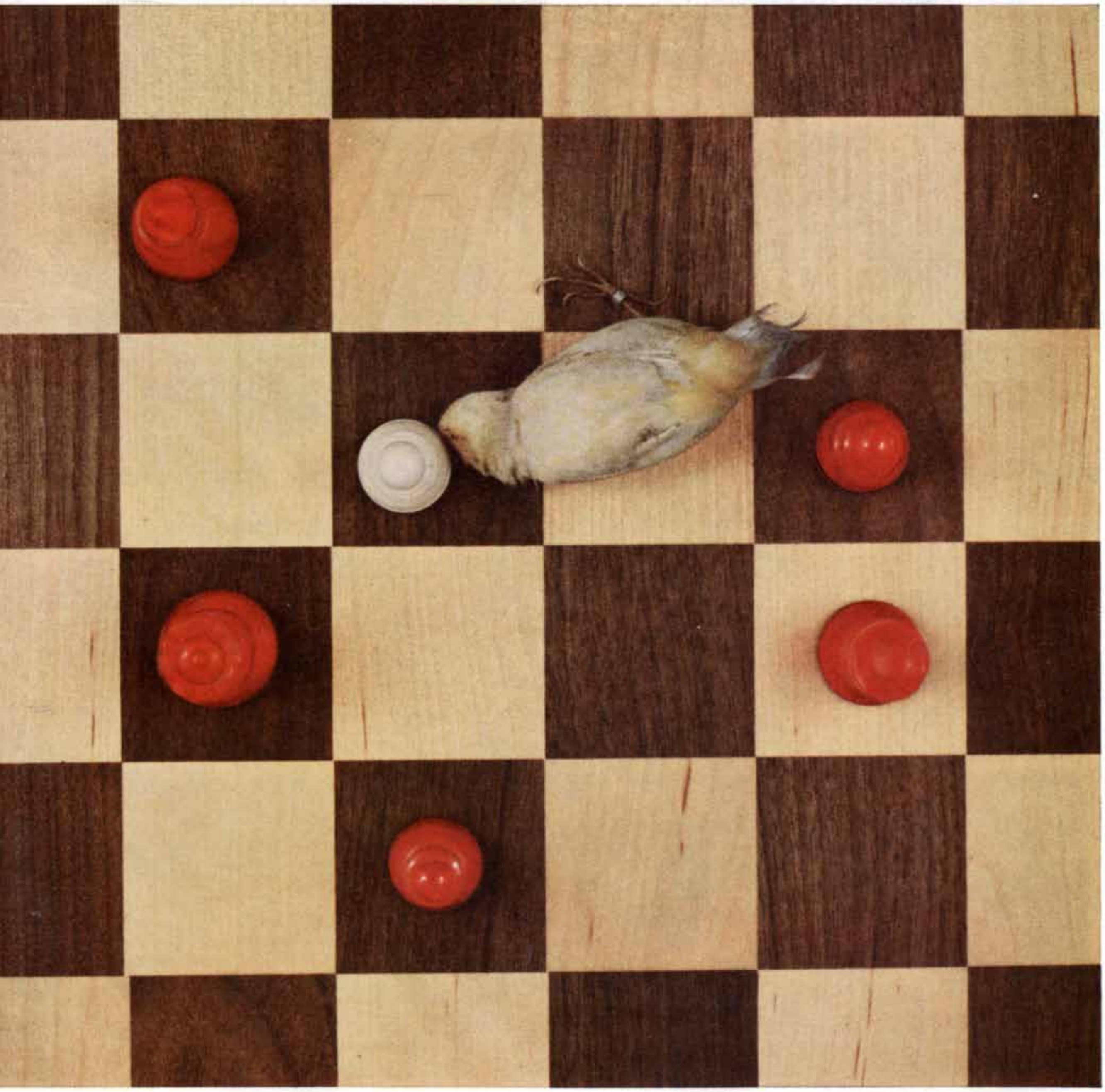
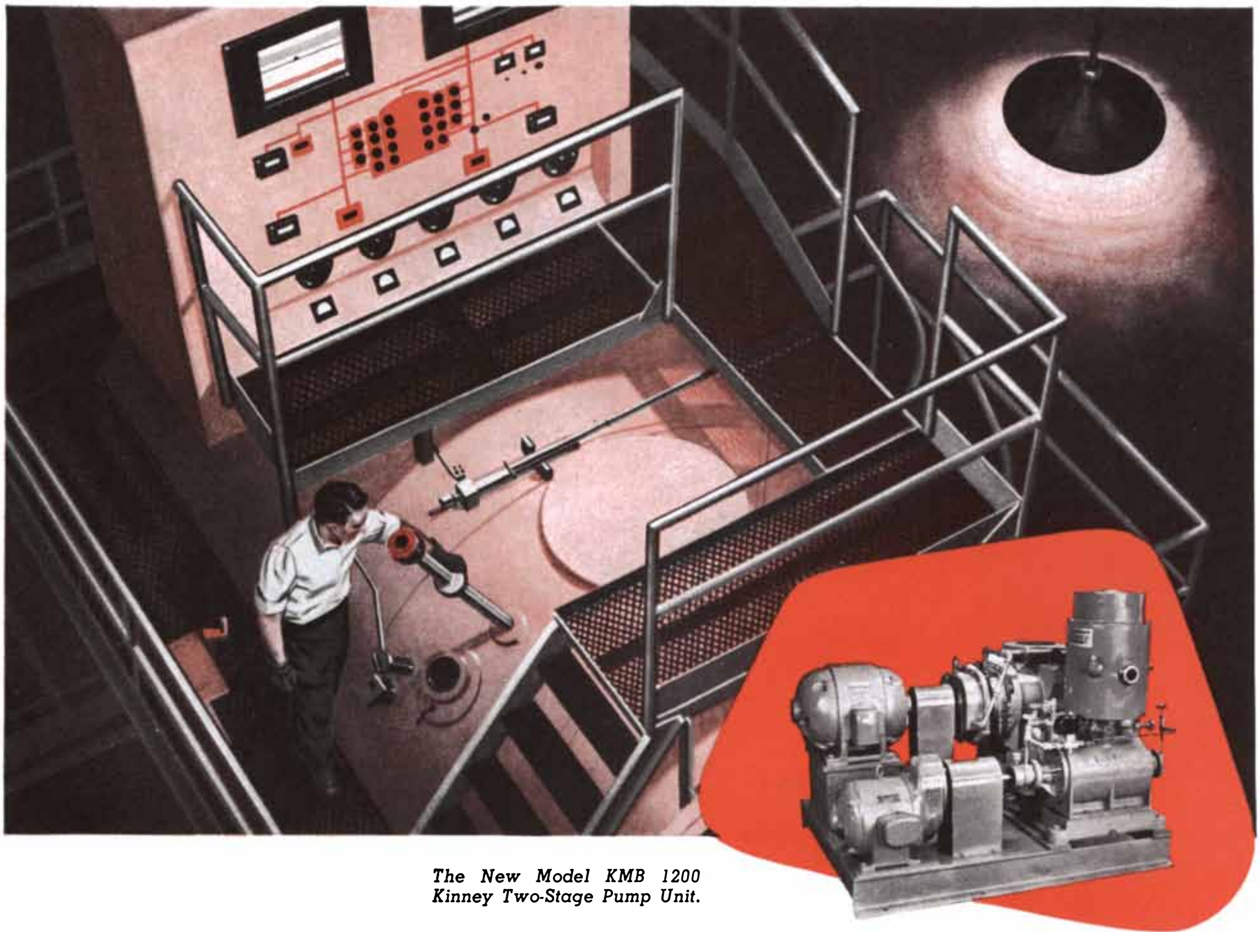
SCIENTIFIC AMERICAN



REASON IN THE CANARY

FIFTY CENTS

June 1955



The New Model KMB 1200
Kinney Two-Stage Pump Unit.

Secrets of Metallurgy, Unsolved for Centuries, Now Yours with

MODERN VACUUM PROCESSING

DUDCO DIVISION
Hazel Park, Mich.
Dual-Vane Hydraulic Pumps, 3 to 120 gpm; Fluid Motors, 7 to 140 hp; 2000 psi operation. Piston-Type Pumps for 5000 psi.

HYDRECO DIVISION
Cleveland, Ohio
Gear-Type Hydraulic Pumps, 3 to 120 gpm; Fluid Motors, 3 to 52 hp; Cylinders; Control and Auxiliary Valves; 1500 psi.

WATERTOWN DIVISION
Watertown, N. Y.
Railroad air brake valves for freight and passenger equipment, STRATOPOWER Hydraulic Pumps for Aircraft, to 3000 psi.

KINNEY MANUFACTURING DIVISION
Boston, Mass.
Rotating Plunger and Heliquad Liquid Handling Pumps, to 3000 gpm. Vacuum Pumps, 0.2 micron, evacuate 1800 cfm.

AURORA PUMP DIVISION
Aurora, Ill.
Liquid Handling Pumps, Centrifugals and deep well Turbines, 7000 gpm, 500 ft. heads. Turbine-type, 150 gpm, 600 ft. heads. Condensate Return Units.

Air and gases encourage many metals to misbehave in furnace or retort and stubbornly resist purification or amalgamation. But, in a vacuum, these same capricious metals become orderly, well-behaved and thoroughly responsive to your wishes. Thus, has High Vacuum Processing with KINNEY Vacuum Pumps released thousands of potentials . . . made many new metals available . . . extended the usefulness of many common metals . . . and brought costs into realistic focus.

In many other fields, Kinney Vacuum Pumps help to make possible many things for modern living...TV Tubes, Audion Tubes, Electronic Equipment, Photoflash Bulbs, Fluorescent and Incandescent Lights. In the Refrigeration and Air Conditioning fields, Kinney Vacuum Pumps effect more complete evacuation of condensers to better charge equipment with Freon gas or other refrigerants.

Vacuum packing of foods, vacuum distillation of antibiotics and chemicals, and vacuum dehydration of blood plasma are but a few more in the long list of vital services Vacuum Processing contributes to the modern scene.

Just as Kinney Vacuum Pumps reach into the future . . . so do developments in other Divisions of The New York Air Brake Company contribute to industry, to the home, and to the nation. Three Divisions concentrate their facilities on advanced design Hydraulic Equipment . . . Gear, Dual-Vane and Piston Pumps . . . Gear and Dual-Vane Motors . . . Single, Double-Acting and Telescopic Cylinders . . . Control and Auxiliary Valves.

America also finds the answer to liquid handling problems in Aurora and Kinney Pumps, for in the broad selection of types and sizes, the *right* pump in the *right* size to do the job at the *right* cost is available.

Write for descriptive literature and engineering information to help you improve your product, speed production and lower costs.

THE NEW YORK AIR BRAKE COMPANY

230 PARK AVENUE • NEW YORK 17, N. Y.

INTERNATIONAL SALES OFFICE, 90 WEST ST., NEW YORK 6, N. Y.

THE CHALLENGE OF CYANOETHYLATION

NEW CHAPTERS are currently being written about the process of cyanoethylation. It is a story about research that began years ago. The men who are writing it are meeting the challenge of the countless derivatives that may be obtained when almost any material containing a labile hydrogen is reacted with acrylonitrile.

Lignin, for example, with its phenolic hydrogen and other reactive centers, is susceptible to cyanoethylation. But the question of what properties might now be developed from the altered molecular structure containing a reactive nitrile group opens a broad new field of experimentation and study.

Some day the answers to thousands of questions like these will be known. Perhaps the reaction of acrylonitrile with some of your materials will result in new and interesting products.

If your company *would like to experiment with acrylonitrile, you are invited to write on your letterhead to Monsanto, the Monomer Headquarters of America, for laboratory-size samples. Address Monsanto Chemical Company, Plastics Division, Dept. SA6, Springfield 2, Mass.*

MONSANTO

Nothing contained herein shall be construed as a recommendation to produce or use any product in conflict with existing patents.

SERVING INDUSTRY...WHICH SERVES MANKIND

LETTERS

Sirs:

In his fine article "The Ecology of Desert Plants" in your April issue, Frits W. Went expressed the view that competition between individuals of the same species of plants is distinctly rare in nature. For example, he stated, "Even in the dense forest there is little killing of the small and weak." While I do not wish to challenge his conclusions about the undesirability of warfare among humans, it is difficult for a forester to agree with his ideas about competition in stands of forest trees.

The competition between the trees of a forest stand is so fierce that, but for scavenging insects and fungi, the forest floor would soon become choked with the remains of trees that had succumbed in the struggle for existence. A very young natural forest is usually composed of thousands or tens of thousands of tree seedlings per acre. By the time most stands have reached the age of 100 years the number of trees has been reduced to no more than 200 trees per acre. This general observation was first made at least two centuries ago and has been verified repeatedly in almost every part of the world. It is true that the heavy losses that occur during the first few years in the life of a forest stand are caused more by biotic enemies and physical agencies of the environment than by factors directly related to competition between plants. However, once the crowns of the trees have closed together the rate at which an individual grows in height largely determines its prospect for survival. The laggards are gradually submerged and, after their crowns have been sufficiently reduced by natural pruning from below and abrasion from above, their ability to carry on photosynthesis diminishes so greatly that they die.

There are exceptional situations which conform to that which Went has incorrectly assumed to represent the general case. Some species, like lodgepole pine and balsam fir, have rather low inherent variability in height growth. If such species develop in exceedingly dense stands, all the trees are very slender, all slowly increase in height at a very uniform rate and only a relatively low percentage die. However, the majority of trees have sufficient intraspecific variability in height growth to enable the most vigorous to forge ahead and shade out their competitors even in the densest stands.

In his article Went contended that if growth in height were an adaptation useful in the struggle for survival "there would be an evolutionary tendency for . . . trees to become taller and taller." Probably the main reason why no such tendency exists is that growth in height eventually becomes a liability rather than an asset so far as survival is concerned. As the tree grows taller it becomes subject to rapidly increasing wind load, and such physiological processes as the transport of water to the foliage decrease in efficiency. As a result, the final survivors in the race for the sky gradually succumb, leaving openings in which new trees may compete among themselves. The vacancies left by losses sustained throughout the development of the forest vary enough in size and other characteristics to provide a wide variety of environmental conditions favorable to many different plant species, both woody and herbaceous. If this kind of variation in the environment is sufficiently great and if losses of older trees occur frequently enough, it is not difficult to account for the diversity of species referred to by Went. However, the variation in environmental conditions rather than any absence of competition accounts for the diversity.

Some forest trees exhibit the controlled germination observed by Went in desert annuals; the vast majority do not. During years when abundant crops of seed have been produced, tree seedlings usually germinate in riotous profusion throughout the forest. However,

Scientific American, June, 1955; Vol. 192, No. 6. Published monthly by Scientific American, Inc., 2 West 45th Street, New York 36, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer. Entered at the New York, N. Y., Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn.

Editorial correspondence should be addressed to The Editors, Scientific American, 2 West 45th Street, New York 36, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

Advertising correspondence should be addressed to Martin M. Davidson, Advertising Manager, Scientific American, 2 West 45th Street. New York 36, N. Y.

Subscription correspondence should be addressed to Circulation Manager, Scientific American, 2 West 45th Street, New York 36, N. Y.

Change of address: Please notify us four weeks in advance of change. If available, kindly furnish an address imprint from a recent issue. Be sure to give both old and new addresses, including postal zone numbers, if any.

Subscription rates for U.S.A. and possessions: 1 year, $5; 2 years, $9; 3 years, $12.50. Canada and Latin America: 1 year, $6; 2 years, $10; 3 years, $14. All other countries: 1 year, $8; 2 years, $12; 3 years, $16.

• Stymied by a

High-Temperature Barrier?

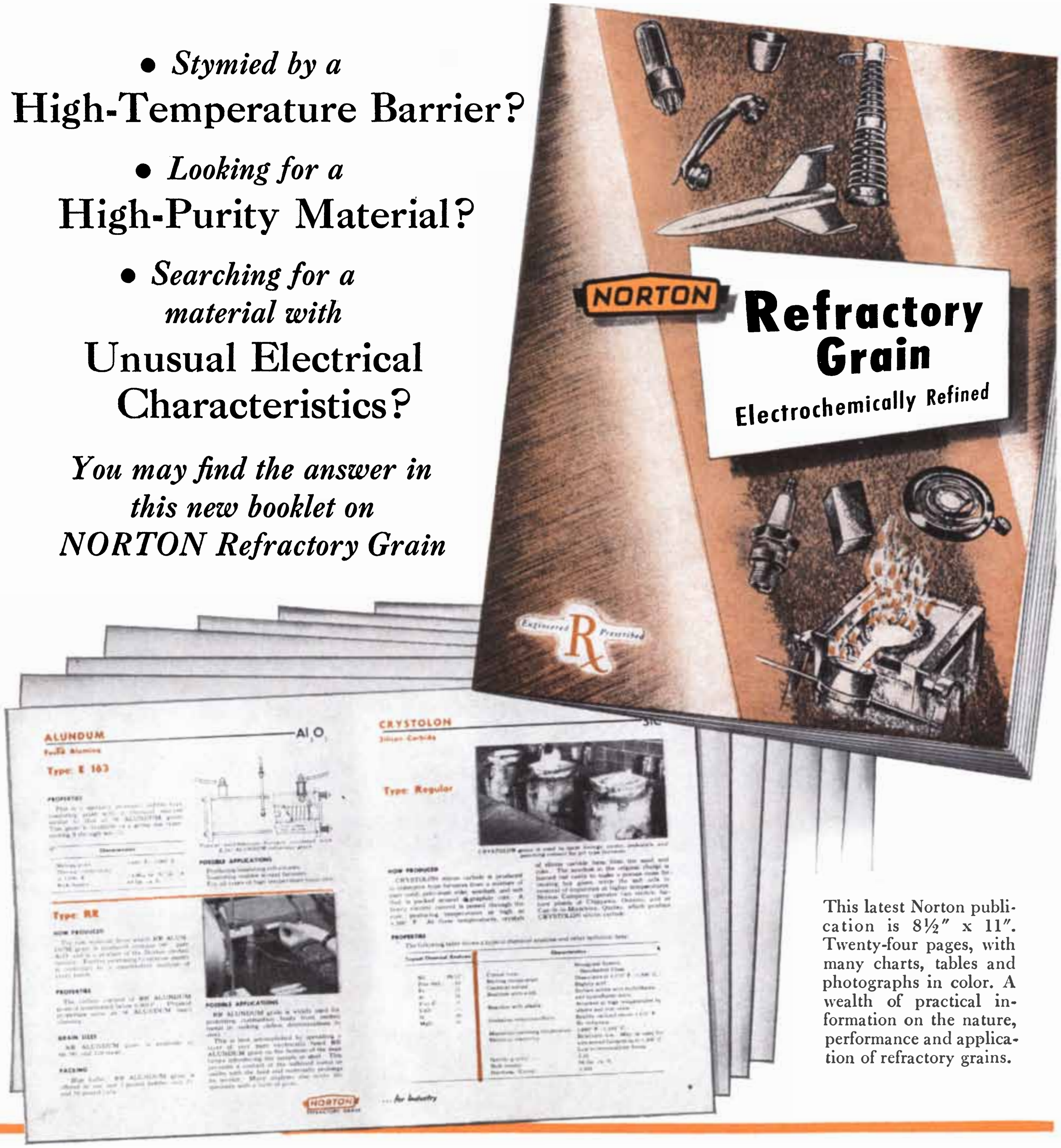
• Looking for a

High-Purity Material?

• Searching for a material with

Unusual Electrical Characteristics?

You may find the answer in this new booklet on NORTON Refractory Grain



This latest Norton publication is 8½" x 11". Twenty-four pages, with many charts, tables and photographs in color. A wealth of practical information on the nature, performance and application of refractory grains.

IF you're concerned with industrial processing involving temperatures ranging upwards to 4000°C and materials to contain your inferno — if you're looking for a high-purity material such as high-purity fused alumina for coating electronic heater filaments — if you're searching for a material with unusual electrical characteristics such as E 179 CRYSTOLON* Silicon Carbide for lightning arrestors — one of the many types of Norton Refractory Grain available may solve your problem.

This new booklet describes in detail Norton Refractory Grain — produced and purified in electric arc and high temperature resistance furnaces — which is helping industry to improve existing products and processes and to create new ones.

It's a valuable reference book with up-to-the-minute information on the chemical and physical characteristics of such materials as CRYSTOLON* Silicon Carbide, ALUNDUM* Aluminum Oxide, MAGNORITE* Magnesium Oxide, Fused Zirconia and Boron Carbide. In it you'll find data on how these materials are produced; their behavior under varying conditions; available grain size and applications.

These electrochemically refined materials may be just what you've been looking for to solve your problem. Write today for your free copy of "Norton Refractory Grain." NORTON COMPANY, Refractories Division, 545 New Bond Street, Worcester 6, Mass.

NORTON

REFRACTORIES

Engineered... ℞... Prescribed

Making better products... to make your products better

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries only those that happen to lodge in a very limited number of favorable spots have any chance of survival. All but a few perish during the first growing season. Only the seeds of a few specially adapted species are capable of surviving in a dormant condition for more than two growing seasons. Although many seeds of ordinary tree species land in spots where conditions do not allow germination, such dormant seeds are soon consumed by the voracious animal population of the forest floor and serve no useful purpose so far as perpetuation of the species is concerned. The kind of birth control observed by Went in desert annuals is the exception rather than the rule in less rigorous climates where forests form the dominant vegetation.

DAVID M. SMITH

School of Forestry
Yale University
New Haven, Conn.

Sirs:

It seems unfortunate that Frits W. Went chose to step outside the field of ecology in order to draw a moral from his desert plants. Though I cannot dispute his conclusion that mankind would be better off with more birth control and less war, nevertheless his desire to reach this conclusion seems to have led him into making some rather curious statements.

It is asserted that competition or the struggle for existence is a phenomenon of negligible importance in nature—apart from human warfare. It is true that cannibalistic species are relatively rare, but this is not to deny intraspecific competition. The benevolent forest giants of Java which did not kill their smaller companions after a period of 40 years are material for a very touching story, but are hardly representative of the give-and-take of survival in nature. One might have a better example to consider the number of seeds shed by an elm tree and the seedlings germinating therefrom in relation to the number of these seedlings which survive to maturity. It is true that one elm seedling will not bend over and nip its neighbor off at the base, but there is nevertheless competition between them; and when one considers the small proportion of these seedlings which do survive, it is evident that the competition is intense. When this competition results in differential survival, or selection, we have the raw material of which evolutionary change is made.

