agreed to work out the slab by hand, which proved to be an expensive undertaking because the fossiliferous zone was situated 25 feet below the surface of the ledge. The overburden was carefully drilled and shot away, after which the slab was removed in sections of various sizes about two feet thick. The colony measured more than 20 feet in diameter, and its full removal took four years.

"The sections were transported to my back yard, where I have an open-air shop equipped with a strong bench, block and tackle and a low stool. The preparation of the specimens for display is as simple as the tools with which the work is accomplished. In addition to the workbench, you need only a geologist's or a stonemason's hammer, a toothbrush and a fine needle gripped in a pin vise.

"Examination of the edge shows the thin horizon, or bedding plane, in which the fossils are located. After the section is worked down to within a few inches of the fossils on each side, the slab is split at the critical horizon by tapping the edge with the sharp face of the hammer. Eventually the tapping will open a small crack. A magnifying glass is useful for locating the cleavage zone, and some workers mark it with a lead pencil line before attempting to make the split. The

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AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE art of hitting accurately with the hammer is easily mastered with practice. Fine nails, which serve as wedges, are then driven partly into the crack every half inch around the slab. Successively heavier nails are used to widen it until the slab parts. With luck you get a clean separation. Most of the fossils will cling to one slab, the opposite half showing matching depressions. Invariably fragments of the limestone matrix cling to some specimens, obscuring the fine detail or even large portions of the body. Removing the matrix can be a long and tedious job. Fortunately it is usually softer than the specimen, and some of it can be scrubbed away with a moistened toothbrush. When the toothbrush has done its work, the remaining part of the matrix is picked away with the sewing needle. Depending on the size of the slab and how cleanly it split, the needle job will require from three hours to three months. I have been working on one exceptionally large specimen off and on during the past 30 years.

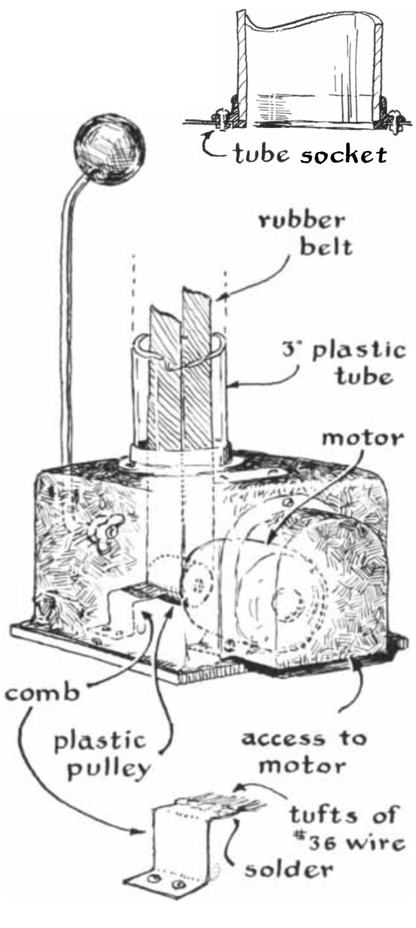
"It is evident that echinoderm fossils are not easily come by, and until 20 years ago I kept every specimen I found. I was under the illusion that the satisfaction one derived from the hobby increased in proportion to the size of his collection. Then, at a geologist's suggestion, I visited the Morrill Hall Museum at the University of Nebraska. There I met Dr. Erwin H. Barbour, the curator, and showed him a couple of my crinoids. After examining them, he asked if I would make some specimens available to the University. He listened patiently as I explained how I felt about my collection and then said: 'Mr. Beane, we should have a heart-to-heart talk. You own hundreds of exceedingly rare fossils, and it is wrong for you to keep them in your little village. They should be widely distributed to universities and museums for students to study and for the public to admire.' By the time our discussion ended I understood, for the first time, the obligation under which the amateur collector works and the contribution he can make to science.

"Shortly afterward I presented Dr. Barbour's museum with some items in my collection, including a slab which measured two by three feet and contained more than 200 crinoids and stems. He was delighted, and within a short time published an illustrated description of the fossils, in which I received credit as the collector. My mail was soon full of requests for collections from various institutions. About half of the universities in the U. S. and many museums abroad now own LeGrand crinoids.

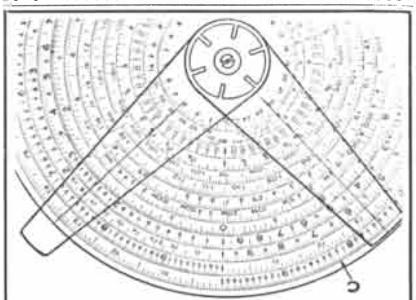
"I must confess that the resulting expressions of gratitude have far outweighed the satisfaction which came with owning a ton or so of rock. Raymond C. Moore, the state geologist of Kansas and head of the geology department of the State University, visited me a few years ago and after examining my remaining specimens said: 'Mr. Beane, I must hand you a bouquet. You have put the little town of LeGrand on the map of the world where many larger communities will never appear.'

"Perhaps the greatest thrill of my collecting career came in 1930. I split a slab measuring approximately three by five feet. To my astonishment I counted 183 perfect starfish, along with 12 sea urchins, two trilobites and a sea lily! According to Charles Schuchert of Yale University, it was the greatest find of fossil starfish ever made. This is the specimen on which I have worked so long.

"I must mention one example of the privileges that open to an amateur who learns to share the fruits of his hobby. In 1937 I was invited to collaborate with Lowell R. Laudon of the University of Tulsa in a study of LeGrand crinoids and to publish with him a comprehen-



Van de Graaff motor assembly



sive description of all our local species. I was given the additional honor of naming 11 new species in recognition of friends. I named one of them for George F. Kirby, owner of the LeGrand quarry, whose generosity enabled me to enjoy a lifelong hobby."

F. J. Hedley, of Lancaster in England, submits an interesting version of the Van de Graaff electrostatic generator that was described in this department in April, 1955. His machine demonstrates that a resourceful amateur can sometimes improve on the performance of a design by substituting his own materials.

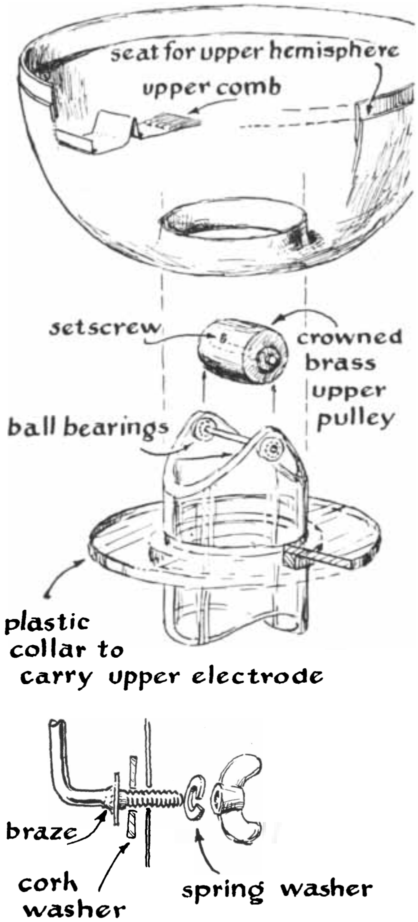
The version of the Van de Graaff machine described here last year has a rubber belt which runs between a pair of pulleys, one made of metal and the other of polyethylene. They are enclosed in insulated housings that serve as high-voltage terminals. Static electricity, generated frictionally between the belt and the polyethylene pulley, is transported by the belt to the metal pulley, where the charge is transferred to the terminal by a comb of metal points. The work expended in moving the charge up the belt increases the voltage. Machines of this type employing belts an inch wide and a foot or so long can generate a continuous current of several microamperes at potentials up to 100,000 volts. They permit scores of fascinating experiments, particularly those involving gas discharge tubes.

A number of amateurs have requested more specific information about the construction details of the "baby" Van de Graaff. Hedley writes the following report on his machine.