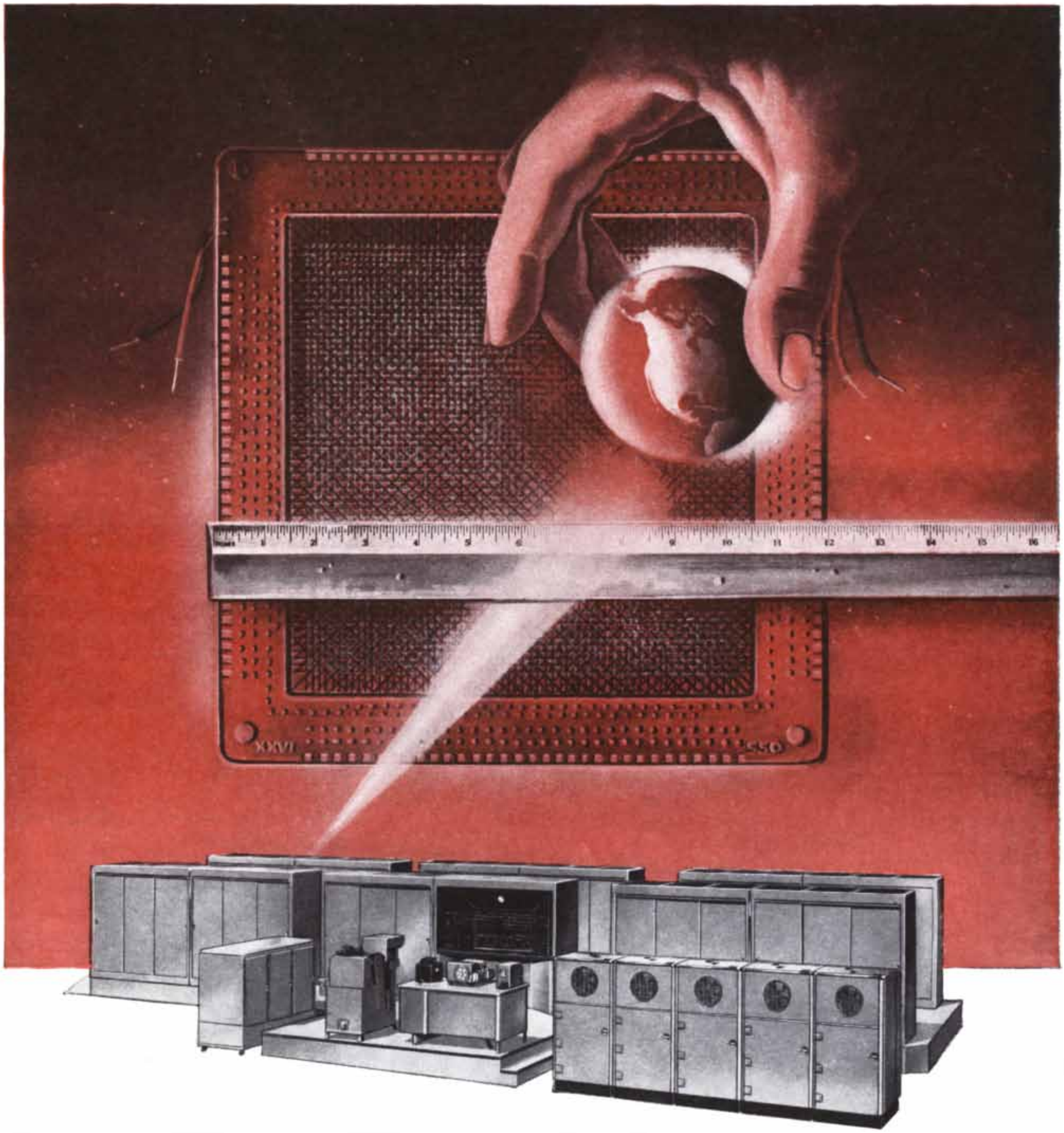
Man is a unique species in many respects. He is unique in practicing warfare. This we can only deplore. He is also unique in having a conscious, potential control over his population size and thus over his own welfare. This control is birth control, the full advantages of which have not yet been realized. The analogy drawn by Went between birth control in humans and germination control in certain plants through adaption to factors of the environment is an imperfect one. These adaptions and other adaptions are largely the result of natural selection. They are thus the *result* of the "struggle for existence"; they are not means of circumventing it through altruistic motives. Birth control, on the other hand, *is* a means of reducing competition (though not of eliminating it) and thus of alleviating human suffering due to excess population. This is a unique property of human culture and not an imitation of nature. . . .

PAUL A. FRYXELL

New Mexico College of Agriculture
and Mechanic Arts
State College, N. M.

Sirs:

I frankly admit that I know practically nothing about the eastern forests Professor Smith is discussing. It is quite evident that germination and seedling behavior there is entirely different from what I have observed in climax forests in the tropics. In none of the jungles I saw in Java or South America have I ever found a tree broken or felled by wind. This could not be said for New England forests, which I saw after the 1938 and 1954 hurricanes! In the secondary forest which develops in the tropics, after the jungle is cut down, there is an enormous excess of seedlings of which most perish for many different reasons. But once the primary forest with its often slow-growing but very hard-wooded trees and dense undergrowth has taken over, replacing the fast-growing but short-lived trees of the secondary forest, germination becomes much rarer. I believe that the New England forests which Professor Smith considers can be best compared with the unstable secondary forests of the tropics: they, too, are young. Therefore I believe that we are talking about very different things, and that we both are right, inasmuch as very little tree germination occurs in the tropical jungle, whereas extensive germination of pines and other trees occurs in the young eastern forests. However, even under the latter conditions, I believe that we should



revise our idea about the fierceness of competition. As Professor Smith has indicated in his letter, and as he has shown in his publications, pine seedlings die from excessive shade largely through damping off, which means that under unfavorable growing conditions parasites finish the plants off. An additional large number of seedlings are killed by rodents, cutworms, pine locusts and pales weevils. Therefore, the death of most of these seedlings is due to the fact that they germinated under unfavorable conditions. It is difficult to accuse the established forest trees of providing competition in this connection.

Concerning the arguments of Dr. Fryxell, I believe that he generalizes from one observation concerning seedlings of elm trees on the general behavior of plants in nature without considering other cases. In my article I have shown that, in the case of the creosote bush, far more seedlings germinate than can survive. But in the case of the annual plants there was very little dying before seeds were reproduced once germination had occurred. I am sure that when Dr. Fryxell looks not only at his elm tree, but also starts to watch all sorts of other plants under natural conditions, then he will be surprised how seldom he finds the actual death of plants due to competition. I quite agree with Dr. Fryxell, however, when he says that the adaptations of plants to germinate only under conditions in which they will survive is a result of natural selection.

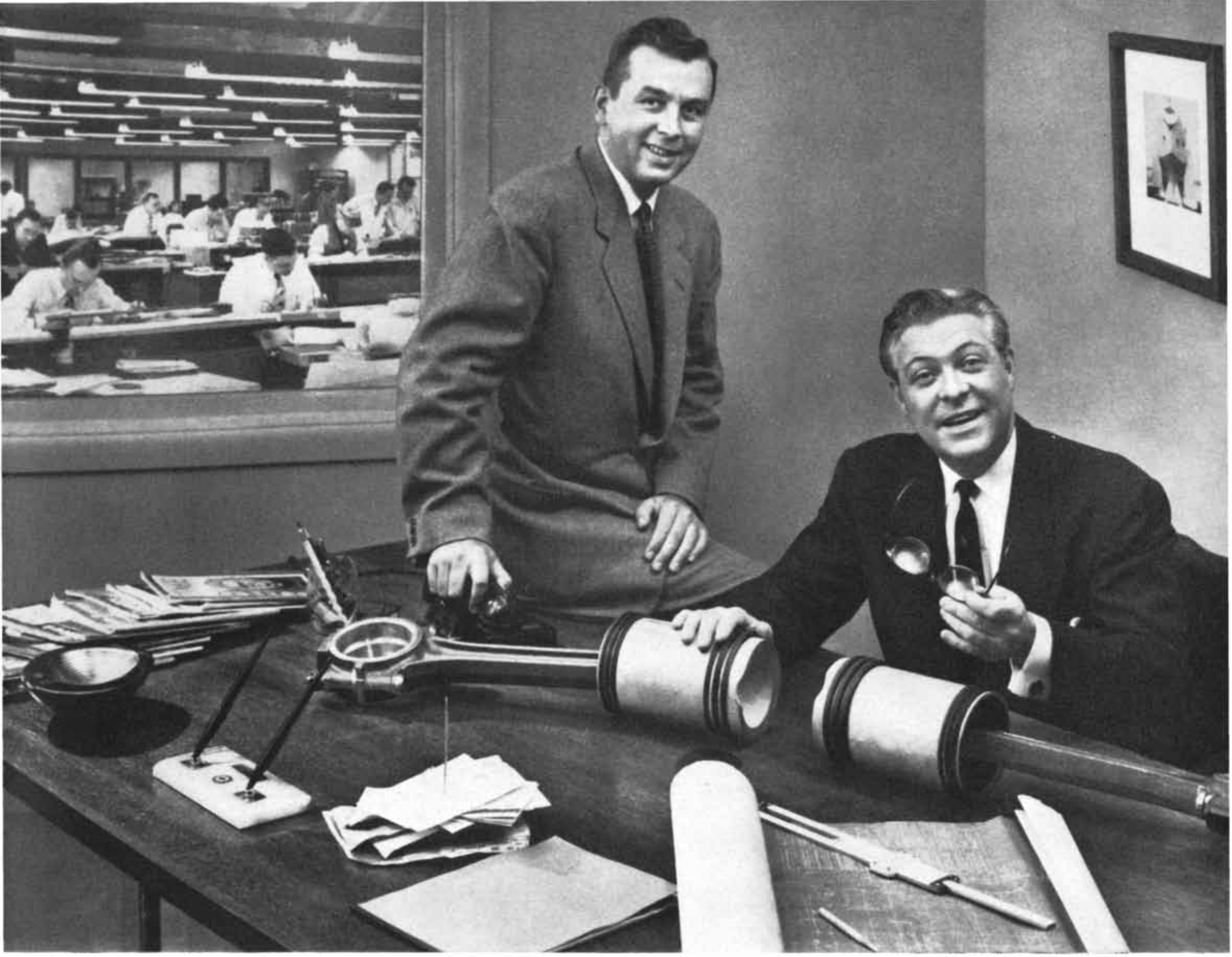
Frits W. Went

Earhart Plant Research Laboratory
California Institute of Technology
Pasadena, Calif.

Errata

In the article entitled "Man Viewed as a Machine" [Scientific American, April] it was stated that the computer called MANIAC was built at the Institute for Advanced Study in Princeton, N. J. The machine was built at the Los Alamos Scientific Laboratory. In the same article the two illustrations representing the "and" circuit were inadvertently reversed.

In the book section of the same issue Rinehart & Company was given as the publisher of *The Mental Hospital*. The publisher is Basic Books, Inc.

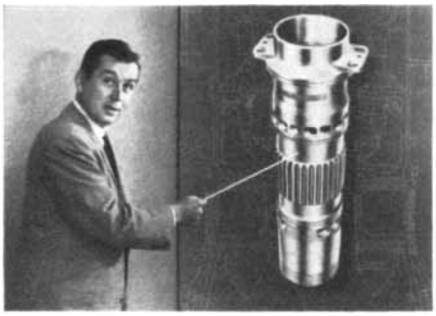


They were asked "Why two when one will do?"

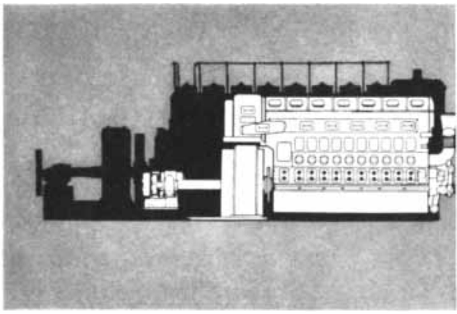
That's often the first reaction to the Fairbanks-Morse Opposed Piston Diesel . . . "Why two pistons in each cylinder?"

The answer given by the F-M Diesel Design Staff is quite simple: two pistons reacting to the forces of combustion in a common cylinder give you greater horsepower per cylinder . . . more power per foot of floor space . . . and as it happens, a far more simple engine with 40% fewer moving parts to wear and maintain.

Only from Fairbanks-Morse can you get such originality and soundness of *new* design that assure outstanding performance. When next you need a Diesel Engine . . . or a scale . . . an electric motor . . . or a pump . . . look for the famous F-M Seal and see the difference that quality makes. Fairbanks, Morse & Co., 600 So. Michigan Avenue, Chicago 5, Illinois.



The Secret is this cylinder liner that contains two pistons. It eliminates cylinder heads and their gasketed joints, intricate valve trains and their timing—all parts that require skilled maintenance by skilled personnel.



The Result is a compact, lightweight diesel that permits installing *more* power in the *same* space occupied by any comparable engine. And horsepower for horsepower, the O-P is the easiest to maintain.

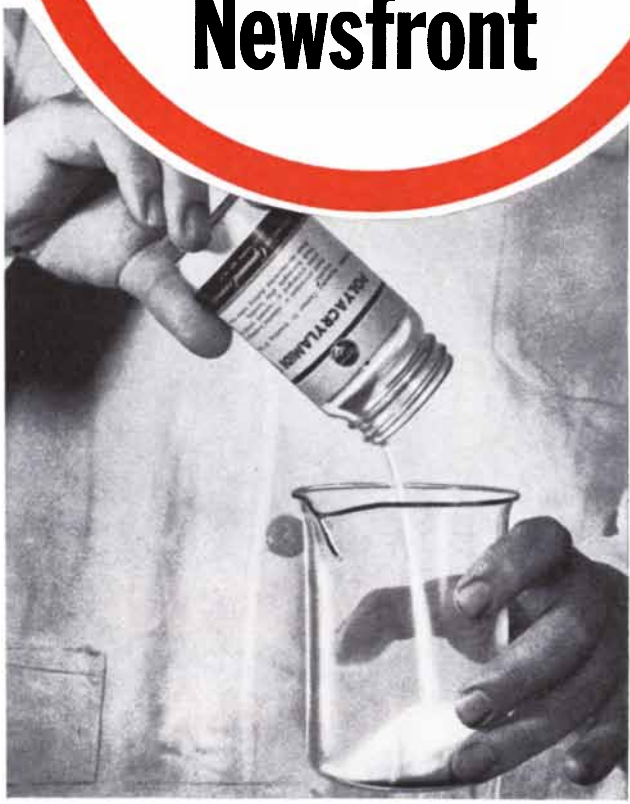
FAIRBANKS-MORSE

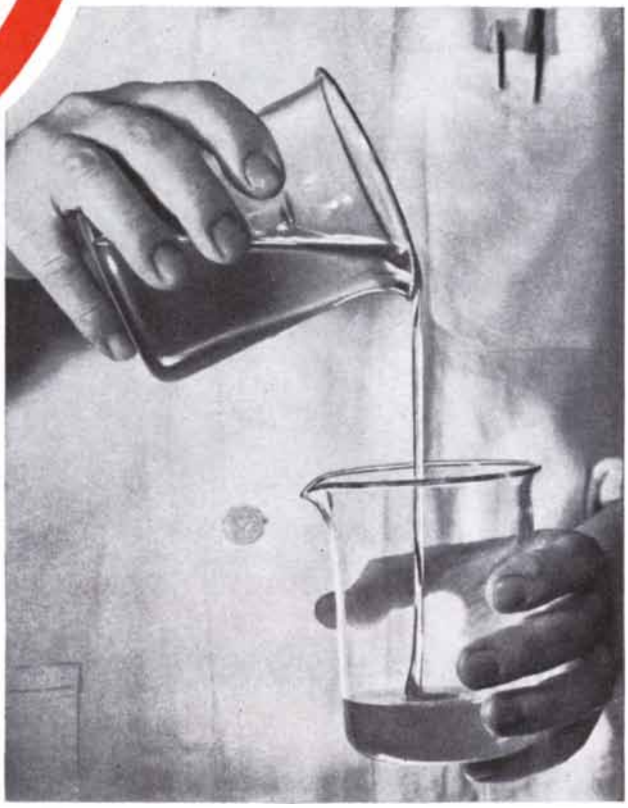
a name worth remembering when you want the best

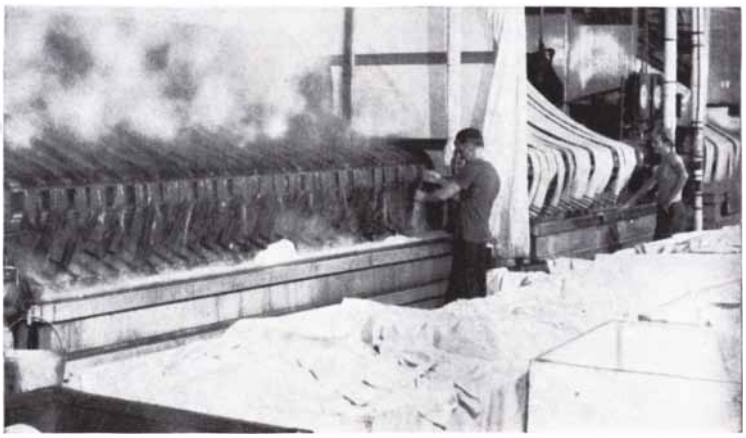
DIESEL AND DUAL FUEL ENGINES • DIESEL LOCOMOTIVES • RAIL CARS • ELECTRICAL MACHINERY • PUMPS • SCALES • HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS

Life... on the Chemical Newsfront

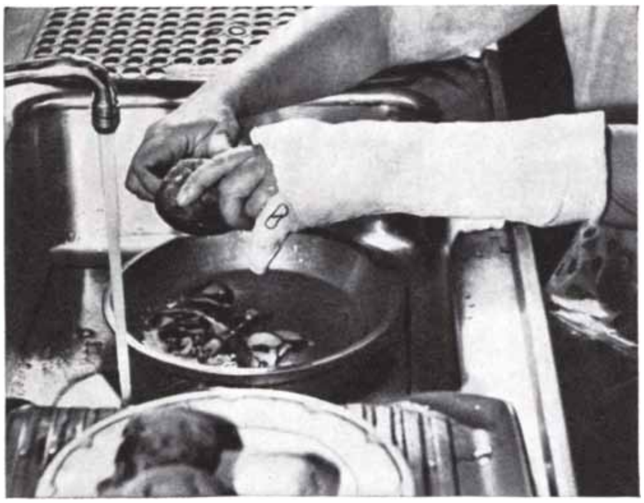
STABLE UNDER ALL pH CONDITIONS, POLYACRYLAMIDE is a versatile thickener for aqueous systems such as rubber and paint latices, ceramic slips, metal cleaners and adhesives. Polyacrylamide is an odorless, free-flowing powder essentially free of ash and metallic ions. With its high thickening action and excellent stability, new water-soluble Polyacrylamide is a highly efficient thickening agent for many uses. **(No. 1)**



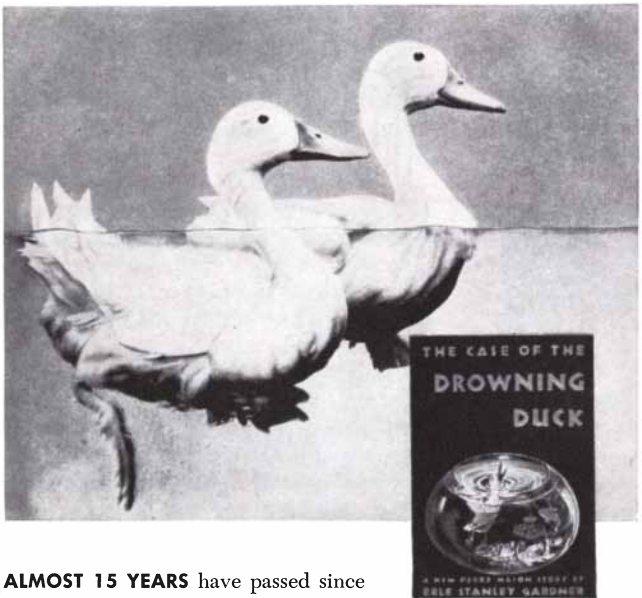




BETTER COLOR FASTNESS IN RESIN-TREATED FABRICS now is possible with Cyanamid's line of CALCODUR* Resin Fast Dyes. Unlike ordinary dyes, which are adversely affected when fabrics are resin treated for softness, wrinkle resistance and other qualities, CALCODUR Resin Fast Dyes actually *improve* in color fastness after treatment. Also, they offer ease of application to various types of fabrics containing cellulosic fibers either alone or in blends. **(No. 2)**



LIGHTWEIGHT CASTS FOR FRACTURE PATIENTS now are being prepared from a new cast material made from plastic resin and plaster of Paris. The new casts are lighter and thinner than ordinary casts, but provide four times the wet strength and twice the dry strength of materials used previously. As a result, they are more comfortable and less fatiguing, they encourage earlier mobilization, and permit clearer X-ray examination. Developed by Davis & Geck, Inc., a unit of Cyanamid, these casts are washable as well as water-, perspiration-, and urine-resistant. Doctors prepare the new casts quickly by merely wetting with water. **(No. 3)**



ALMOST 15 YEARS have passed since Cyanamid's famous ducks first appeared. Because this illustration explained wetting power so graphically, it was featured by the press and newsreels. In 1942, Erle Stanley Gardner made it the theme of his Perry Mason mystery, "The Case of the Drowning Duck." For 15 years, while our two ducks continued to mean wetting power to millions, industry has found use for AEROSOL® Surface Active Agents in thousands of processes and a progression of new uses. Among these uses are crystal growth modification, leak-testing tanks used to store liquids of lower surface tension than water, powerful new dry-cleaning detergents, and wallpaper removers. These and many other important applications are highlighted in our new booklet on AEROSOL Surface Active Agents. **(No. 4)**

News Briefs

OUTSTANDING PERFORMANCE IN SURFACE COATINGS is being reported for the new XA Polyester Coating Resins. Similar in composition to the unique polyester/glass-fiber plastics, XA Polyester Coating Resins are solutions in a reactive monomer such as styrene. Properly catalyzed, they cure to insoluble, infusible films in a few hours at room temperature. Since they cure without loss of volatile material or liberation of water, they can be applied in films up to 10 mils thick. Thick films reduce labor of finishing porous materials such as wood, fiberboard and masonry. XA Polyester Coating Resins also exhibit excellent resistance to chemicals, solvents and water. Since this type of polyester resin is a new development for the paint industry, only experimental samples are available at present. **(No. 5)**

CRUMBLED BATCHES OF OIL-EXTENDED GR-S STOCKS can be avoided by using PEPTON® 22 catalytic plasticizer for GR-S and natural rubber. PEPTON 22 also improves processing of stocks by reduction of viscosity during mastication. This means faster breakdown time, lower power consumption and reduced processing cost. The peptizing action of PEPTON 22 during hot mastication demonstrates its efficiency as a catalytic plasticizer. **(No. 6)**

BLACKHEAD DISEASE IN TURKEYS now is controlled more economically with new ENHEPTIN®-A 2-acetylamino-5-nitrothiazole. The new drug is more effective than the former ENHEPTIN® 2-amino-5-nitrothiazole. Extensive research among many groups of chemical compounds did not reveal a better drug than ENHEPTIN but its acetyl derivative, ENHEPTIN-A, was found to be more effective so that lower dosage may be used. The drug is supplied to feed manufacturers for proper distribution in feed, and is available to turkey raisers as medicated feed. It may be used at specified levels as a disease preventive, or at higher levels as a control after an outbreak occurs. Extensive tests have shown that the drug has no effect on breeding activity or egg production, and medicated birds grow and maintain body weight equal to unmedicated birds. Devastating blackhead disease no longer means disaster for turkey raisers; ENHEPTIN-A in medicated feeds controls it economically **(No. 7)**

*Trade-mark

AMERICAN *Cyanamid* COMPANY
30 ROCKEFELLER PLAZA
NEW YORK 20, NEW YORK

S.A.