"I have now made two Van de Graaffs, the first substantially the same as the one described in 'The Amateur Scientist.' The second machine is twice as large [*see photograph on page 160*]. It performs quite satisfactorily, giving bright intermittent sparks about four inches long and weaker ones six inches or more in length when one's hand is brought near the underside of the terminal.

"The machine is supported by a housing which encloses the motor and lower comb assembly. The housing consists of 1/16-inch sheet steel welded to form a rectangular box measuring six inches high, six inches wide and eleven inches long, the base being of 3/16-inch steel. A detachable cover at one end provides access to the motor. One side can also be removed for exposing the pulley, comb assembly and belt.

"The belt is powered by a series-wound motor (Royal Air Force war sur-

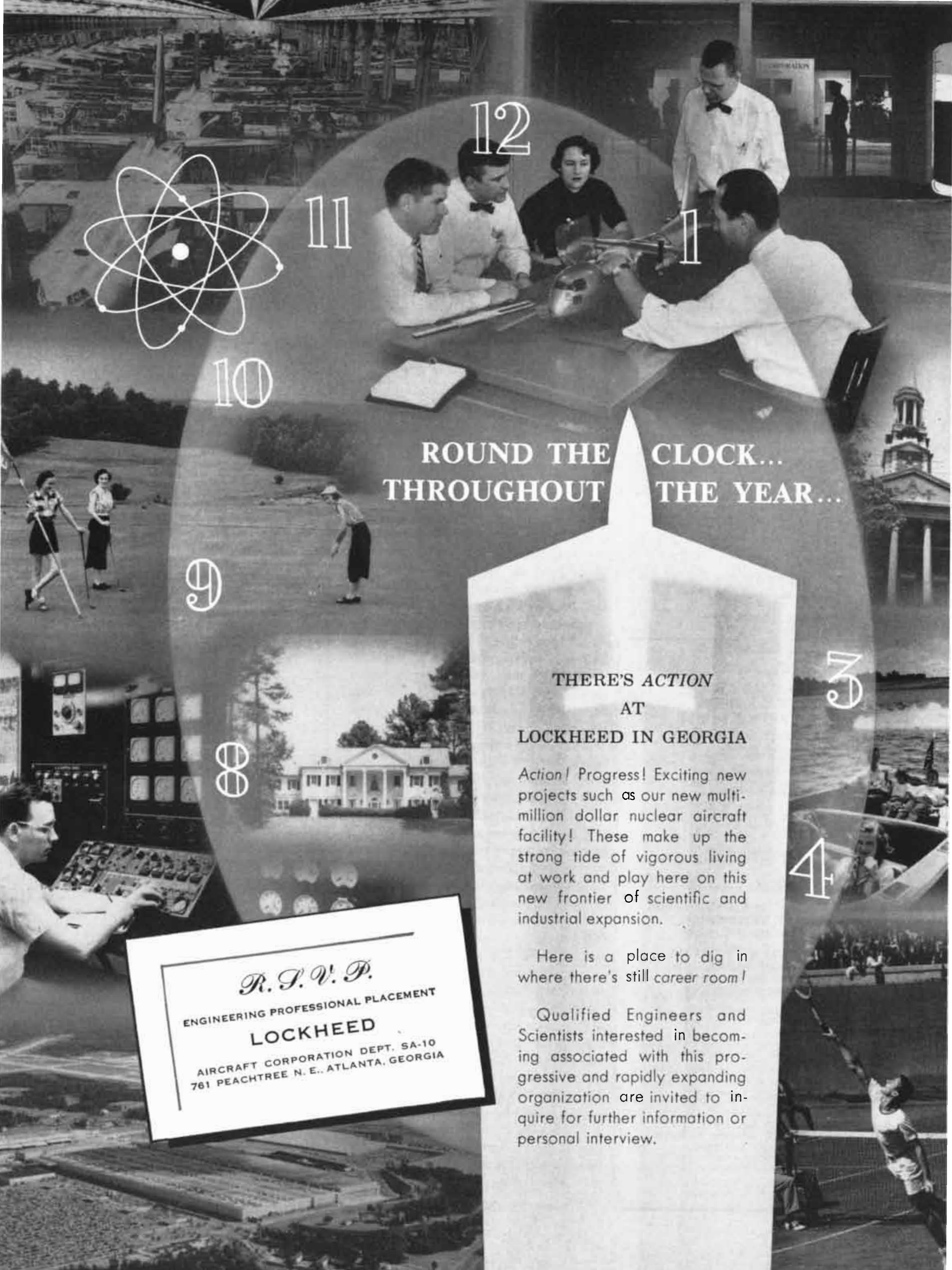


Upper terminal of Van de Graaff

plus) which runs under full load at a speed of 6,000 revolutions per minute. This is fitted with a pulley machined from polyethylene, one and a quarter inches in diameter and one and three quarters inches long. It is crowned slightly and makes a driven fit with the shaft. A wooden pulley of the same size with a jacket of polyethylene would work equally well. The jacket could be covered with a layer of polyethylene friction tape of the kind now sold by dealers in electrical supplies, or it could be made of a cylindrical section cut from one of the small polyethylene bottles in which cosmetic preparations are commonly sold.

"The lower comb assembly consists of a bracket made of 1/16-inch sheet copper, an inch and five eighths wide, to which six tufts of number 36 copper wire are soldered at one end. The wires are spread out to form an even row and clipped straight at the ends [*see drawing on page 162*]. The brush assembly is bolted to the base plate and adjusted to bring the wire comb slightly above the center of the pulley.

"A switch for operating the motor and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a small neon bulb are mounted in the fixed side of the housing. The lamp glows when the machine is operating properly. Originally I mounted it on top of the housing but lost several bulbs when they were perforated by high-voltage sparks!