SEND more information on the following items mentioned in the June, 1955 issue of LIFE on the Chemical Newsfront:

No. 1, 2, 3, 4, 5, 6, 7.

Literature ☐ **Price** ☐ **Samples** ☐ **of**____________

Name____________

Company____________

Address____________

City______ Zone____ State____

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JUNE, 1905: "Thanks to the zeal of Prof. Perrine, a sufficient number of observations of each of the two new satellites of Jupiter has been obtained, before Jupiter got too near the sun to be seen by night, to enable their orbits to be roughly calculated. The results which Prof. Perrine has announced are somewhat remarkable. The sixth satellite is about seven million miles from the planet, and takes about 250 days to complete a revolution. The seventh satellite, which is much fainter, revolves in an eccentric orbit, at a mean distance of about six million miles, with a period of some 200 days. The planes of the orbits of these two satellites are considerably inclined to that of the orbit of Jupiter, to the orbits of the inner satellites, and to each other. They are so far from the planet that they might have remained undiscovered for centuries had it not been for photography."

"It has generally been conceded that there is a demand on the part of dairymen, soda fountain proprietors, saloonkeepers, butchers, and grocerymen for something that would make them independent of the iceman, and this seems at last to have been accomplished. An electric refrigerator has been in operation for some time as an experiment in a Philadelphia grocery store. When the store is opened in the morning, the current is turned on and remains so during the day. Although the box is being constantly opened and closed, the temperature is maintained at 34 degrees. When the store is closed for the night the current is shut off, and the temperature remains almost constant all night. The iceless refrigerator is much the same in appearance as any large refrigerator. The motor and compressors are at one end, and the place usually occupied by the ice is given over to brine, which is the means of cooling the interior of the refrigerator. No expert knowledge of either electricity or refrigeration is required to operate one of these outfits. The switch controlling the electric current is the only part that must be manip-

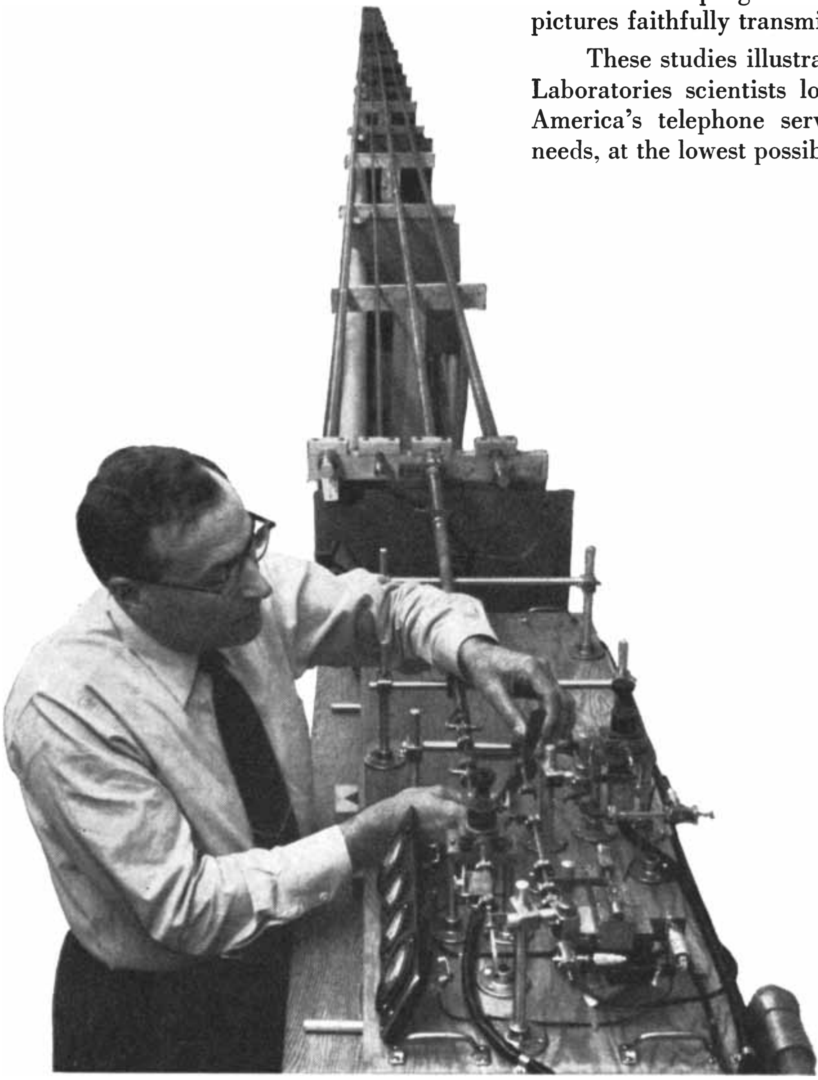
Pipes of Progress

Hundreds of thousands of telephone conversations or hundreds of television programs may one day travel together from city to city through round waveguides—hollow pipes—pioneered at Bell Telephone Laboratories.

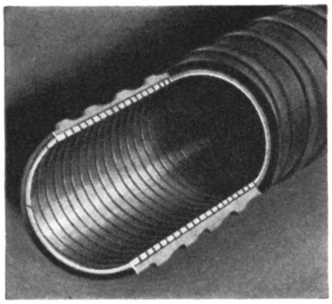
Round waveguides offer tremendous possibilities in the endless search for new ways to send many voices great distances, simultaneously, and at low cost. Today, Bell Laboratories developments such as radio relay, coaxial cable and multivoice wire circuits are ample for America's needs. But tomorrow's demands may well call for the even greater capacity of round waveguides.

Unlike wires or coaxial, these pipes have the unique property of *diminishing* power losses as frequencies rise. This means that higher frequencies can be used. As the frequency band widens, it makes room for many more voices and television programs. And the voices will be true, the pictures faithfully transmitted.

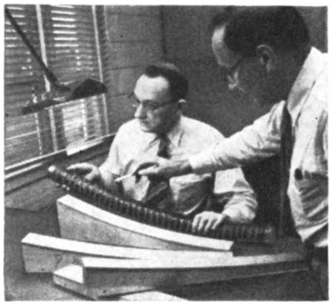
These studies illustrate once more how Bell Telephone Laboratories scientists look ahead. They make sure that America's telephone service will *always* meet America's needs, at the lowest possible cost.



Testing round waveguides at Bell Telephone Laboratories, Holmdel, New Jersey. Unlike coaxial cable, waveguides have no central conductor. Theoretically, voice-capacity is much greater than in coaxial cable.



New type of waveguide pipe formed of tightly wound insulated wire transmits better around corners than solid-wall pipes.



New type waveguide is bent on wooden forms for study of effect of curvature on transmission. The waveguide itself is here covered with a protective coating.

Bell Telephone Laboratories

Improving America's telephone service provides careers for creative men in scientific and technical fields.

ulated. Where it is desired to have ice for use on the table, these machines will make it, in ten-pound pieces or in small cubes, while performing their ordinary functions."

"Last month in SCIENTIFIC AMERICAN Mr. Lodian described the compressed tea which is used by the Siberians and by the Russian Army in Manchuria. The article was accompanied by an illustration of a tablet of compressed tea, bearing the imprint of the Russian government. The printer was not familiar with the Russian language, for which reason the engraving appeared upside down, so that the insignia of the Czar upon the tablet were reversed. This revolutionary proceeding proved too much for the censor. In every copy of SCIENTIFIC AMERICAN that reached our Russian subscribers the unfortunately placed engraving was ruthlessly blacked out."

"The constant proportionality found in most minerals between the uranium and the radium in them lends color to the supposition that radium is a product of the disintegration of uranium. B. B. Boltwood has endeavored to throw further light on this important probability by carefully examining a large number of minerals of various origins, including pitchblende from Joachimsthal, Colorado and North Carolina; uranothorite, euxenite, thorite, fergusonite and monazite from Norway; monazite from Brazil and Connecticut; allanite, gummite, uranophane and samarskite from North Carolina. All the analyses point to uranium as the parent of radium. All the monazites contain notable quantities of uranium and radium, and this affords a plausible explanation of the occurrence of helium in this mineral, without recourse to the unsubstantiated hypothesis of the formation of helium from thorium. The age of monazite is extreme, since it occurs in some of the oldest igneous rocks of the globe. It may, therefore, be assumed that it originally contained much more uranium than at present, and that the accumulated helium represents the disintegration product of radium for countless ages."

SCIENTIFIC AMERICAN

JUNE, 1855: "The average duration of human life throughout the world is 33 years. One quarter die previous to the

age of seven years; one half before reaching seventeen."

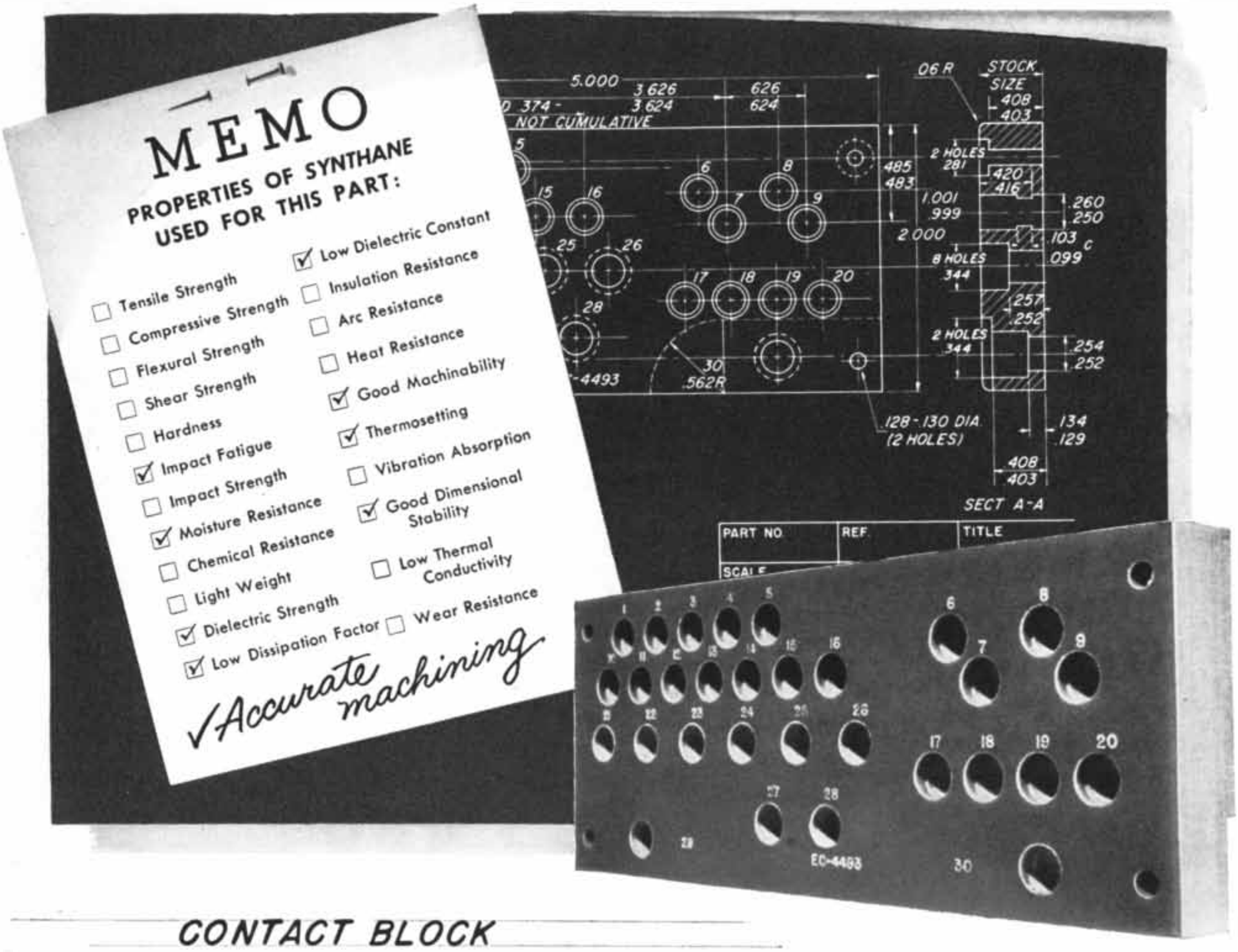
"The Academy of Sciences in Paris have been investigating the causes which almost invariably make the west end of a city grow more and become more fashionable than the east. 'It arises from the atmospheric pressure,' answers the Academy of Sciences. The wind which causes the greatest ascension of the barometric column is that of the east, and that which lowers it most is the west. When the latter blows, it has the convenience of carrying with it to the eastern parts of a town all the deleterious gases which it meets in its passage over the western parts; and the inhabitants of the eastern part of a town have to support not only their own smoke and miasma, but those of the western part of the town, brought to them by the west winds. When, on the contrary, the east wind blows, it purifies the air by causing the pernicious emanations, which it cannot drive to the west, to ascend. The deduction from this law is, that the western part of a city is the best place of residence for persons of delicate health."

"The *Annales d'Hygiène* of Paris has published an article pointing out the danger arising from packing snuff in lead, as the damp in the snuff acting on the lead oxydizes it, and forms a soluble salt of a poisonous nature. The tobacco administration of France has acted on this advice and discontinued the use of the lead envelopes."

"A young French chemist of the name of Berthelot has made the discovery that alcohol can be procured directly from olefiant gas, which can be extracted in large quantities from coal."

"No train is considered safe in this country unless there is a cord running through or over every car, and connecting with a gong on the locomotive, which cord, in case of accident, the conductor or passenger pulls, and so signalizes the engineer to stop. Although this simple contrivance has been in use here for years, with the utmost success, our transatlantic friends refuse to adopt it. One British plan, which we read not long ago, was to have a large gong placed over the engineer's head, and to furnish the conductor with a bow and arrow. The conductor has a seat on the top of one of the cars, and it was to be made his duty, in case of accident, to shoot at the gong and so alarm the engineer."

YOU FURNISH THE PRINT, WE'LL FURNISH THE PART



CONTACT BLOCK
OF SYNTHANE LAMINATED PLASTIC
MEETS MANY ELECTRICAL, MECHANICAL REQUIREMENTS

This contact block—for an electronic device—illustrates the rising demand for materials with many properties in combination. High dielectric strength, mechanical strength and dimensional stability are essential for the application; accurate machining is a must for proper mating of components.

SYNTHANE CORPORATION, 2 River Road, Oaks, Pa.

Please send me more information about *Synthane* laminated plastics and the *Synthane* fabrication service.

Name____________________

Title____________________

Company____________________

Address____________________

City__________ Zone_____ State__________

The customer supplied the blueprint; Synthane Corporation did the rest—first producing the proper grade of material and then fabricating—accurately and without waste or delay.

The more than 33 grades of *Synthane* laminated plastics offer *you* a very wide range of properties in combination—physical, mechanical, electrical, and chemical. And good service and quality characterize *Synthane* fabrication. The coupon will bring you further information and technical data covering *Synthane* sheets, rods, tubes, and molded parts, and *Synthane* service.

SYNTHANE
LAMINATED S PLASTICS

SYNTHANE CORPORATION · OAKS, PENNSYLVANIA

Bendix brakes just about

WHEN Bendix four-wheel brakes were introduced to the American motoring public in 1925 the way was opened for safely controlling today's swift, high-powered cars. Since then we've built millions of brakes for many kinds of vehicles, each with its own peculiar braking problem.

From the day we patented the first airplane brakes, for example, stopping heavy planes has gotten tougher and tougher. When a large airplane comes roaring in for a landing it's like stopping 150 passenger cars going 60 m.p.h. Ordinary brakes and lining couldn't do it. So we invented a completely new lining called Cerametallic† for use on our segmented rotor brake—and that did the job!

Many years ago we pioneered power braking for trucks—known today as Bendix* Hydrovac*. What we learned building millions of these dependable brakes has been incorporated in today's power brakes for passenger cars. Now Bendix "Low Pedal" Power Brakes have been selected by more car makers than other types. We also make a power brake that can be installed on your present car; you can buy it from car dealers, service stations and independent garages.

Other brake products made by our Bendix Products Division at South Bend, Ind., include heavy-duty systems for farm tractors and off-the-road equipment and what we call Factory-New Lined Brake Shoes. These brand-new, deluxe shoes, equipped with the exact lining recommended by your car's manufacturer, can be installed by your dealer.

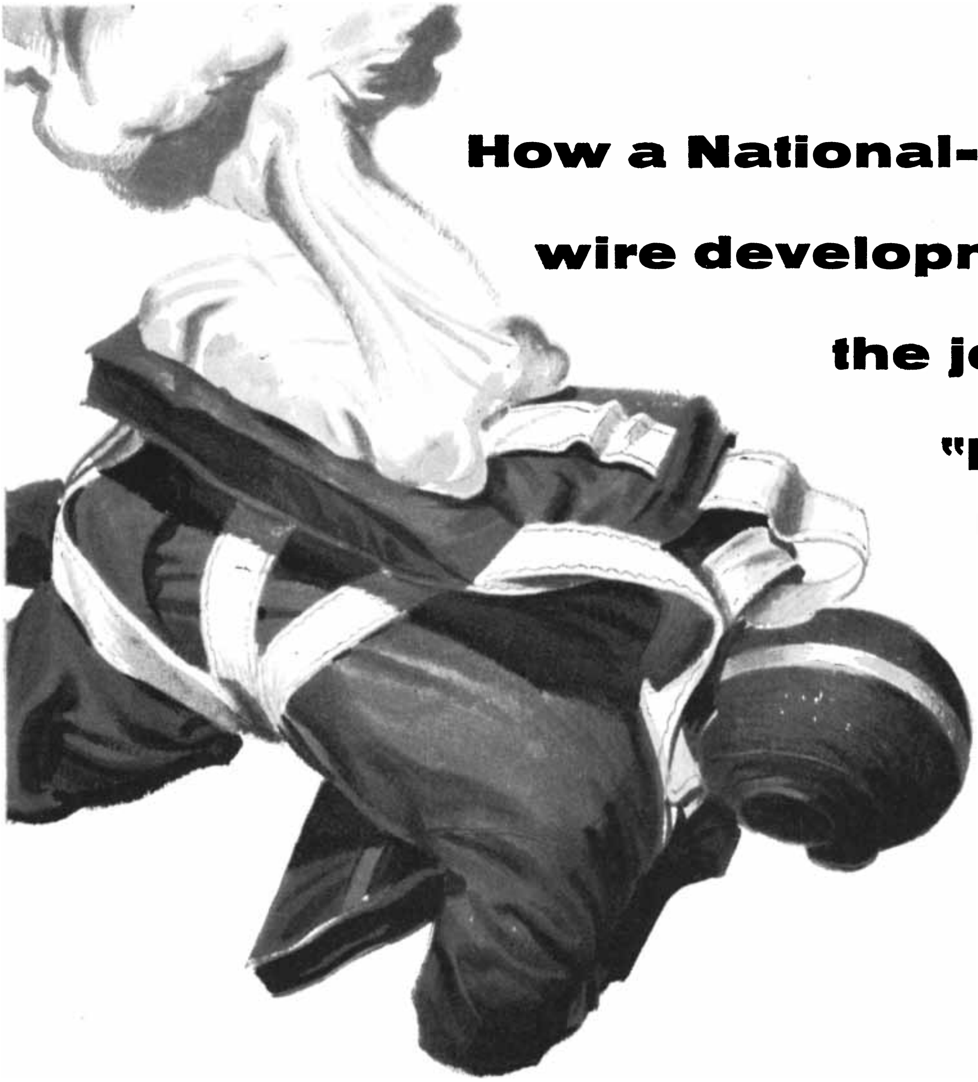
For years our Eclipse Machine Division at Elmira, N. Y., has built Bendix* Coaster Brakes for bicycles. Last year they brought out a foot-operated "power

THE AUTHORS

NIELS BOHR and I. I. RABI ("Albert Einstein: 1879-1955") were personal friends of Einstein, as have been most of the other leading physicists of this century. Both men are atomic physicists, and their tributes to Einstein's work significantly stress his contributions to atomic physics, which are perhaps less widely appreciated than his relativity theory. Bohr, the author of the classic picture of the hydrogen atom that hangs on the mental wall of every modern physicist, was born in Copenhagen six years after Einstein. Like Einstein he made his first great discoveries in his late twenties; like Einstein he fled from the Nazis (escaping from Denmark in a small boat in 1943); and he received the Nobel prize in physics the year after Einstein did (in 1922). Bohr is still director of the Copenhagen Institute for Theoretical Physics, a post which he has held since 1920. Rabi, winner of the Nobel prize in 1944 for his explorations of the atomic nucleus, is professor of physics at Columbia University. He has been a leader and spokesman of physicists in the U. S., widely known as the associate director of the Radiation Laboratory (radar) at the Massachusetts Institute of Technology during World War II and as the present chairman of the General Advisory Committee of the Atomic Energy Commission.

SIX STAFF MEMBERS OF BOSTON PSYCHOPATHIC HOSPITAL ("Experimental Psychoses") are a group of researchers of differing professional backgrounds. Robert W. Hyde is a psychiatrist and assistant superintendent of the Hospital; he has been particularly interested in studying the social factors at work in mental illness. Max Rinkel, also a psychiatrist, has for many years made a specialty of tracking down biochemical and pharmacological aspects of various mental states. H. Jackson DeShon is a clinical psychologist; in the experiments described in the article his responsibility was to determine the subjects' psychological state. The group also includes K. Morimoto, a sociologist, and R. H. York and H. Salvatore, clinical psychologists, all trained at Boston University. In contributing to the article, each man wrote a section covering his own work.

J. P. WILD ("Radio Waves from the Sun") is a radio astronomer on the staff



How a National-Standard wire development took the jolts out of "bail-outs"

● Until recently, when a pilot "hit the silk", the shock was almost more than his frame could absorb. A better parachute harness was needed.

A leading spring maker brought this problem to National-Standard.

Our engineers came up with a special stainless steel wire that would take the severe forming stresses created in coiling long, thin springs. In addition, this wire could be made into springs with unusual resistance to permanent set. And, finally, this wire enabled the spring designer to create a spring with high initial tension . . . a sort of delayed action characteristic which prevented the spring from opening until the severe shock of deceleration was applied.