"A tube of clear plastic, three inches in diameter and 18 inches long, which makes a push fit with a polished pipe flange bolted to the housing, supports the upper terminal. The inner threads are filed from the flange prior to assembly. The upper end of the tubing is beveled, and two holes are drilled on the diameter to receive a pair of ball bearings. A ¼-inch shaft turns in these and supports a crowned brass pulley which matches the size of the lower pulley. The pulley makes a sliding fit with the shaft and is anchored with a set screw. This arrangement provides for easy disassembly when changing the belt.

"The high-voltage terminal consists of a nine-inch spherical copper float of the type commonly used in industrial plumbing. It is split on the diameter by means of a thin hack-saw blade. A flat, narrow ring is soldered to the inner edge of the lower half, on which the upper half makes a snug fit and clean joint. A two-inch hole is cut in the center of the lower hemisphere and the metal is worked into a doughnut shape by means of a rawhide hammer and rounded anvil. A cylindrical collar is then soldered to the inner face of the re-entrant edge for an easy fit with the plastic tubing. The upper collecting comb is bolted to a lug soldered to the inner surface of the lower hemisphere. A kink in the bracket provides for final adjustment relative to the center of the upper pulley.

"A disk of ¼-inch plastic, six inches in diameter, serves as a platform for supporting the upper terminal. A hole is cut in the center for admitting the plastic tube, to which the disk is fastened by one of the quick-drying plastic cements. In addition to supporting the terminal, the disk minimizes corona discharge from the bottom of the terminal. A discharge gap is provided at the side of the machine, as shown in the drawings.

"These machines are sensitive to the high humidity prevalent in England, and for reliable operation I found it necessary to install a 50-watt heating element inside the motor housing. My next project will be a Van de Graaff of the type in which the charge is sprayed onto the belt at the lower pulley by a high-voltage source. I should appreciate any constructional tips that amateurs who have built such machines would care to pass along."

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OCTOBER, 1956

BIBLIOGRAPHY

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

THE FUEL SITUATION

COAL RESOURCES OF THE UNITED STATES. U. S. Geological Survey Circular 293, November, 1953.

CONCERNING ESTIMATES OF POTENTIAL OIL RESERVES. L. G. Weeks in *Bulletin of the Association of Petroleum Geologists*, Vol. 34, No. 10, pages 1,947-1,953; October, 1950.

TISSUE CULTURE AND CANCER

THE CULTIVATION OF ANIMAL AND PLANT CELLS. Philip R. White. The Ronald Press Company, 1954.

METHODS OF TISSUE CULTURES. Raymond C. Parker. Paul B. Hoeber, Inc., 1950.

TISSUE CULTURE TECHNIQUE IN PHARMACOLOGY. Edited by Roy Waldo Miner in *Annals of the New York Academy of Sciences*, Vol. 58, Article 7, pages 971-1,326; 1954.

A NATIONAL RADIO OBSERVATORY

AN INTRODUCTION TO ASTRONOMY. Robert H. Baker. D. Van Nostrand Co., Inc., 1952.

HARVARD'S NEW RADIO TELESCOPE. David S. Heeschen in *Sky and Telescope*, Vol. 15, No. 9, pages 388-390; July, 1956.

RADIO ASTRONOMY. Bernard Lovell and J. A. Clegg. John Wiley & Sons, Inc., 1952.

THE GENE

LIFE OF MENDEL. Hugo Iltis. W. W. Norton & Company, Inc., 1932.

ON THE EVOLUTION OF BIOCHEMICAL SYNTHESES. N. H. Horowitz in *Proceedings of the National Academy of Sciences*, Vol. 31, pages 153-157; June, 1945.

WHAT IS LIFE? Erwin Schrödinger. Cambridge University Press, 1948.

MESONIC ATOMS

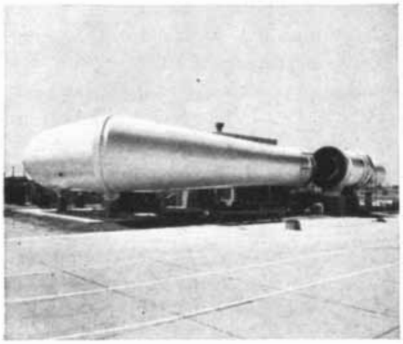
ATOMIC AND NUCLEAR PHYSICS. Robert S. Shankland. The Macmillan Co., 1955.

MESONS, VOLUME II. H. Bethe and F. deHoffmann. Row, Peterson & Company, 1955.

NORTHROP WIND TUNNEL

New Unit Installed at Hawthorne, Calif.

(HAWTHORNE, CALIF.) Climaxing many months of planning and construction, Northrop Aircraft's high-performance wind tunnel has been installed in the



company's new engineering and science center at Hawthorne, California. The immense rectangular shaped structure is 200 feet long by 65 feet wide, and is 33 feet in diameter in the settling chamber. Steel components alone weigh over 300 tons.

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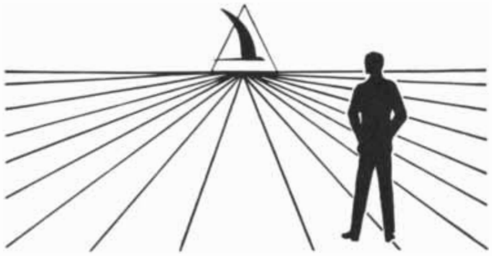

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PLEASURE CENTERS IN THE BRAIN

THE BEHAVIOR OF ORGANISMS: AN EXPERIMENTAL ANALYSIS. B. F. Skinner. Appleton-Century-Crofts, Inc., 1938.

DIENCEPHALON. Walter Rudolf Hess. Grune & Stratton, Inc., 1954.

PSYCHOSOMATIC DISEASE AND THE "VISCERAL BRAIN": RECENT DEVELOPMENTS BEARING ON THE PAPEZ THEORY OF EMOTION. Paul D. MacLean in *Psychosomatic Medicine*, Vol. 11, pages 338-353; 1949.

ARTIFICIAL LIVING PLANTS

AUTOMATA STUDIES. Edited by C. E. Shannon and J. McCarthy. Princeton University Press, 1956.