We solved this problem by staying with it long after most wire and steel makers would have given up. It is this stay-with-it approach that has enabled National-Standard to solve more of the fussy problems in steel and wire making than anyone else in the industry.

If you have a need for steel or wire with unusual or even "impossible" characteristics, check first with National-Standard. We may already be making such products. And, if we don't know how to make it now, we'll learn.

NS NATIONAL-STANDARD Company NILES, MICHIGAN

NATIONAL-STANDARD COMPANY • NILES, MICHIGAN
Tire Wire, Stainless, Fabricated Braids and Tape
ATHENIA STEEL DIVISION • CLIFTON, N. J.
Flat, High Carbon, Cold Rolled Spring Steel
REYNOLDS WIRE DIVISION • DIXON, ILLINOIS
Industrial Wire Cloth
WAGNER LITHO MACHINERY DIVISION • JERSEY CITY, N. J.
Special Machinery for Metal Decorating
WORCESTER WIRE WORKS DIVISION • WORCESTER, MASS.
Round and Shaped Steel Wire, Small Sizes

of the Commonwealth Scientific and Industrial Research Organization in Sydney, Australia. He was born in Yorkshire, England. After reading mathematics and physics at the University of Cambridge and taking an M.A., he served in the Royal Navy as a radar officer on the battleship *King George V.* Attracted to Sydney, his ship's base during part of World War II, he went back to Australia after the war and joined the Radiophysics Laboratory of the C.S.I.R.O. With his collaborator L. L. McCready, Wild was the first to develop, in 1948, a solar radio spectroscope that could respond to a wide band of frequencies.

JAMES R. NEWMAN ("James Clerk Maxwell") is a member of the board of editors of this magazine, for which he also conducts the book department. He writes: "I have long been interested in 19th-century science—as a graduate student in mathematics (after getting my law degree) at Columbia, and afterwards. I am an amateur, of course, but absorbed in this period of thought." Newman is the coauthor with Edward Kasner of the well-known book *Mathematics and the Imagination.* He also edited an edition of William Kingdon Clifford's *Common Sense of the Exact Sciences,* for which he wrote a long note on the scientific achievements of the age of Clifford and Maxwell. He is writing a book of essays on 19th-century scientific thought, covering Faraday, Maxwell, Clifford, Helmholtz and Poincaré among others, and is contemplating a full-scale biography of Maxwell. Next fall Simon & Schuster will publish his *The World of Mathematics,* which will include selections of famous writings on the relation of mathematics to a wide variety of subjects, from art and literature to war, physics and philosophy.

NICHOLAS PASTORE ("Learning in the Canary") is an instructor in psychology at Queens College in New York City and a lecturer on statistics at New York University. His Ph.D. thesis at Columbia University (1948) was on the effects of scientists' political and social attitudes on their stand in the historic nature-nurture controversy. He has long been interested in the psychology of learning, and a close-out sale of a neighborhood pet shop two years ago provided him with subjects. He turned his home into an aviary and began experiments. Some of his results are described here.

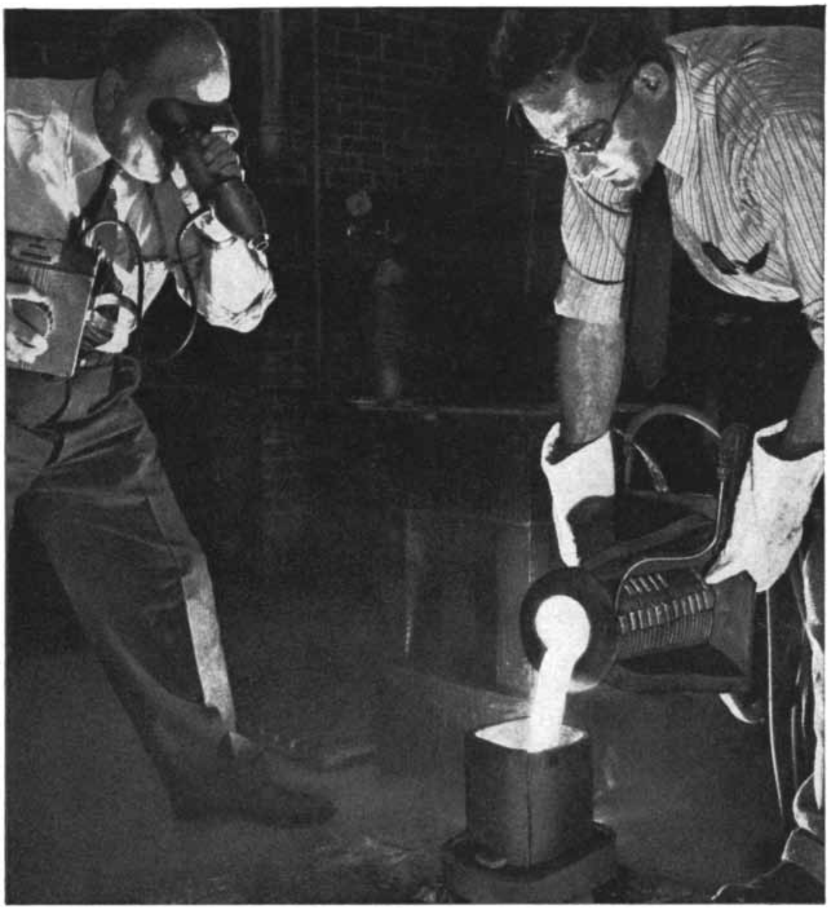
DAVID PRAMER ("Antibiotics against Plant Diseases") is assistant pro-

fessor of agricultural microbiology at Rutgers University. After taking his doctorate at Rutgers in 1952 Pramer spent two years in England at the Butterwick Research Laboratory of Imperial Chemical Industries. At Rutgers, to which he has now returned, he works at the New Jersey Agricultural Experiment Station.

LOUIS N. RIDENOUR ("Computer Memories") is a physicist currently engaged in industrial work with the Missile Systems Division of the Lockheed Aircraft Corporation. Educated at the University of Chicago and the California Institute of Technology, he was a nuclear physicist before he went to the Radiation Laboratory at the Massachusetts Institute of Technology in 1940 to work on radar. At the end of the war he edited the Laboratory's 27-volume summary of its work in radar and electronics. Later he was dean of the University of Illinois Graduate College for several years, spent a year as chief scientist with the Air Force and then entered industrial work.

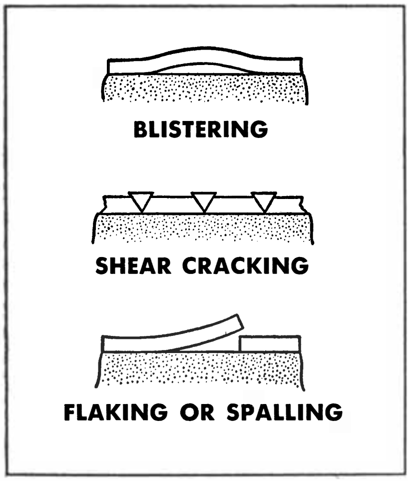
ESMOND R. LONG ("The Germ of Tuberculosis") is the retiring director of medical research of the National Tuberculosis Association. Like many other prominent researchers in tuberculosis, he once had the disease himself. "It was first diagnosed in 1913," he writes, "and I spent over five years in getting back on my feet." Long, then a young assistant in pathology at the University of Chicago, went to Tucson, Ariz. He worked in the desert laboratory of the Carnegie Institution of Washington there and later became a Trudeau Fellow in the laboratories at Saranac Lake, N. Y. In 1919 he returned to the University of Chicago, where he obtained a Ph.D. in pathology and an M.D. at the Rush Medical College. After 1932 he was professor of pathology at the University of Pennsylvania, director of the Henry Phipps Institute laboratory and a member of the National Research Council. He has received the Trudeau Medal of the National Tuberculosis Association.

MORTON GRODZINS, who reviews Samuel A. Stouffer's *Communism, Conformity and Civil Liberties* in this issue, is professor of political science at the University of Chicago. He took his Ph.D. at the University of California in 1945 and taught there before coming to Chicago in 1953. For several years he was editor of the Chicago University Press; he now serves as adviser to the chancellor on special projects.



INCO RESEARCH OFFERS HELP

(Left) One phase of the search for answers to high temperature questions is the continuing work on new INCO Nickel Alloys. Here INCO metallurgists pour an experimental melt from their laboratory radiofrequency induction furnace. The resulting alloy may be a new solution to some of the unanswered high temperature problems facing engineers today.



Breakdown of oxides by blistering, cracking or spalling can cause rapid destruction. As the oxide layer breaks away, it keeps exposing fresh metal to further attack until its strength is wasted away. This type of failure can be avoided by using an alloy that resists the corrosive action at high temperature and protects itself with a tough adherent oxide.

What causes high temperature failure?

Strange reactions can take place when metals are exposed to high heat.

Even common soot and the air itself become destructive corrosives that can disintegrate a metal and waste away its strength.

High Temperature Corrosion

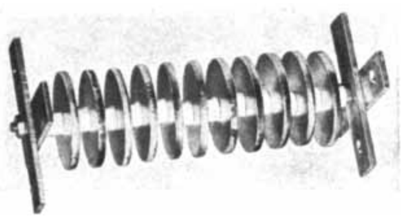
The more these reactions are studied, the more evident it becomes that the damage caused by high temperature corrosion is one of the most serious reasons for metal failures.

No single metal or alloy can resist all these corrosive conditions. For 20 years Inco metallurgists have been experimenting with controlled compositions of metals . . . searching for the answers to the problems posed by expanding temperature frontiers. From this work have come such strong, heat-resisting alloys as Inconel and Inconel "X," Incoloy and the Nimonic Alloys.

Have metals reached their limit?

Inco metallurgists think not. Who knows what future research programs may reveal?

Do you have a problem involving high temperatures? The solution may already be in the files of Inco's High Temperature Engineering Service. If not, our engineers will be glad to work with you to find it. Write for a "High Temperature Work Sheet" to help you outline your problem for study. After that it is up to us. There is no obligation on your part.



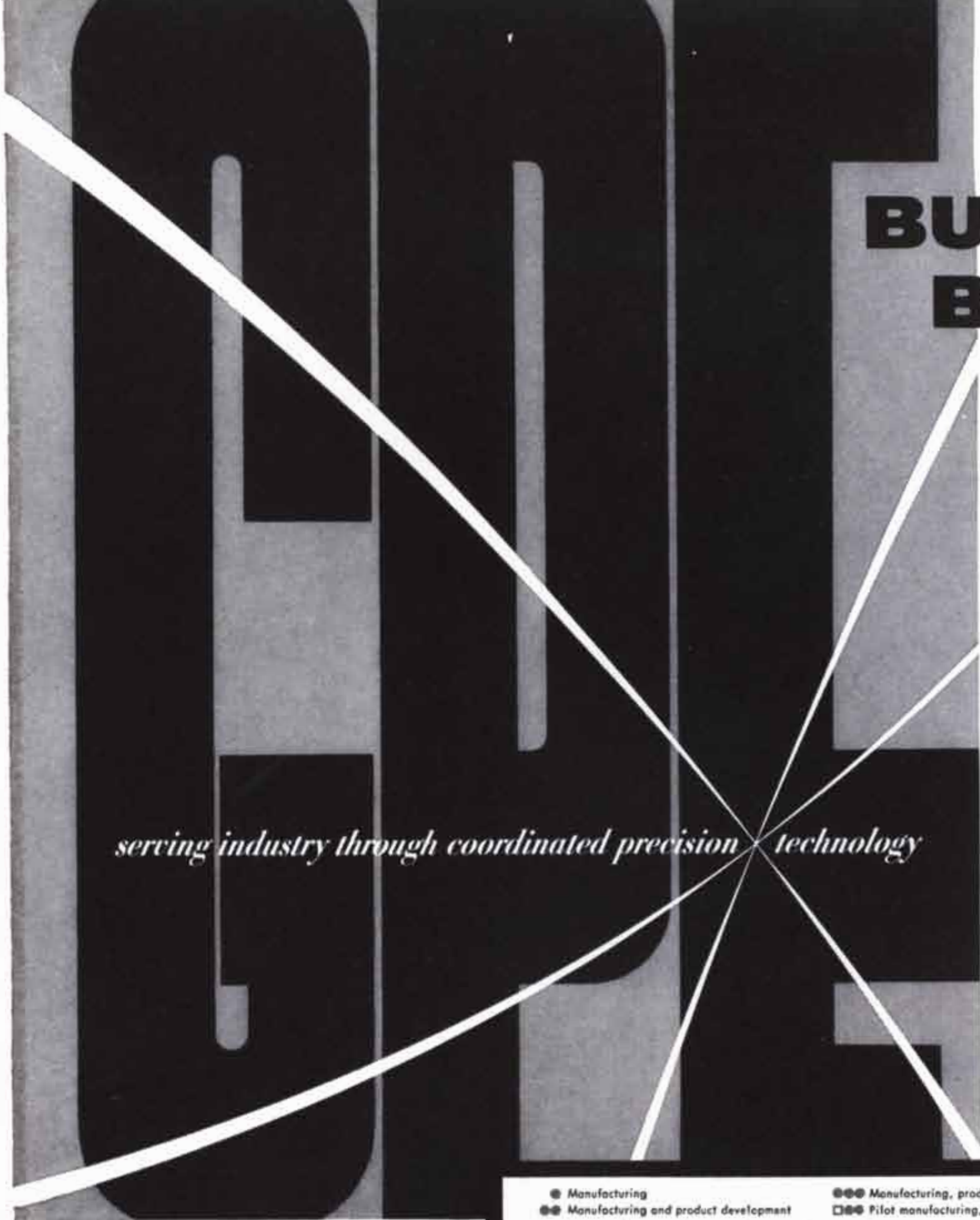
Which of these metals will solve your problem? When INCO's High Temperature Engineers do not have a ready answer in all their amassed information, they make use of a test rack like this. After exposure to high temperature corrosion under actual service conditions, a direct comparison of the different samples indicates which metal or alloy may solve your particular problem.

Nickel Alloys Perform Better Longer

INCO TRADE MARK

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street New York 5, N. Y.

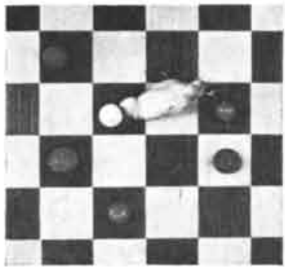


BUILDING BLOCKS

● Manufacturing
●● Manufacturing and product development
●●● Manufacturing, product development and research
□●● Pilot manufacturing, product development and research

	Kearfott Company, Inc.	International Projector Corporation	Bludworth Marine Division	General Precision Laboratory Incorporated	The Griscom-Russell Company	Link Aviation, Inc.	The Hertner Electric Company	The Strong Electric Corporation	J. E. McAuley Mfg. Co.	Askania Regulator Company	Ampro Corporation	Librascope, Incorporated
PRECISION MECHANICS, OPTICAL DEVICES, CERAMICS	●●●	●●	●●	□●●	●●	●●●	●●	●●●	●●	●●	●●	●●●
ELECTRICAL EQUIPMENT and COMPONENTS	●●●	●	●			●●●	●●●	●●	●	●●	●	●●●
ELECTRONICS	●●●	●●	●●●	●●●		●●●	●	●●		●●●	●●	●●●
HYDRAULICS, LIQUIDS PROCESSING, HEAT EXCHANGE		●●			●●●					●●●		
TELEVISION Studio, Theatre, Educational, Business, Industrial	●	●		●●●		●				●		
INSTRUMENTS, SERVOS, CONTROLS Hydraulic, Pneumatic, Magnetic, Electronic	●●●	●	●●	□●●		●●●	●●	●●		●●●	●	●●●
AIRCRAFT and MISSILE GUIDANCE, CONTROL, SIMULATION	●●●	●		●●●		●●●	●			●●	●	●●●
AUTOMATIC COMPUTERS and COMPONENTS	●●●	●	●	□●●		●●●				●●●		●●●
RADAR, MICROWAVE, ULTRASONICS	●●●	●	●●	●●●		●●		●		●		
MOTION PICTURE and AUDIO EQUIPMENT		●●●		□●●			●●	●●●	●●●		●●●	
NUCLEAR POWER COMPONENTS and CONTROLS	●●●				●●					●●		●●●
SYSTEMS ENGINEERING Aeronautical, Naval, Industrial	●●●			●●●	●●●	●●●				●●●		●●●

THE GPE PRODUCING COMPANIES



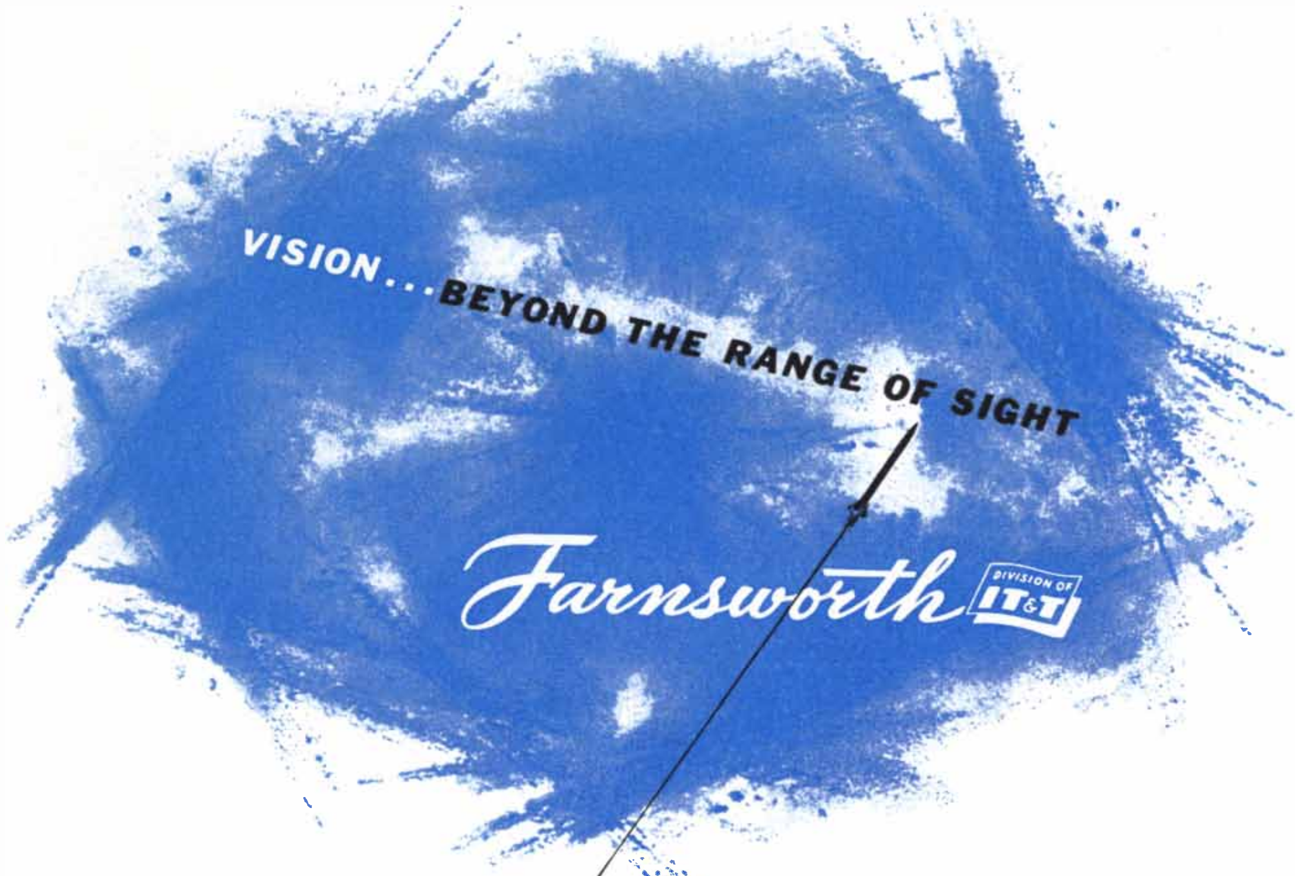
THE COVER

The photograph on the cover obviously shows a canary on a chessboard. It should be stated at once that the canary is not playing chess. It is the subject of a psychological experiment (*see page 72*). Before the experiment was conducted, the canary had been trained to distinguish one unique object among a number of objects. Here the canary demonstrates its ability to generalize on this lesson. It chooses one white chessman among five red ones.

THE ILLUSTRATIONS

Cover photograph by David Linton

Page	Source
33	Lotte Jacobi
34	Sara Love
35	Paul Weller
36-38	Boston Psychopathic Hospital
39	Sara Love
40	High Altitude Observatory of the University of Colorado
41	Mount Wilson and Palomar Observatories
42	Commonwealth Scientific and Industrial Research Organization
43	Irving Geis (*top*), Commonwealth Scientific and Industrial Research Organization (*bottom left*), Irving Geis (*bottom right*)
44	Irving Geis
58-61	The Burndy Library
62-66	Bunji Tagawa
68	The Burndy Library
72-73	David Linton
74	David Linton (*top*), Sara Love (*bottom*)
76-79	Nicholas Pastore
82-86	Eric Mose
92-95	William Vandivert
96-98	Bunji Tagawa
102	Georges Knaysi
103	Hubert Bloch
104-108	Paul Weller
122-126	Roger Hayward
128	Stuart Lichtman
130	Philip Lichtman



Since the beginning of time man has sought to escape the limitations of the known. Though his feet are planted on the ground, his vision goes beyond the range of sight to limitless space . . . dwelling place for a hundred million universes.

Exploring these realms of the unknown . . . wresting the electron's secrets from Nature has been Farnsworth's sole function for over a quarter of a century . . . the last ten years continuously participating in the design, development and production of guided missile systems such as Talos, Terrier, Sparrow and others.

We hope our contributions to this country's defenses act as deterrents to aggression and help influence the peaceful settlement of differences between nations.

The next decade, added to this vast storehouse of electronic knowledge, will bring man's age-old vision of reaching the stars into closer focus.