THE GENERAL AND LOGICAL THEORY OF AUTOMATA. John Von Neumann in *Cerebral Mechanisms in Behavior: The Hixon Symposium*, edited by L. A. Jeffress. John Wiley & Sons, Inc., 1951.

MAN VIEWED AS A MACHINE. John G. Kemeny in *Scientific American*, Vol. 192, No. 4, pages 58-67; April, 1955.

THE LANGUAGE OF BIRDS

CHARACTERISTICS OF SOME ANIMAL CALLS. P. Marler in *Nature*, Vol. 176, No. 4470, pages 6-8; July, 1955.

COMMENTS ON 'THE BIRD FANCYER'S DELIGHT': TOGETHER WITH NOTES ON IMITATION IN THE SUB-SONG OF THE CHAFFINCH. W. H. Thorpe in *Ibis*, Vol. 97, No. 2, pages 247-251; April, 1955.

THE PROCESS OF SONG LEARNING IN THE CHAFFINCH AS STUDIED BY MEANS OF THE SOUND SPECTROGRAPH. W. H. Thorpe in *Nature*, Vol. 173, No. 4402, pages 465-469; March, 1954.

THE AMATEUR SCIENTIST

THE CRINOID FAUNA OF THE HAMPTON FORMATION AT LEGRAND, IOWA. L. R. Laudon and B. H. Beane in *University of Iowa Studies: Studies in Natural History*, Vol. 17, No. 6; December, 1937.

MODERNITY IN PALEOZOIC STARFISHES. Charles Keyes and B. H. Beane in *The Pan-American Geologist*, Vol. 62, No. 3, pages 197-212; October, 1934.

ELECTROSTATIC SOURCES OF IONIZING ENERGY. J. G. Trump in *Transactions of the American Institute of Electrical Engineers*, Vol. 70, Part 1, pages 1,021-1,027; 1951.

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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 Y	L Y	L	L Y	L Y	L	L	L	L	L Y	L Y
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	H	H	H	H	H	H
MICROWAVE TUBES—Tube Development and Manufacture (Traveling Wave—Backward Wave—Magnetron)	H		H	H		H	H		H	H		H	H
GAS, POWER AND PHOTO TUBES—Photosensitive Devices—Glass to Metal Sealing—UHF and VHF—Power		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—Automation—Transistorization	W C	W C X	W C X	W C X	W C	W C X	W C X	W C X	W C X	W 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—Information Handling—Displays	M C	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—Specialized Military Systems—Microwave—Aviation—Audio—Propagation Studies		C	C	C		C	C	C	C	C			
MISSILE ELECTRONICS—Systems Planning and Design—Radar—Fire Control—Shock Problems—Servo Mechanisms	M	M X	M X	M X	M	M	M X	M	M X	M X			
COMPONENTS—Transformers—Coils—TV Deflection Yokes (Color or Monochrome)—Resistors—Ferrites (Material and Parts)		C	Z C	Z C	C	Z C	Z C	C	C	C		Z C	Z C
• SYSTEMS APPLICATION *(Evaluation and Planning—Design and Development—Modification—Specification)*													
MISSILE TEST INSTRUMENTATION (Data Acquisition and Processing)—Radar—Telemetry—Timing—Communications—Optics—Computers	F	F S	F S	F S	F S	F S	F S	F S	F S	F S			
RADAR—Airborne—Surface—Shipboard—Sonar—Fire Control	F	F S	F S	F S	F S	F S	F S	F S	F S	F S			
COMMUNICATIONS—Radio—HF—VHF—UHF—Microwave—Telephone—Teletype—Telegraph Terminal Equipment—Wave Propagation	F	F S I	F S I	F S I	F S	F S	F S	F S	F S	F S			
• MACHINE DESIGN Mechanical and Electrical—Automatic or Semi-Automatic Machines		L	L		L	L H Y	C H Y		L	L			

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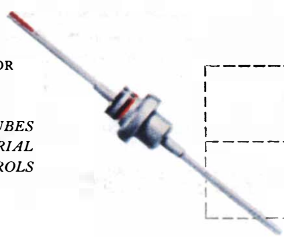