ELECTRONICS . . .
THE KEY
TO AMAZING TOMORROWS

Farnsworth Products and Activities include:

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

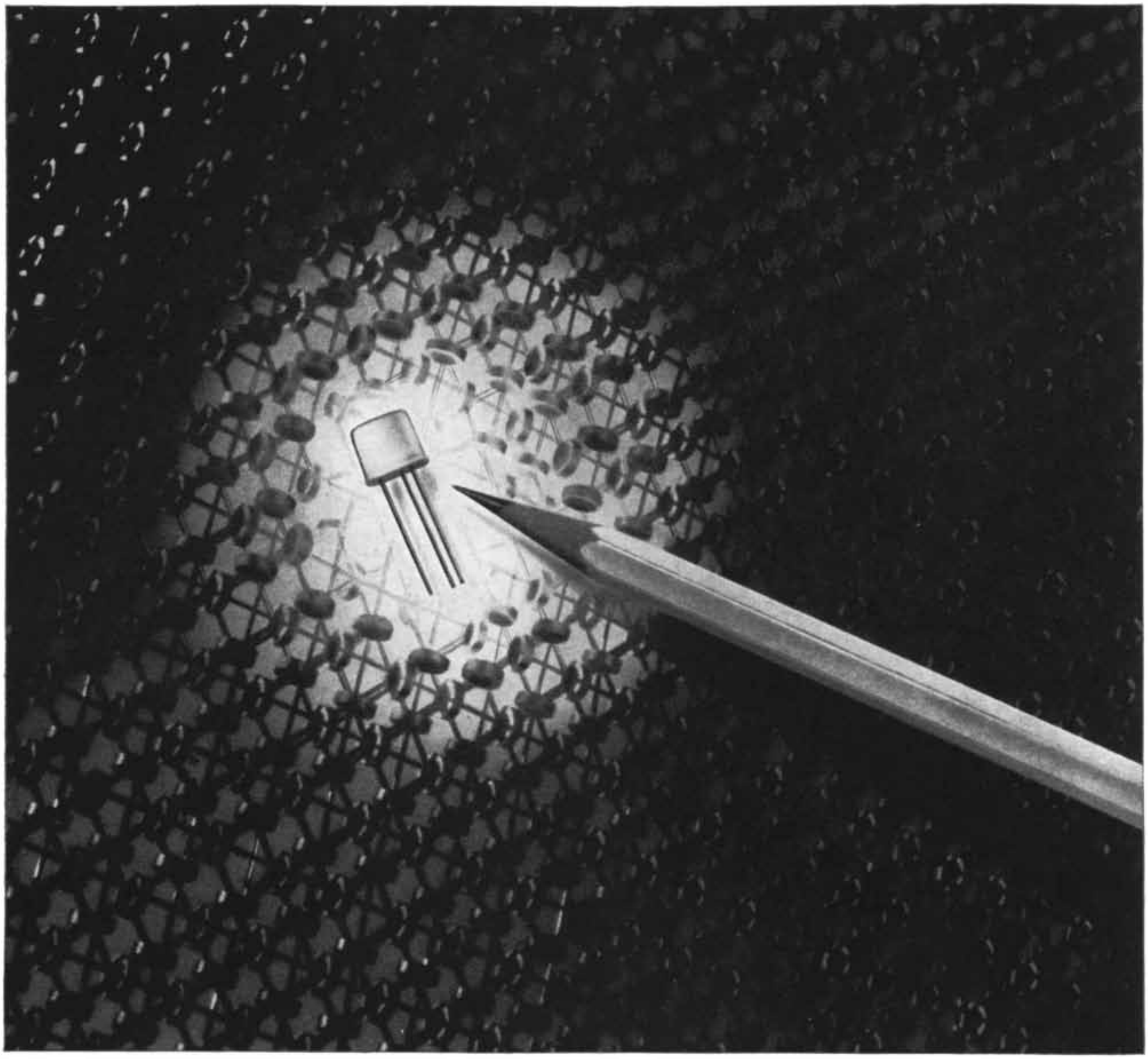
Radar—Transmitters and Receivers, Computers, Microwave Components, Pulse-Coding and Circuitry.

Electron Tubes—Photomultipliers, Storage Tubes, Image Tubes, Infrared Tubes.

Missile—Guidance and Control Systems, Test Equipment.

FARNSWORTH ELECTRONICS COMPANY ★ FORT WAYNE, INDIANA
a division of International Telephone and Telegraph Corporation

Through **IBM** research, another **FIRST** for business



KEY TO THE FIRST ALL-TRANSISTOR CALCULATOR OFFERED TO BUSINESS!

In the IBM 608, tiny transistors are combined with the fantastic "memory" capacity of magnetic cores to give business a data processing machine with significant new advantages. Made without a single vacuum tube, the IBM 608 Transistor Calculator uses these new solid state electronic components to meet the needs of business for faster computing and greater storage capacity with traditional IBM reliability.

The new IBM 608 reduces power requirements by 90%, saves valuable floor space, requires no forced air cooling, and can be operated from a standard 110-volt A.C. outlet. Exciting developments like the IBM 608 Transistor Calculator open the way to electronic data processing for more businesses than ever. International Business Machines Corp., 590 Madison Ave., New York 22, N. Y.

IBM TRADE-MARK | **DATA PROCESSING**

World's largest producer of data processing machines

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR JUNE, 1955 VOL. 192, NO. 6

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN

JUNE, 1955 VOL. 192, NO. 6

ALBERT EINSTEIN: 1879-1955

Tributes by Niels Bohr and I. I. Rabi

With the death of Albert Einstein, a life in the service of science and humanity which was as rich and fruitful as any in the whole history of our culture has come to an end. Mankind will always be indebted to Einstein for the removal of the obstacles to our outlook which were involved in the primitive notions of absolute space and time. He gave us a world picture with a unity and harmony surpassing the boldest dreams of the past.

Einstein's genius, characterized equally by logical clarity and creative imagination, succeeded in remolding and widening the imposing edifice whose foundations had been laid by Newton's great work. Within the frame of the relativity theory, demanding a formulation of the laws of nature independent of the observer and emphasizing the singular role of the speed of light, gravitational effects lost their isolated position and appeared as an integral part of a general kinematic description, capable of verification by refined astronomical observations. Moreover, Einstein's recognition of the equivalence of mass and energy should prove an invaluable guide in the exploration of atomic phenomena.

Indeed, the breadth of Einstein's views and the openness of his mind found most remarkable expression in the fact that, in the very same years when he gave a widened outlook to classical physics, he thoroughly grasped the fact that Planck's discovery of the universal quantum of action revealed an inherent limitation in such an approach. With unfailing intuition Einstein was led to the introduction of the idea of the photon as the carrier of momentum and energy in individual radiative processes. He thereby provided the starting point for the establishment of consistent quantum theoretical methods which have made it possible to account for an immense amount of experimental evidence concerning the properties of matter and even demanded reconsideration of our most elementary concepts.

The same spirit that characterized Einstein's unique scientific achievements also marked his attitude in all human relations. Notwithstanding the increasing reverence which people everywhere felt for his attainments and character, he behaved with unchanging natural modesty and expressed himself with a subtle and charming humor. He was always prepared to help people in difficulties of any kind, and to him, who himself had experienced the evils of racial prejudice, the promotion of understanding among nations was a foremost endeavor. His earnest admonitions on the responsibility involved in our rapidly growing mastery of the forces of nature will surely help to meet the challenge to civilization in the proper spirit.

To the whole of mankind Albert Einstein's death is a great loss, and to those of us who had the good fortune to enjoy his warm friendship it is a grief that we shall never more be able to see his gentle smile and listen to him. But the memories he has left behind will remain an ever-living source of fortitude and encouragement. —Niels Bohr

With Albert Einstein's death a great light has gone out in the world of physics, for Einstein, more than any other man, set the tone of the physics of the 20th century. His theories of special and general relativity were the capstone of classical physics and the theory of fields. His theory of light quanta and his later demonstration of the nature of the fluctuations of "black body" radiation raised the paradox of the wave-particle duality, which was partly resolved two decades later in the principle of complementarity of Niels Bohr and Werner Heisenberg. His 1917 paper, introducing the ideas of spontaneous and stimulated emission of radiation, was the first clear statement of the statistical nature of fundamental atomic phenomena. The famous Einstein A and B coefficients led to the quantitative use of the correspondence principle and to the formulation of the Kramers-Heisenberg dispersion formula, which in turn led to Heisenberg's matrix mechanics. Einstein was therefore in a very real sense the founder of the statistical theory of fundamental atomic phenomena.

There is scarcely any important fundamental idea in modern physics whose origin does not trace back at least in part to Einstein. Yet, like many another father, he was not really satisfied with the children of his scientific imagination. He never regarded his mighty contributions to quantum theory as other than provisional suggestions for the ordering of phenomena. The subsequent formulations of quantum mechanics and especially the thoroughgoing statistical interpretations were to him philosophically and esthetically repugnant.

The Einstein-Bose statistics and the Einstein condensation phenomenon were his last important positive contributions to quantum theory. His subsequent role with respect to quantum theory was that of a critic. He applied the force of his great imagination to the construction of imaginary experiments which involved the theory in seemingly paradoxical and contradictory predictions. The resolution of these paradoxes, chiefly through the efforts of Bohr, served to refine and clarify the principle of complementarity but left Einstein unconvinced.

His real love was the theory of fields, which he pursued with unremitting vigor to the very end of his more than 50 years of active scientific life. This preoccupation is to a large degree the key to his scientific personality. The theory of general relativity was constructed on the basis of a physical observation of the equivalence of inertial and gravitational mass under certain simple circumstances. Beyond that, his guiding principles were his esthetic and philosophical urge for simplicity and symmetry. His intuition and taste led him to believe that the equivalence principle was true in general, and that the equations of physics must be covariant in all systems of coordinates. With these guidelines and with the use of mathematical tools already at hand, he built a theory of gravitation and of the structure of the cosmos.

Like a mystic who has had a divine illumination, Einstein in his search for the ideal could be satisfied with nothing less than a theory which would encompass all phenomena—atomic and cosmic. He once remarked to me in a discussion concerning the newly discovered meson: "We already know that the electron is quantized in charge and mass. Should not this be enough empirical information for a theory of matter?" It was a goal of this grandeur that drove him in his search for a unified field theory.

Einstein was a unique personality. He was not attracted by fame or fortune nor swayed by the opinions of the majority. He knew his talent and guarded it jealously against outside interference. Although fearless in support of any cause he considered worthy, he gave only so much of himself and no more. Physics was his life, and he lived it according to his own lights, with complete objectivity and integrity.

He was the prince of physicists, and the imprint of his mighty strides will give direction to his beloved science for generations to come.

—I. I. Rabi

THE YOUNG EINSTEIN posed for the photograph on the opposite page in 1905. He was 26 and a clerk in the Swiss patent office. This was the year of his greatest productivity. In 1905 he made a great contribution to the quantum theory and published a paper entitled "On the Electrodynamics of Moving Bodies." This paper set forth the special theory of relativity.

Experimental Psychoses

When the drug called LSD is administered to human subjects, it produces the symptoms of psychosis. The phenomenon provides a remarkable new tool for the investigation of psychotic states

by Six Staff Members of Boston Psychopathic Hospital

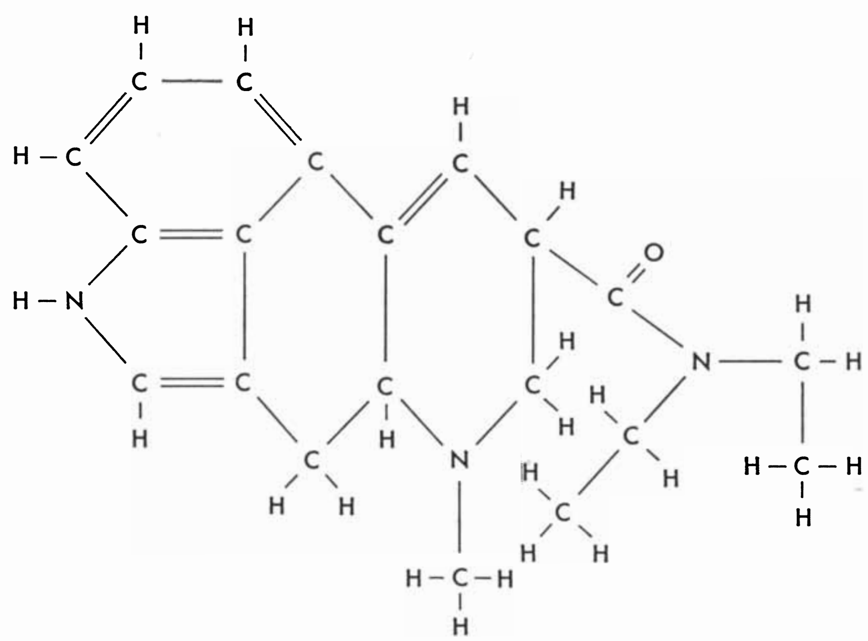
In the spring of 1943 a Swiss chemist, Albert Hofmann, while working with a chemical in his laboratory one day, was overcome by peculiar mental sensations. He became restless, felt disembodied, could not concentrate on his work. Fantastic images of extraordinary plasticity and kaleidoscopic coloring flitted through his mind. In a dreamlike state, he left the laboratory and went home. Correctly connecting his disturbance with the chemical he had been preparing, Hofmann conscientiously recorded every sensation. His description was the beginning of a remarkable series of discoveries.

The chemical that so affected Hofmann was a derivative from ergot, a fungus that grows on rye. The derivative is called d-lysergic acid diethylamide tartrate, or LSD for short. Hofmann's account indicated that the drug first acted on the autonomic nervous system and then produced psychotic symptoms. The discovery was intensely interesting to psychiatrists. Not only did it show a definite link between a physiological disturbance and mental changes, but it suggested that here at last was a drug of which investigators of mental illness had long dreamed: a drug which would produce experimental psychoses for study in the laboratory.

Many of man's diseases (yellow fever, diabetes, tuberculosis and a host of others) have been brought under control by the classic method of producing the disease experimentally to study its cause, process and cure. When we know enough to be able to create a disease, we are closer to its cure. With a drug capable of creating temporary psychoses equivalent to the states of psychotic patients we could accomplish many things: (1) learn to understand what a psychotic person is feeling and thinking; (2) study what mental changes take place as a psychosis develops; (3) relate the psychological changes to physiology and body chemistry; (4) test various treatments.

Since 1949 we have been studying the effects of LSD at the Boston Psychopathic Hospital. The research began with no elaborate plan, but after some preliminary observations we undertook a systematic investigation of the reactions of various types of subjects under various conditions, together with certain physiological and biochemical studies. So far we have examined the responses of more than 100 healthy volunteers and a number of psychotic patients.

The studies led to a new chemical concept of psychosis. Our observations tie in strikingly with the findings of Daniel H. Funkenstein at our hospital concerning the roles of adrenalin and nor-adrenalin in the emotions [see "The Physiology of Fear and Anger," by Daniel H. Funkenstein; Scientific American, May]. Dr. Funkenstein has shown convincingly that people who repress their anger liberate an abundance of the adrenalin-type substance and become depressed, while those who act out their anger release more nor-adrenalin. Our experiments showed that LSD affects mainly the adrenalin system. One interesting case was that of a lobotomized



CHEMICAL STRUCTURE of LSD is shown by this formula. LSD stands for d-lysergic acid diethylamide tartrate. It is a derivative of ergot (*see photograph on the opposite page*).

patient. When she was given LSD, she reverted to her pre-lobotomy depression. As the effects of the drug wore off, her agitation and depression subsided and she recovered the marked improvement she had shown after her operation.

Other studies related the psychotic state to the complementary functioning of the pituitary and adrenal glands, commonly thought of as the "pituitary-adrenal axis." Hudson Hoagland and Gregory Pincus at the Worcester Foundation for Experimental Biology demonstrated that LSD reduces the output of inorganic phosphates in the urine—a situation usually characteristic of schizophrenics—while the pituitary hormone ACTH increases this output.

In the experiments with normal subjects, a standard dose of LSD was given and the subject's reactions were carefully recorded for a number of hours, both by the person under the influence of the drug and by observers. On the average the major effects last for six hours. Within an hour after taking the drug, the subject shows a number of physical symptoms—restlessness, tremor, weakness, sweating, sensations of heat and cold. These persist without much change throughout the six hours, but the mental effects progress through a series of different stages. At first the subject has feelings of irritation, hostility, anxiety and apprehension, such as any normal person may experience under stress. In the second hour he begins to lose touch with reality and show psychotic symptoms. The subject withdraws into himself and is overcome by apathy, lethargy and confusion. He feels that something strange has happened, that things seem different. He may have the sensation that he does not exist or that parts of his body have altered form; one subject felt that there was nothing between his hip and his foot, although he knew perfectly well that his thigh and leg were intact. All sorts of visual illusions appear, and the subject commonly has the illusion of a metallic taste in his mouth. His thoughts slow down. He becomes more or less inarticulate, apparently because he cannot put into words the unfamiliar ideas and strange sensations he is experiencing. He may smile at inappropriate times; occasionally a subject laughs against his will. Often there is a peculiar change in the sense of time: though the subject may know quite well the date and time of day, it seems to lose its meaning, and he may feel himself "out of time." During the period of unreality the subject may experience a recognizable mood, such as depression,

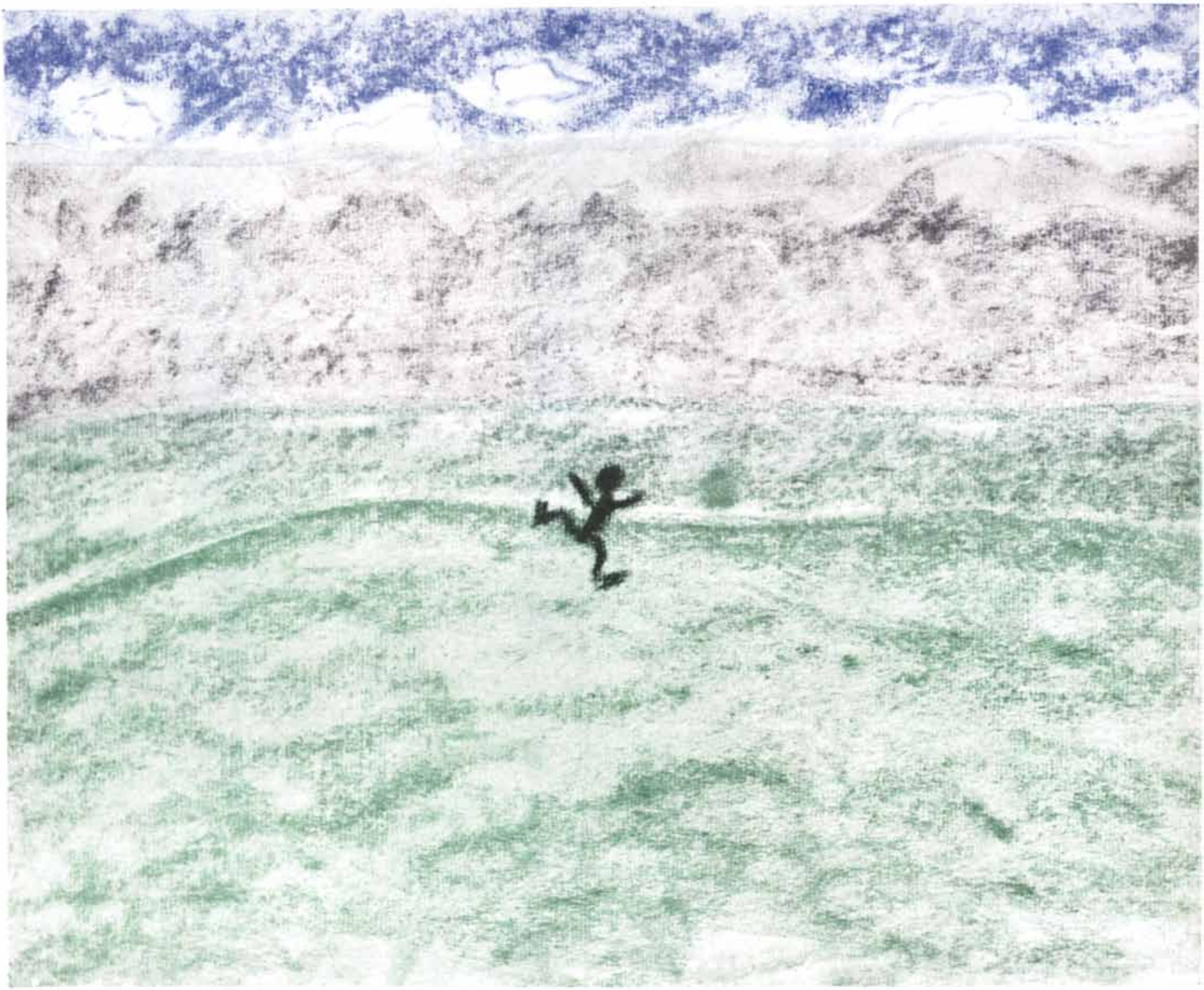
ERGOT is a fungus that grows on rye. At the left in this photograph is a healthy head of rye. At the right is a head infected with ergot. The ergot appears as brownish-black bodies.

elation, anxiety or anger, but even this emotion has a vacuous quality.

In the fourth hour after the drug was taken, the psychotic symptoms begin to decline rapidly. In the sixth hour the early symptoms of irritation, hostility and anxiety return. Then the effects of the drug subside and by the tenth to the twentieth hour the subject becomes completely normal again.

We tested the changes of personality of a number of LSD-drugged subjects with the Rorschach, Draw-a-Person, Thematic Apperception and Wechsler-Bellevue tests. Of 29 subjects so tested, all but two changed significantly in at least one major area of personality, such as perception, cognition or emotion. The drug usually impaired the ability to concentrate and to make complex associations and abstractions. It narrowed the subject's perceptual field to those parts of the environment close to him. It reduced the capacity to organize and interpret experience and diminished concern about the past and future; the subject focused primarily on the immediate situation. He lost his usual discrimination between himself and others: he frequently attributed his own feelings to other persons or to physical objects. Sometimes he acquired an unusual insight into his own and other people's underlying attitudes.

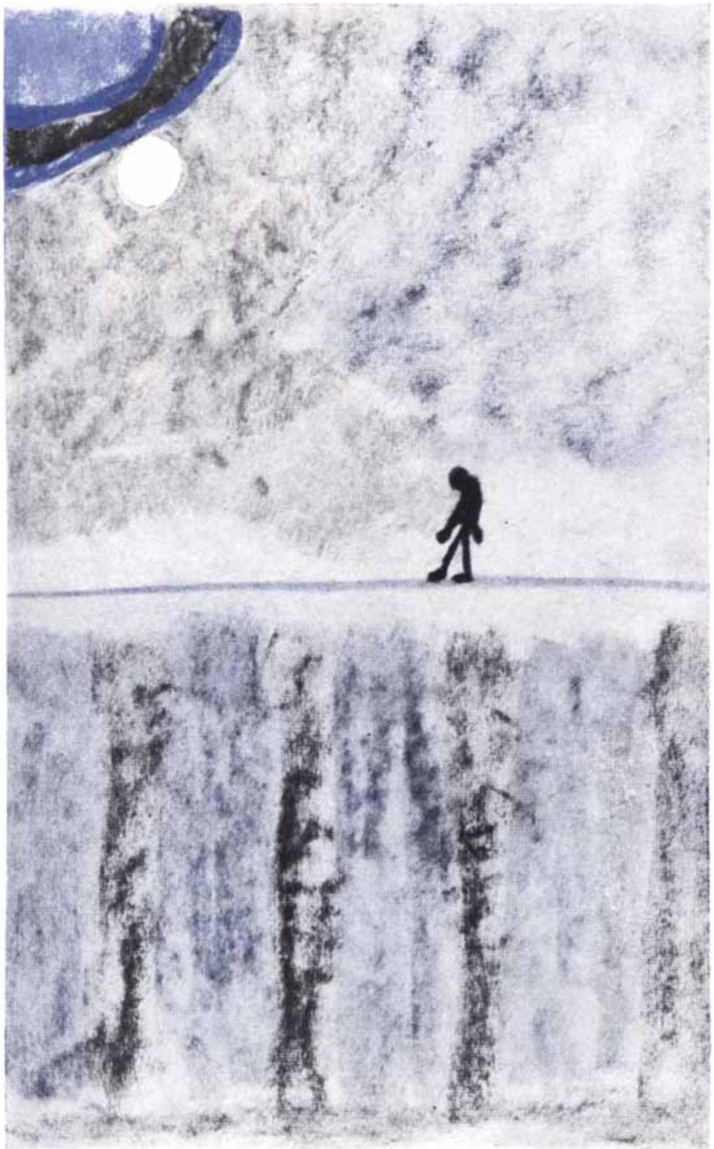
To help the subjects express the feelings they had experienced under the drug, which they found so difficult to communicate, we asked them to draw pictures afterward. These pictures vary considerably in the feeling tone expressed. One clearly evokes sadness and dejection; another, warmth and togetherness with people; still another, confusion. New subjects shown these



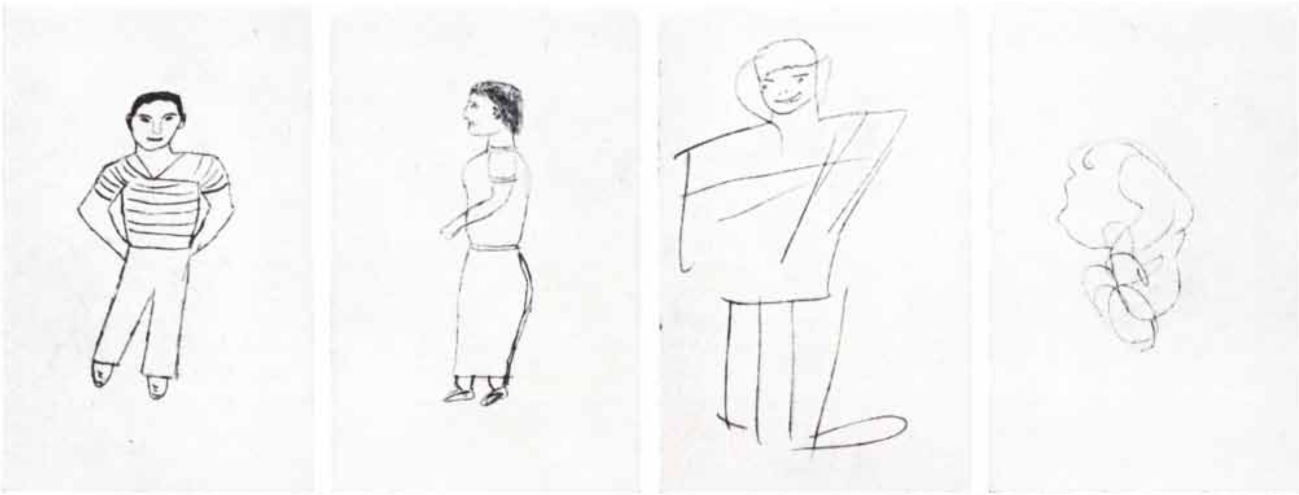
THREE STAGES of the reaction to LSD are illustrated by these three drawings by the same subject. The first picture expresses a stage of euphoria. The description of the picture by the subject was paraphrased as follows: "The figure is happy and, above all, free. He has thrown off all cares, problems, ugliness, anger and fear. The world around him is bright and beautiful. Beyond the next rise in the field is that which he wishes more than all else. He feels liberated and unlocked within, integrated, realized." The second drawing expresses a brief but intense stage of transition. The description was paraphrased: "The image of the dancing figure is retained as a memory only, and one about to disappear. The feeling is one of loss. A loss of perfection, a departure from Eden. The intensity of the pictures usually found them helpful in clarifying their feelings and verbalizing their experiences.

From the social point of view, the LSD experiments serve two purposes. Firstly, they make it possible to study experimentally the effects of the psychotic state on social behavior. Secondly, they afford a means of comparing the reactions of people of different social status or in different social situations. The experiments have emphasized the importance of social and cultural factors in mental illness. For instance, the drug caused more severe disturbances of social behavior in younger people and those with less formal schooling than in those who were older or had more education. Another comparison was made between two groups of volunteers, one consisting of workers in the hospital, the other of outsiders. The hospital staff members showed more response to the drug, were able to describe their symptoms better and carried a more lasting memory of the experience. One reason was that they entered into the experience more willingly because they wished to learn the feelings of psychotic patients; another was that they were in their usual environment and were more conscious of the departures from their normal behavior in that setting. They were under greater stress than volunteers who merely came into the hospital for an experiment.

The drug-induced experimental psychosis generally changed the subjects' social behavior in a marked fashion. They tended to withdraw from other people, to express hostility and to seek support and reassurance. The intensity of their symptoms varied with the stress under which they were placed. When they were questioned, examined or



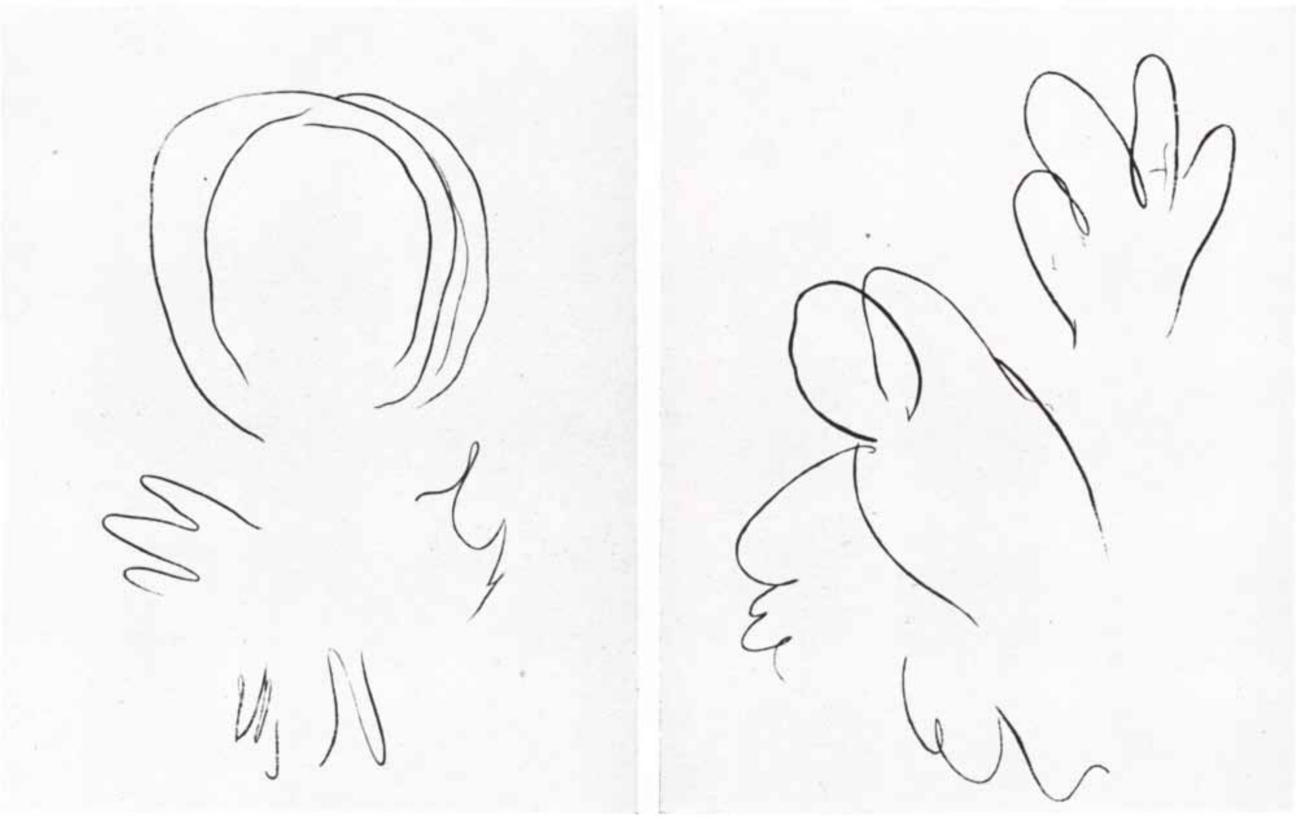
feeling is extreme and expressed through the lack of any environment. The enveloping storm is one of overwhelming feeling, at first nostalgia, then grief, then sheer feeling with no describable content. All of this takes place within. The face is a mere mask which has little meaning. The eyes are closed for this reason. The head is a dead shell, the environment does not exist, the feeling comes from without as well as within and replaces the environment." The third drawing expresses a stage of depression. The description was paraphrased: "The figure is walking on an infinite narrow walk, with an abyss on either side. The sun is a meaningless glare. The feeling is emptiness, apathy. The blotch (*at upper left*) indicates that the figure is aware of the sun, but unable to grasp it."



MAN AND WOMAN at left were drawn by a male subject before an LSD experiment. Drawings at right were made by the subject when he repeated the performance under LSD. He said: "I'm up in the universe. . . . I talk to a person and their face escapes away."

given work tasks, without any compensating social support, their symptoms became more severe. When a subject encountered a person who seemed hostile or too inquisitive, he perceived a change in the person's appearance, creating an unfavorable caricature. On the other hand, when the other person was very friendly, the subject distorted him in an excessively favorable light. The subject was least likely to see the other person as a caricature when the other person was understanding or gave him emotional support.

When subjects received the drug in a group, there was a great deal of joking and laughing among them—often seemingly meaningless. Even subjects depressed by the drug joined in this apparent hilarity, as if involuntarily. Anxiety, distortions of people and inappropriate behavior decreased significantly. Yet all these subjects had just as severe feelings of unreality and confusion as those who



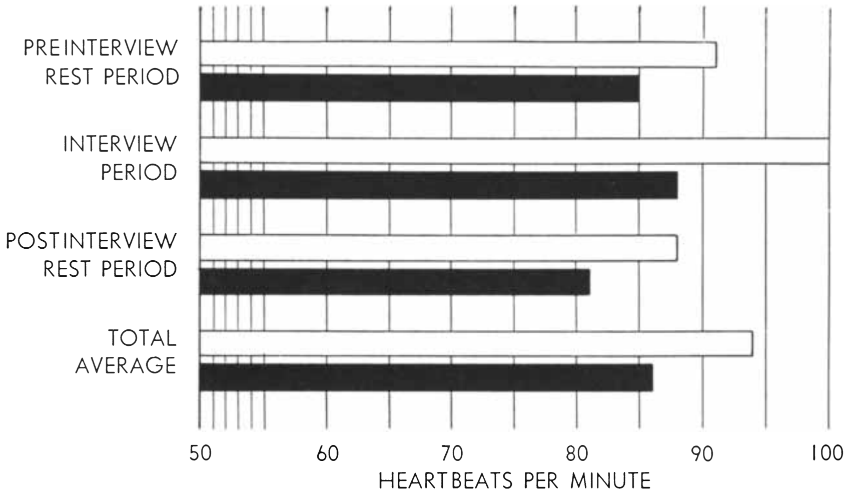
SELF was drawn by another male subject under LSD. He was asked by the investigator: "Draw how you feel. Draw yourself." The subject made the drawing at the left and said: "This is the way I feel. I'm confused. This [the head] is the most important part. I feel apart." One minute later the subject made the drawing at the right and said: "This is how I feel now. My hand is the biggest part." The investigator then asked: "What about your feet?" The subject replied: "Feet are not important. They are pretty pedestrian."

received the drug alone. Evidently group participation relieved the tension. Subjects also showed a decrease in symptoms when attempts were made to aid them, either informally or by planned psychotherapy.

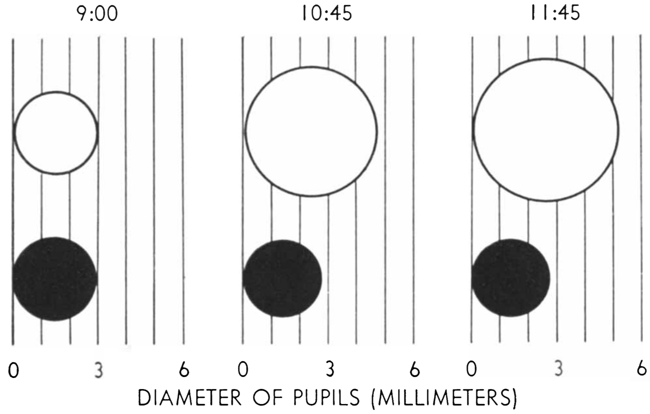
The creation of experimental psychoses with lysergic acid thus opens the way to studying treatments and the nature of mental illness. We can see the various defenses a subject brings into use, one after another, to protect himself from stressful experiences. We can relate the defense mechanisms to the individual's basic personality structure, as determined before the experiment. We can see the similarities of these defenses to those commonly exhibited by psychotic patients, especially schizophrenics. We can detect stressful situations of which hospital staffs have not previously been aware. And we can determine what treatments and what experiences give the most support to a patient and are most effective in reducing his symptoms. Among other things, the experimental psychosis offers a means of testing the effectiveness and studying the action of therapeutic drugs such as the new chlorpromazine and reserpine. For the first time we can investigate experimentally the many relationships between the psychotic state and the body's chemistry and physiology.

Most important, however, is the insight that lysergic acid gives into the mind and feelings of a person afflicted by mental illness. We can telescope a severe psychotic reaction into a period of six to 12 hours and follow the emotional disintegration step by step. The staffs of mental hospitals have struggled year by year to get a deeper understanding of what their patients are actually feeling and thinking. Only in this way can they come into communication with the patient and help him. Now that they can experience themselves something approaching the feelings of their patients, they will be able to communicate better. Moreover, mental illness will no longer be so strange or mysterious; there will be fewer barriers between the sick and the well.

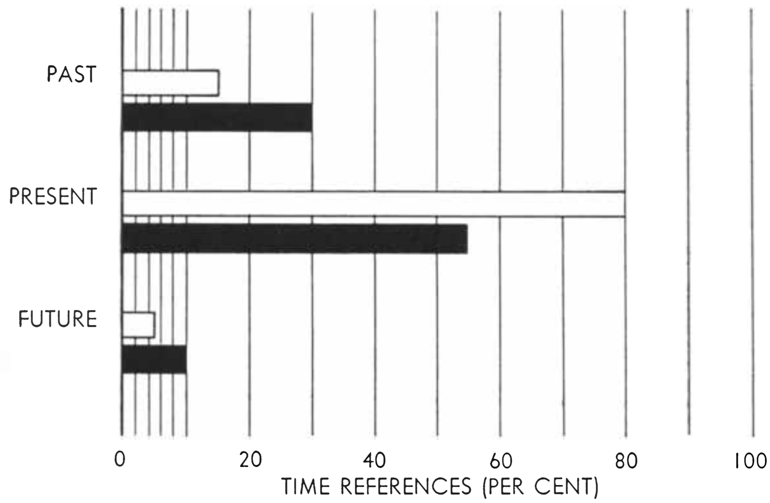
Thus the lysergic acid experiments have greatly broadened our approach to mental illness. They also highlight the advantages of team research combining many disciplines. In this project physiologists, psychologists, clinical psychiatrists and sociologists are all working together on the great problem of mental health.



HEART RATE increases under LSD. The open bars indicate the heart rate of subjects to whom LSD has been administered; the black bars, subjects to whom no LSD has been given.



PUPIL SIZE gradually increases under LSD. The open circles indicate, over two hours and 45 minutes, the pupil diameter of a subject to whom LSD had been given. The black circles show at the same intervals and the same light the pupil diameter of the subject without LSD.



TIME SENSE is also affected by LSD. Here this is plotted on the basis of references to time in the Thematic Apperception Test, in which the subject is shown a dramatic picture and asked to tell a story about it. The open bars represent time references by 29 subjects to whom LSD had been given. The black bars represent time references by the subjects without LSD.

RADIO WAVES FROM THE SUN

To radio "eyes" the Sun is usually a dim object, but occasionally it is brilliant. These blasts of radio energy are associated with the streams of corpuscles that cause magnetic storms on the Earth

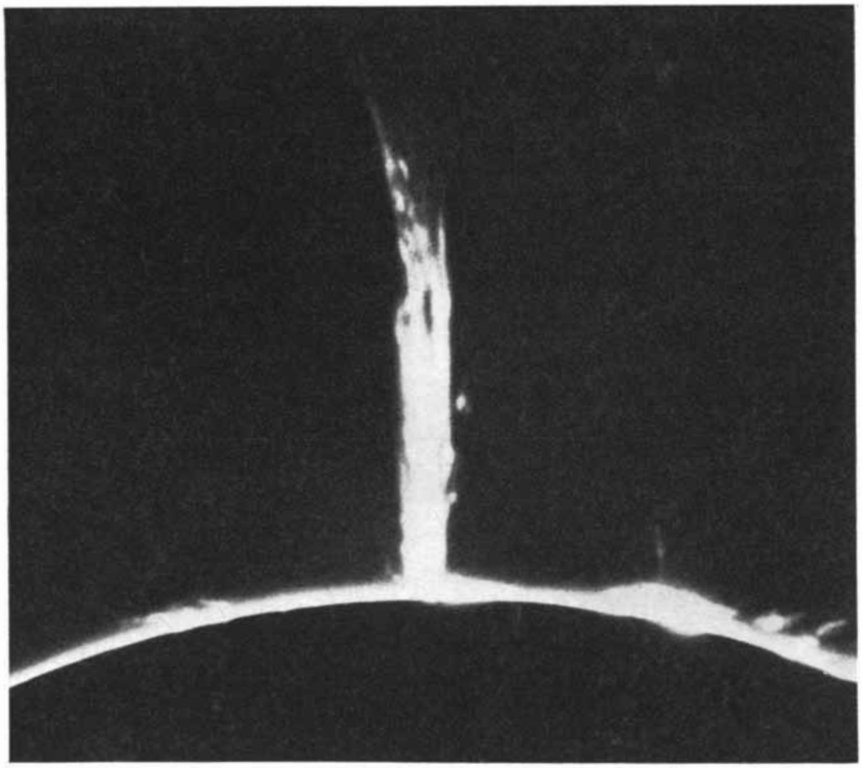
by J. P. Wild

In the new science of radio astronomy the Sun has a special importance. It is the only star whose radio emissions we can study, because the resolution of radio telescopes is not sharp enough to single out the broadcasts from individual stars farther away. Listening to the radio messages from the Sun, we have begun to learn new things about that body—of all stars the one with which we are most vitally concerned.

If we looked at the Sun with eyes attuned to radio waves, we would see an object very different from the familiar ball of fiery gas. The Sun would be a large, irregular patch in the sky, three or four times as big as the visible ball. What we would be seeing is the vast, tenuous corona, ordinarily invisible except during an eclipse. And we would see with vivid brilliance some of the details of the spectacular action that is taking place in the Sun's atmosphere.

Most of the time the radio Sun is not particularly prominent in the sky; it appears rather less prominent, in fact, than the Milky Way. But occasionally it flares up in a burst of dazzling brilliance, which for a few seconds, or sometimes for 10 or 20 minutes, makes the radio Sun a thousand times brighter than before. The burst erupts from a small patch that moves across the Sun's face as we watch it with radio eyes. What we are witnessing is the ejection of a mass of material from the Sun into space—matter which is invisible to light-tuned eyes because its atoms are stripped of electrons, but which can be seen by radio eyes because it emits radio waves as it reacts with electrons and ions in the corona.

It is from these bursts of emission that radio astronomers have obtained most of their new information about the Sun's activities. To interpret the radio observations, we must first recall what optical investigations have told us about the Sun.



SURGE PROMINENCE, a jet of matter shot out of the surface of the Sun, often accompanies a flare. This photograph was made at the High Altitude Observatory of the University of Colorado with the coronagraph, an instrument that eclipses the disk of the Sun.

Ever since the 17th century men have observed spots on the Sun's surface—black, roughly circular regions which sometimes cover a considerable portion of the disk and which move across the visible disk as the Sun rotates. The spots are regions of relatively low temperature and intense magnetic fields, and often there are great centers of activity above them. During eclipses of the Sun (natural or artificially produced with the coronagraph), it is possible to see gigantic "prominences" extending from these active centers for tens of thousands of miles into the Sun's atmosphere. Photographing the Sun with special color filters, we can also see clouds of excited hydrogen atoms streaming from the active centers. Sometimes a hydrogen cloud suddenly brightens and becomes a "flare," which lasts for 10 to 20 minutes. At the same time a jet of luminous material may shoot out from the

Sun and then fall back again. We call this jet a "surge prominence."

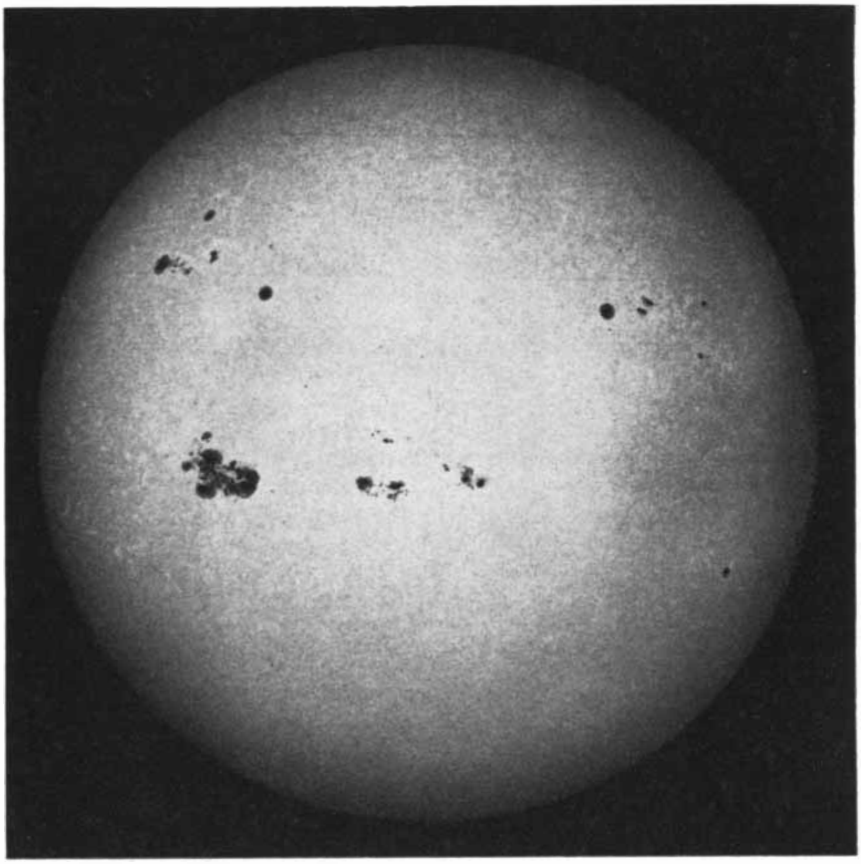
The effects of the Sun's flares travel far and fast through space; they are quickly felt on the Earth. They cause great magnetic storms in the Earth's atmosphere and shower us with cosmic rays [see "Corpuscles from the Sun," by Walter Orr Roberts; SCIENTIFIC AMERICAN, February]. After a large flare the first effect—an increase in cosmic-ray intensity—reaches the Earth in about one hour. If it is caused by a stream of particles bridging the 93 million miles from the Sun to the Earth, they must travel at about 30,000 miles per second—about one fifth the velocity of light. A day or so after the flare other effects arrive: magnetic storms, and often a brilliant aurora in the Northern or Southern sky. The slower stream of particles presumably responsible for these delayed effects has traveled from the Sun to the Earth at about 1,000 miles per second.