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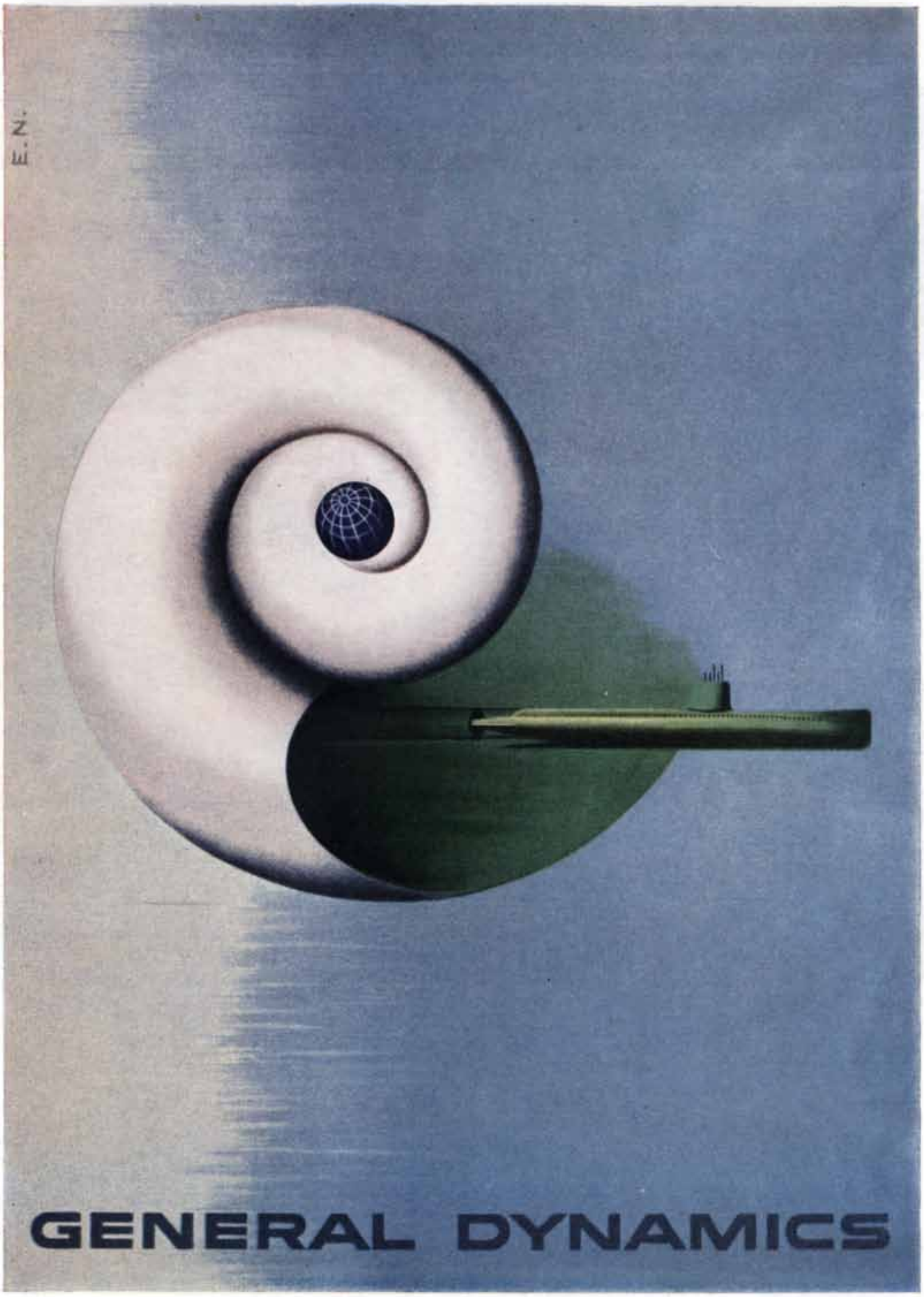

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