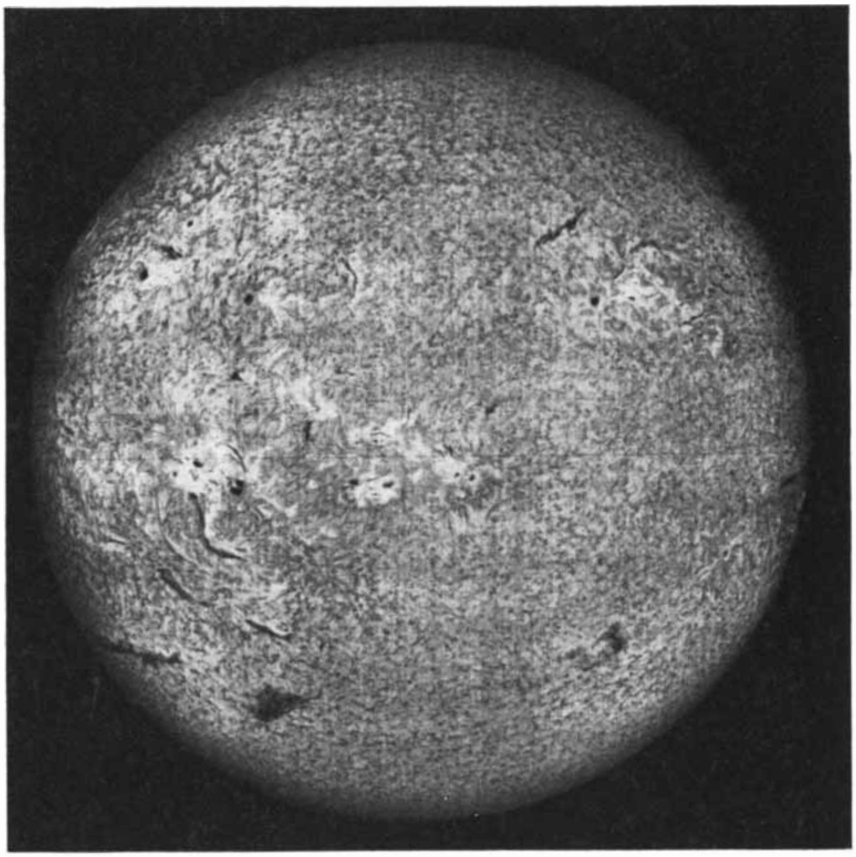
The postulated corpuscles are invisible. They cannot be detected by optical astronomy, and their existence was first inferred merely from circumstantial evidence: namely, the fact that effects on the Earth which apparently were due to particles came soon after a flare on the Sun. But radio astronomy has now detected the particles and actually succeeded in tracking them on the Sun.

Like many fundamental discoveries, the discovery of radio bursts from the Sun was made accidentally. It occurred in England during the air battles of World War II. In the last three days of February, 1942, radar operators watching the skies for enemy airplanes noticed an unusual form of interference which intermittently jammed reception. The interference came only during the daytime. J. S. Hey of the British Operational Research Group investigated and traced the source of the disturbance to the Sun. He observed that the radio emissions from the Sun were associated with a great flare and an accompanying magnetic storm on the Earth.

When Hey published his discovery after the war, radio astronomers began an intensive radio scan of the Sun. Using sensitive radio receivers with special directional antennas, they recorded the Sun's normal radio emissions and its sudden bursts. Its patterns of activity were delineated by pen recorders tracing curves on paper. With a loudspeaker the Sun's broadcasts could be heard clearly: a burst makes a rushing noise, rather like a gust of wind.

The recordings soon showed a strik-





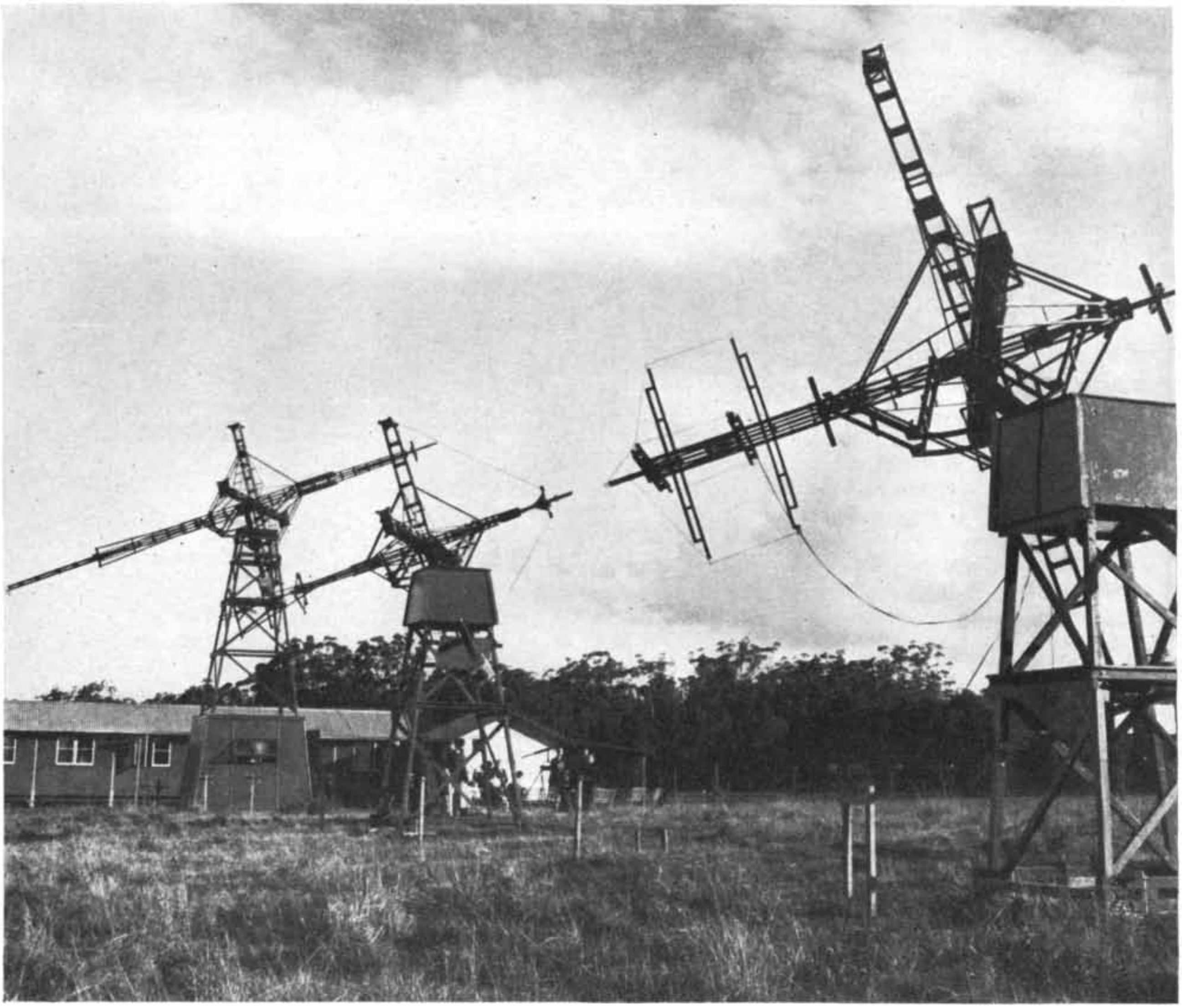
SUNSPOTS are the most prominent features of active regions on the Sun. The photograph at the top was made with white light; the photograph at the bottom, with the red light emitted by hydrogen. The latter shows the structure of matter in the lower solar atmosphere.

ing peculiarity. When a radio burst from the Sun was recorded simultaneously at two different frequencies, the two curves were very different. This at once suggested an explanation which was to prove extremely valuable in the radio exploration of the Sun: the two broadcasts must be coming from different depths in the corona! In other words, different radio frequencies have different penetrating power into the corona. At 30 megacycles we "see" only part way down into the outer shell of the corona (about one million miles above the Sun's visible surface); at 100 megacycles we see down to a layer some 50,000 miles above the surface; at higher frequencies we see still deeper. Thus we can systematically explore all levels of the corona and follow the development of a burst from the depths.

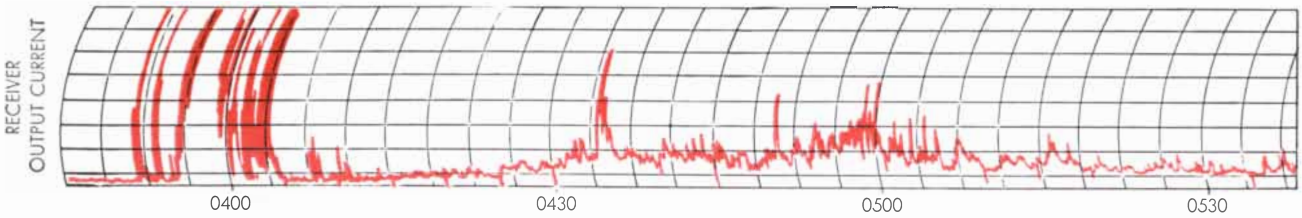
This selective penetration stems from the fact that the electrons in the corona thin out away from the Sun. Higher radio frequencies can probe farther before encountering electron densities great enough to stop them. It is rather like the optical case: when light will not penetrate a substance, we use waves of higher frequency—X-rays.

To explore the Sun's corona in depth, our group in the Australian Commonwealth Scientific and Industrial Research Organization constructed radio "spectroscopes" which could record emissions from the Sun over a wide spectrum of radio frequencies. Our present instrument covers the range from 40 to 240 megacycles. Signals from the Sun, picked up by a broad-band antenna, are fed into a tunable receiver which is swept over the whole band rapidly by an electric motor so that it records the signals received at all frequencies within half a second. Each spectrum is displayed on a cathode-ray tube in the form of a thin line of varying brightness, the brightness of each point on the line indicating the intensity of the signal at that frequency.

We now have recordings with this instrument of the Sun's radio broadcasts over a period of several years, and the bursts fall into two distinct patterns. The more common type of burst is a brief surge of intensity lasting only a few seconds; we call this a "radio flash." During a week of intense activity on the Sun, there may be 100 flashes. The second type, far less frequent, is a burst lasting several minutes; this is called an "outburst."



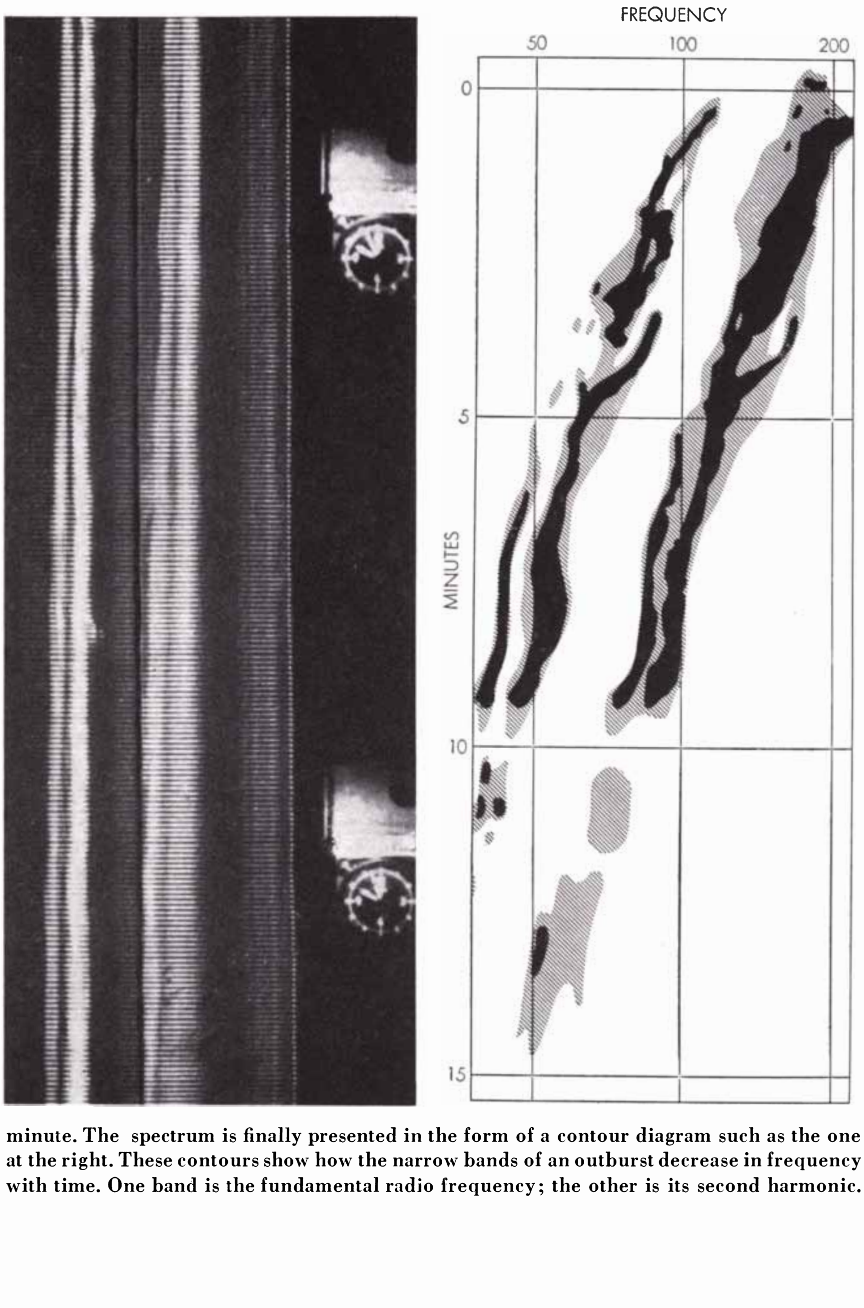
ANTENNAS near Sydney, Australia, receive solar radio energy over the continuous frequency range from 40 to 240 megacycles per second. The actual spectrum of a solar "outburst" is shown at the left on the opposite page. Each of the fine horizontal lines represents a scan of the frequencies from 40 to 240 megacycles. The distance between the two clocks corresponds to an interval of one



OUTBURST of solar radio energy is traced at 100 megacycles by a pen recorder. Intervals of half an hour are indicated by the numbers at the bottom of the record. The outburst starts suddenly, continues violently for 25 minutes and then proceeds at a lower level.

The outbursts, which come only during a solar flare, show a characteristic pattern on the recorder: the tracings are slantwise bands which indicate that the radio frequency of the signal decreases as the outburst progresses [*see illustration at lower left on this page*]. Furthermore, the bands are duplicated, one at just double the frequency of the other: evidently one is the second harmonic of the other.

This picture can be explained in the following way. Let us suppose that a cloud of ionized particles is shot out from the Sun. As it travels up through the solar atmosphere, it disturbs successive levels of the atmosphere's gas of electrons. At each level the excited electrons vibrate in unison at the critical frequency determined by the density in their region. They act like radio transmitters, emitting radio waves at the critical frequency and at harmonics of this frequency. When the cloud of particles shooting upward reaches a thinner level, the electrons there begin vibrating, but their critical frequency is lower because the density is lower. Thus they broadcast at a lower frequency. In this way we can trace the movement of the cloud up through the Sun's atmosphere, and if we know the critical frequency at each level we can determine the height of the cloud at any moment and the speed at which it is moving. In tracing the passage of the cloud, or burst, upward through the corona, it is as if we were tracking an invisible speedboat rushing across an invisible lake. Although we can see neither the boat nor the lake, we can follow the boat by the oscillations of the waves set up in its wake.



minute. The spectrum is finally presented in the form of a contour diagram such as the one at the right. These contours show how the narrow bands of an outburst decrease in frequency with time. One band is the fundamental radio frequency; the other is its second harmonic.

Our radio measurements show that the Sun's large outbursts invariably travel up through its atmosphere at a speed between 100 and 1,000 miles per second; it will be recalled that the corpuscles reaching the Earth from the Sun travel at about 1,000 miles per second through space. The flashes (short-lived bursts), on the other hand, usually move at a speed of about 30,000 miles per second, as measured by our radio tracking technique. This speed corresponds to that of the particles which arrive at the Earth about an hour after a flare.

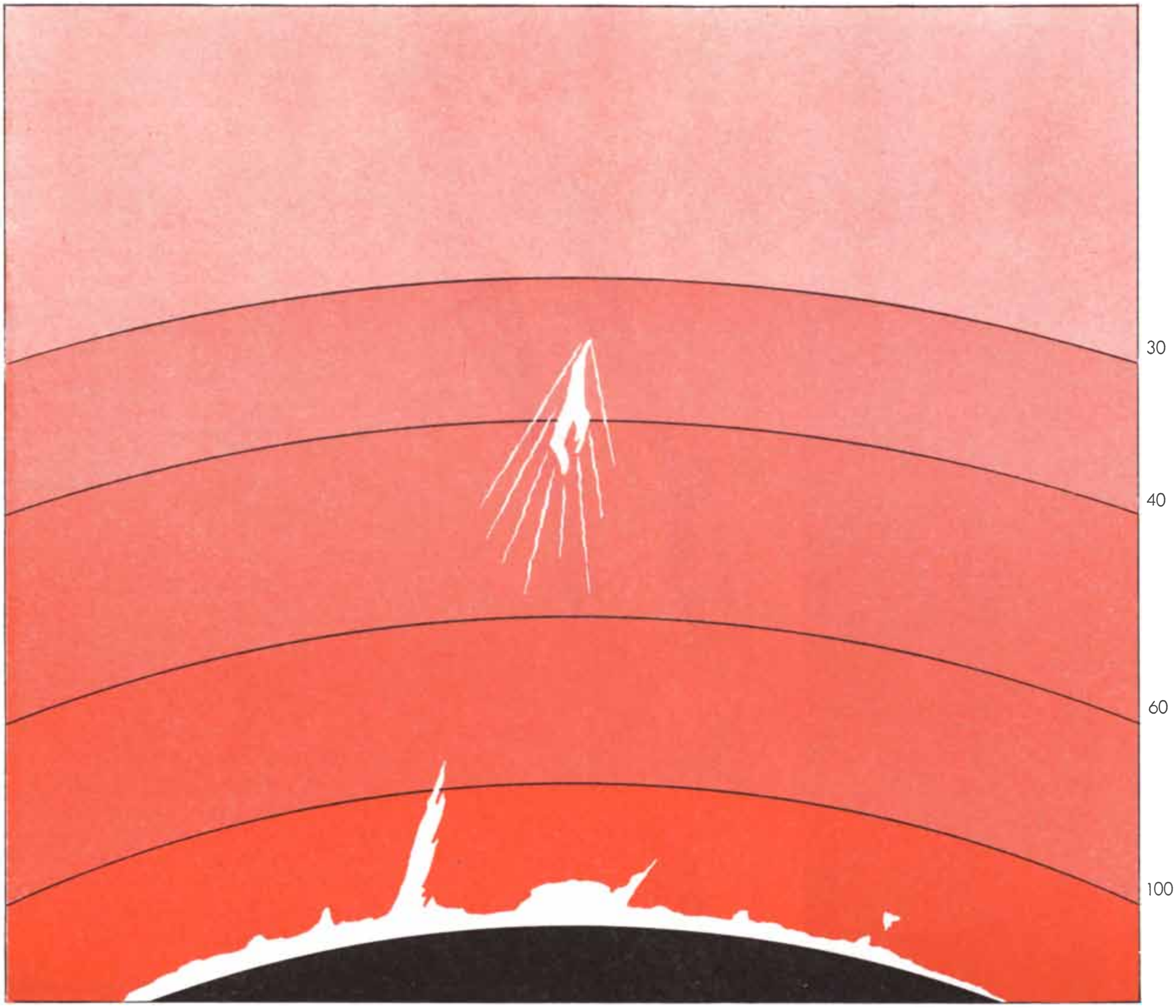
During a solar flare there is often a series of radio flashes in rapid succession at the beginning, and then after two or three minutes the longer-lived outbursts arrive in the corona—like the rumble of thunder after lightning. Perhaps the analogy with terrestrial thunder may not be far wrong.

The remarkable train of events which takes place at the time of solar flares, influencing not only vast regions of the solar atmosphere but also the Earth's atmosphere 93 million miles away, poses one of the most intriguing problems of solar physics. The radio results suggest that the whole phenomenon is the result of a violent explosion near the surface of the Sun. Just what this explosion is we do not know—perhaps a natural hydrogen bomb, perhaps a gigantic electrical discharge. The explosion immediately ejects clouds of fast particles at speeds approaching the velocity of light. At such high speeds the atoms are stripped of their electrons (making them invisible) and are channeled along lines of magnetic force into jetlike streams. These streams reach the outer layers of the corona within seconds of the explosion; their passage through the corona is signaled by the brief radio flashes. When they escape from the Sun's influence and reach our planet, they may cause an increase in cosmic rays.

Simultaneously with the ejection of the fast clouds, a shock wave from the explosion starts to propagate through the solar atmosphere, carrying in its front an avalanche of trapped particles. These also form themselves into an invisible, jetlike stream. Their speed is between 100 and 1,000 miles per second, which is in the supersonic range, as the velocity of sound in the corona is about 100 miles per second. When this stream, after some minutes, reaches the outer coronal layers, it generates an outburst of radio emission. Eventually the stream escapes from the Sun and fans out into space. After about one day of travel some of the particles reach the Earth and cause an aurora and a magnetic storm on our planet.

Meanwhile, at the seat of the upheaval, incandescent hydrogen from the Sun's atmosphere has been sucked up in the void left in the wake of the great mass of material ejected in this stream. It follows the path of the stream and gives rise to a surge prominence, which shoots up and eventually falls back into the Sun. The shorter-lived flare within the Sun's atmosphere is a relatively dense region of hydrogen made highly incandescent as a result of the intense heating and ionizing radiations generated by the explosion.

In suggesting this plausible sequence of events to account for the various optical and radio accompaniments of a solar flare, it has been necessary to use imagination and guesswork to fill in the gaps of what is known experimentally. It is to be hoped that in years to come close cooperation between optical and radio astronomers will yield the whole story.

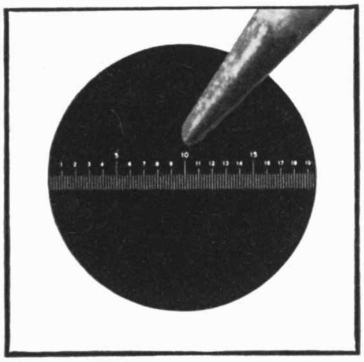


SPECTRA ARE INTERPRETED by this model. The blob of white in the center represents a cloud of corpuscles shot out from an active region on the surface of the Sun. Each layer of the solar atmosphere through which this cloud passes is thought to emit radio waves of a characteristic frequency. The frequency of each layer in megacycles is roughly indicated by the numbers at the right.

Kodak reports to laboratories on:

improving reticle yield . . . a lightweight among the fats . . . a new bench-type contour projector

The uses of immodesty



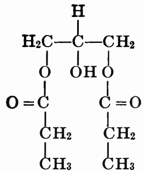
That is an ordinary pencil point you see over this reticle, which was made to go into the eyepiece of an optical instrument. As reticles go, it's a rather fine one but very far from crowding the more than 1,000-line-per-millimeter resolving power which we quote for the *Kodak High Resolution Plate* on which the reticle was made. For a visual conception of 1,000 lines per millimeter, imagine nearly twice as many lines as seen on the above reticle—inscribed across the diameter of the dot on this "i."

Note we say "more than" 1,000 lines per millimeter. We have never been able to devise a situation that drives the resolving power of these plates to its inherent limit. It's too difficult to form and lay down an optical image that fine. The widths of lines or spaces in such a pattern would equal the wavelength of blue light itself!

We crow so because we have just set up new and costlier manufacturing and inspection facilities for *Kodak High Resolution Plates* in order to keep them freer of scratches and specks than was possible when they were known as "Type 548-GH" and were worked in with the production of experimental plates. The special facilities should result in higher yields of high-quality reticles, but they must be kept busy or it's no go. Therefore, we crow to attract more users so that we shall continue to have something to crow about. (Business, too, has its subtleties. Everybody gains, nobody loses.)

If you have use for these plates, write for details to Eastman Kodak Company, Special Products Sales Division, Rochester 4, N. Y.

Artificial fat



To one on the threshold of an investigator's career, what a chance *Dipropionin* offers to flex the muscles and dry the wings!

Think of it! A most unnatural fat, obtainable, so far as we know, from no other source on land or sea! In this newly added Practical Grade Eastman Organic Chemical (Eastman P7041) he will find monopropionins, dipropionins, and tripropionins, in which the dipropionins take the lead, with glycerine and propionic acid far in the rear. As the bottle ages, its bouquet may well grow less enchanting as hydrolysis adds more of the last-named ingredient. Since Eastman P7041 boils at only 112-114 C under 0.5 mm Hg pressure, the investigator can use conventional laboratory distillation equipment for further purification to his heart's content.

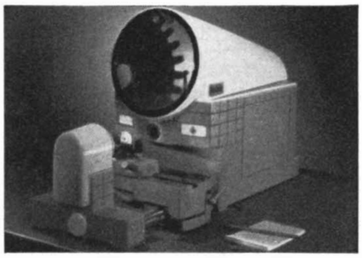
As a partial glyceride, *Dipropionin* might be expected to have interesting interfacial properties. It is notably less miscible with water than is *Diacetin* (Eastman P85). With these physical properties and the odd-length carboxylic chain giving rise to inimical metabolic intermediates, an investigator might look for biological action much different from that of better known fats. In fact, we have a suspicion (only a suspicion, we repeat) that this is a likely place to look for highly reactive free propionyl radicals.

Whether the radicals are free or not, the mobile liquid they may or may not come in costs $6.10 for 100 grams. Our List No. 39 of some 3500 organic chemicals we stock is *free. You get the chemical or the catalog from Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

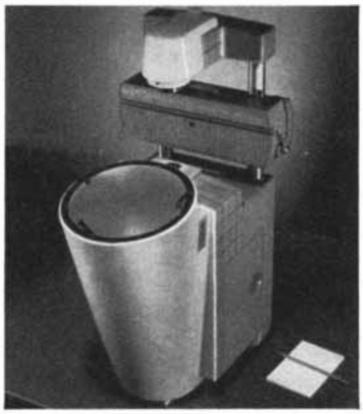
A little one

The contour projector, or optical comparator as some call it, has reached that happy stage where one can mention it to a random industrial audience and be understood without further explanation. This wasn't so as recently as '48, when we came in. That it is now may perhaps be taken as confirmation of our hunch that bold new optical design rather than piecemeal adaptation of the old was what it would take to open this field up. When people found they could magnify objects at 10×, 20×, 31¼×, 50×, 62½×, and 100× all at the same unchanging long working clearance, when they found that images were sharp and reliable all over the screen and contrasty enough to be seen without strain in ordinary room light, then the ideas for routine operations under magnification began to bloom this fair land over.

At San Francisco recently we uncovered the new 8-inch-screen *Kodak Contour Projector, Model 8,* which works horizontally



—or equally well vertically:



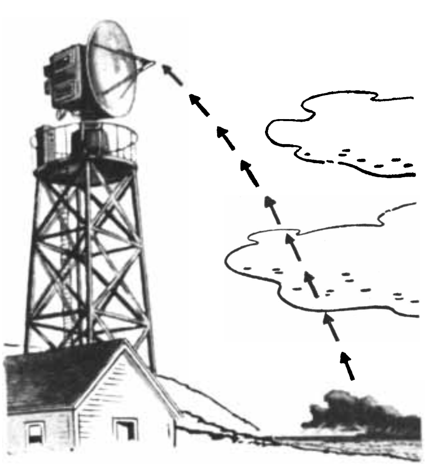
One point that's unusual about it is that whichever way you look, right is right and left is left.

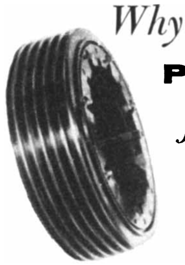
If you want literature or a man to come around and see you about it, write Eastman Kodak Company, Special Products Sales Division, Rochester 4, N. Y.

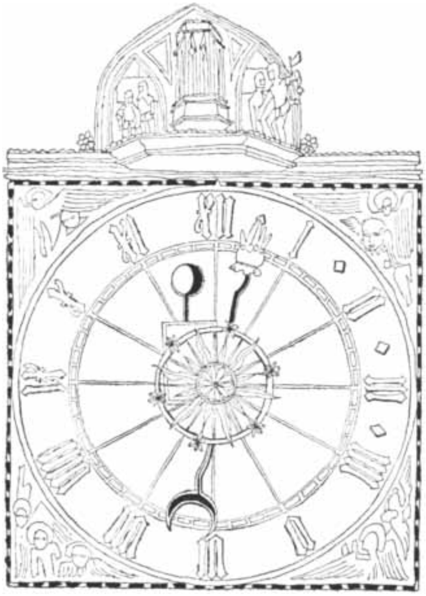
Price quoted is subject to change without notice.

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







Effective, Safe

Although research workers on poliomyelitis prudently cautioned that the war against polio was not over, many of them obviously believed last month that the end was in clear sight. Some authorities discussed the possibility of "eradicating" polio. The National Foundation for Infantile Paralysis began to talk about concentrating on mental health problems.

The 1954 field tests of the "killed" vaccine developed by Jonas E. Salk showed that it was 80 to 90 per cent effective against paralytic polio, said the report of the Evaluation Center at the University of Michigan. But the Center's director, Thomas Francis, Jr., pointed out that no single figure adequately reflects the outcome of the tests because of the great number of variables involved.

The tests were carried out in two ways. In some areas vaccinated children in the first three grades of grammar school were compared with a similar group inoculated with a placebo, or inert fluid; in other areas only second-grade pupils got the vaccine and their polio experience was checked against the uninoculated first- and third-graders. The more strictly controlled placebo study group showed the more favorable results. For the "observed" group the vaccine's effectiveness was from 60 to 80 per cent.

Against the type 1 virus, most common, the vaccine afforded 60 to 70 per cent protection in the controlled group; against types 2 and 3, 90 per cent or more. Separate lots of vaccine varied widely in potency. Salk subsequently stated that the material is now standardized and is more effective than the best batches used last year.

More than 1,800,000 children participated in the trials. In the controlled group some 200,000 were vaccinated, 200,000 got the dummy shots and 339,000 were not inoculated. In the observed group 222,000 were vaccinated. Only 863 reasonably certain cases of polio turned up among the entire study population, and 178 of them were nonparalytic. Among the vaccinated children the rate of paralytic infection was 16 per 100,000; among those who received the placebo, 57 per 100,000.

As to safety, the vaccine used in the tests got a clean bill of health. (All of it had been checked independently by the manufacturers, by Salk and by the Public Health Service.) There was no evidence that it caused polio or that injections increased susceptibility to the disease. Only .4 per cent of those vaccinated had even minor reactions.

The vaccine test was the most extensive field experiment ever undertaken, and its evaluation was an exceedingly complex task. Polio is so rare and often so difficult to diagnose that the number of cases was not far above the minimum needed for meaningful statistical analysis. Among the 400,000 children in the controlled test there were only 148 paralytic cases all told—33 in the vaccinated group. Thus each case had great statistical weight. A few mistakes in diagnosis, failures in reporting or other slips would have altered the results greatly. And the chances for error were numerous. More than 150,000 persons had a hand in the program. There were 1,221,245 separate inoculations in the vaccine-placebo areas. Classification of cases depended on the judgments of individual doctors and physical therapists and on analyses from different laboratories. The Center labored mightily to achieve uniformity and completeness. It established uniform diagnostic standards; it checked laboratory work by having identical check samples analyzed in several different places; its representatives constantly toured the field areas; it pursued each case record, pressing local health authorities until, some four months behind schedule, the last delinquent report was in. Although the procedures were "basically standardized," the evaluation report emphasized, "qualitative and quantitative variation was quite evident" among the different local areas. "Interpretation must, of necessity, accept that fact."

Nevertheless, Francis and his group announced their figures confidently, subject to the express qualifications they attached. They were not presenting "incomplete, preliminary data," they said, but a completed study.

In his article, "Vaccines for Poliomyelitis," in Scientific American for April, Salk mentioned that whatever the outcome of the trials, the killed *v.* live vaccine question would "continue to be an issue among virologists." After the report was issued, several laboratories which have been working on live polio vaccines announced that their research would continue. English public health authorities were reported to prefer to wait for a live vaccine.

Radiation Study

The National Academy of Sciences announced last month that it will undertake a broad study of the effects of atomic radiation on living organisms. Funds will be provided by the Rockefeller Foundation. The Academy's investigators will collect and evaluate the available information, decide what conclusions are now warranted, pick out problems needing further research and initiate the necessary studies. The Academy said it will also "evaluate the availability of information to scientists, physicians and the general public."

A note on radiation effects appeared recently in the English medical journal *The Lancet.* It said that all 22 of the surviving Japanese exposed to fall-out from the 1954 H-bomb test were completely sterile nine months after their exposure. Their sperm counts showed a steady fall after the accident and by December of last year "had in every case fallen to zero." The condition is not permanent, the article said, but may last as long as two years, as it did in some of the Hiroshima and Nagasaki victims.

New AEC Manager

Brigadier General K. E. Fields has been appointed general manager of the Atomic Energy Commission. He succeeds Major General K. D. Nichols (U.S.A., Ret.), who resigned to go into private business.

General Fields, a graduate of West Point, served for a time as assistant to the commanding general of the Manhattan Project. Since 1951 he has been director of military applications for the AEC.

Information

The Federal Government's increasingly stringent censorship of unclassified technical information has alarmed the American Society of Newspaper Editors. "The most disquieting development in this area," according to the Society's committee on freedom of information, "has been the recent obliteration of the line between classified secret material not available to the public and unclassified, technical material never classified at all or officially declassified."

The editors referred particularly to the Office of Strategic Information set up by the Department of Commerce to control publication of nonrestricted material. Last month Secretary of Defense Charles E. Wilson cut down the flow of news from his department. The White House subsequently explained that President Eisenhower felt too much technical information of value to a potential enemy had been published.

"Unless this attitude is clarified," the editors' committee said, "it is bound to have a profound and paralyzing effect upon the flow of information to the American public. . . . If the flow of information on technical material and in other areas is to be diminished to that which involves no risk whatever, cut down to the facts which no potential enemy could ever make any possible use of, the volume will be so infinitely small that the American people will not have the foundation of truth upon which to judge their Government."

Dry Land

A series of international conferences on the problems of arid lands was held last month in Arizona and New Mexico. The United Nations Educational, Scientific and Cultural Organization convened its Advisory Committee on Arid Zone Research at Tucson. Later the Committee participated in a four-day open meeting at Albuquerque, sponsored by the American Association for the Advancement of Science.

The Albuquerque program included sessions on the use of present land and water resources, the prospects for get-

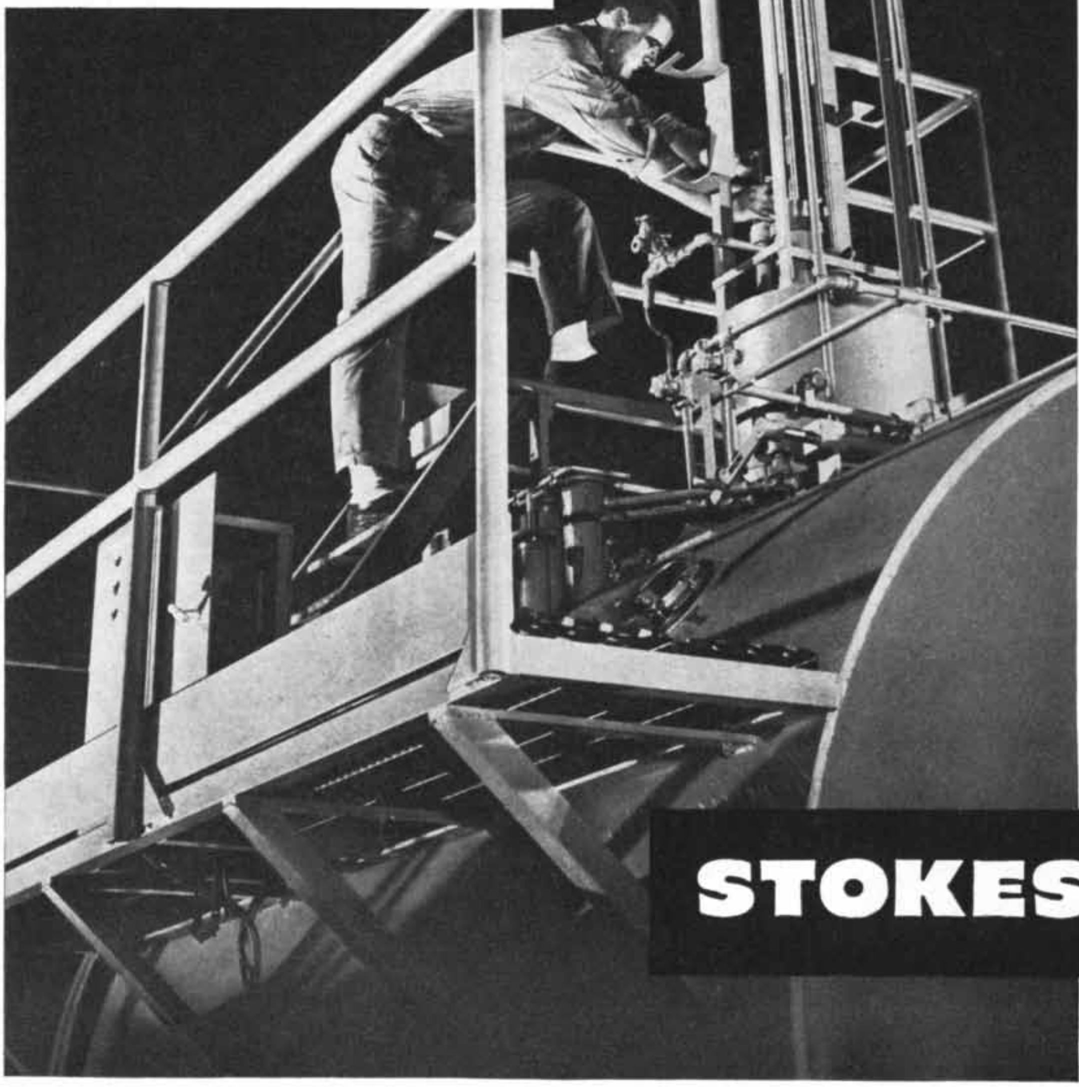
The new "miracle metals" are nickel, steel and copper

Processed by vacuum metallurgy, these metals and their alloys have such amazingly improved high-temperature characteristics, strength and purity as to have little resemblance to nickel, steel and copper as we have always known them. Metals melted and cast under vacuum are economical too, since they can be melted from scrap materials. Production rejects rates are sharply cut on specification alloys.

Thompson Products, Inc. of Cleveland, Ohio has installed the illustrated high-vacuum furnace to aid in its investigation of new and improved materials for the automotive and aircraft industries. Currently rated at 200-pound melt capacity, Thompson's furnace is capable of 1000-pound production with minor modification, an important advantage should full-scale vacuum metal production be initiated.

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

F. J. Stokes Machine Company, Philadelphia 20, Pa.

STOKES

ting more water, and the adaptation of plants and animals to arid conditions. R. Merton Love, professor of agronomy at the University of California, told the meeting that dry California soil can be made to produce two to 10 times as much as at present by improved agricultural practice. Revegetating the area with plants more drought-resistant than the native flora and fertilizing the land are two of the most helpful measures.

Knut Schmidt-Nielsen, professor of zoology at Duke University, reported on his study of the camel's adaptation to its dry environment. The animal has no facilities for storing water, but has a remarkable set of physiological mechanisms for conserving it. A camel's intestinal excretions are practically dry; those from its kidney amount to less than a pint per day even when it can drink all the water it wants. It never pants and hardly ever sweats. It can tolerate a rise of body temperature from its normal 93 degrees to 104 degrees before beginning to cool itself by perspiration. It can also withstand a degree of dehydration that would kill most animals. Its blood is exceptionally slow to lose water.

Cloud-seeding experiments in dry regions, it was generally agreed, have not yet been proved useful. Edward G. Bowen, an Australian radiophysicist, offered a new theory about a natural seeding mechanism: that dust from meteor showers may trigger world-wide rainfall. He displayed charts showing that unusually heavy rains regularly follow about 30 days after the earth passes through a meteor shower.

Noisy Planet

Radio astronomers are finding new celestial transmitters almost everywhere they look. Now Jupiter has got into the act. It is the first planet from which radio signals have been picked up.

The waves were detected by astronomers at the Carnegie Institution of Washington, who recently began to operate a new, ultranarrow-beamed radio telescope in Maryland. Every three nights or so the instrument picked up some unexplained static-like signals at 22 megacycles. At first the researchers blamed the spark plugs of passing automobiles. Finally they realized that the program came on only during the six minutes that Jupiter took to cross their receiving beam. They suggest that the signals may originate in very large electrical storms in the planet's ammonia and methane atmosphere.

The Jovian transmission was reported to the recent Princeton meeting of the

CORNING GLASS BULLETIN

FOR PEOPLE WHO MAKE THINGS

Ingredients for light that's absolutely right . . .

Light that really meets the needs of surgeons must be glareless, shadowless, cool and color balanced.

That's the kind they get from the Wilmot Castle Company's surgical lights. Glare and shadows are disposed of by an ingenious metal reflector of Castle design.

Cooling and color balance are handled by a *special* glass we make—for use in Castle lights. Called AKLO, it blocks infrared waves emanating from an artificial light source by converting the infrared into molecular heat.

A piece of AKLO 4 mm. thick absorbs some 87% of the infrared waves. Result—after an hour of continuous exposure, for every 1,000 foot-candles of illumination, a thermometer 20 inches from the light source shows a rise of less than 3° F.

Light from AKLO is the right *hue*, too, since it eliminates the greenish cast normally associated with heat-filtering glasses. And, this light is as close to natural as it's possible to obtain from artificial sources. That's a vital point in proper diagnosing of pathology, and in observing a patient's coloring.

AKLO's light is also balanced in terms of temperature. It runs to about 4,000° K., just right for shooting accurately rendered color movies and telecasting operations in color.

AKLO is one example of Corning's several successful conquests of problems involving energy control.

Experience suggests that there's more than just an outside chance that any pressing energy control problem you may have can be effectively (and economically) coped with by a glass we already make.

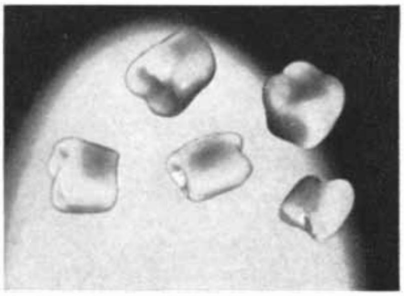
If you want to find out, drop us a note about your problem wave. We'll peer into our files and let you know *which* glass, if any, can do the job.

Denture adventure

A dental chap, we learn, is experimenting with glass for artificial teeth.

He's molding them from a mixture that's mainly ground-up VYCOR brand glass. Reason? Ordinary enamels don't stand up very well under the high heat needed to set the teeth in rubber. VYCOR brand glasses do. Result? Savings in breakage, annoyance, and time.

VYCOR brand glasses come in seven different forms. Basic characteristic of all is a very high percentage of silica—96%. It's the silica which makes the VYCOR brand glasses almost immune to temperatures up to 900° C. (higher under certain operating conditions) and endows them with unusual resistance to thermal shock.



The thermal properties of the VYCOR brand glasses make them useful in such products as calcining jars, thermocouple protector tubes, sight glasses for high heat furnaces. And ability to handle ultraviolet and infrared rays make them favored contenders for use in germicidal lamps, sun lamps, photochemical lamps and the like.

This is a far cry from our starting point on dentures, but, it may help you to see that the VYCOR brand glasses are both versatile and quite remarkable.

Bulletin B-91 details types, physical characteristics, and present uses of these glasses. Your name in the coupon will bring the literature to your desk.

Print it in glass!

These pictures tell the story much better than words.

Designs, name plate, dial face—they're all printed in glass. Not *on* glass, but *in* it!

The glass is called *Photolay*. One of the things that intrigues most people who see a picture printed *in* Photolay is its three-dimensional effect. It has depth. The image seems to float in the glass with all the attributes of reality. Even lettering, or a line drawing, acquires a special sort of difference.

Besides, an image in Photolay is permanent. It won't ever fade, get scratched off, or tarnish.

Photolay is one of several photosensitive glasses developed by Corning. They all have this in common: When exposed to ultraviolet light through a negative, a latent image forms right in the glass. Heat treatment develops this image.

What's it good for? Maybe *you* have some ideas a photosensitive glass might give a special twist to. So far, stove and appliance manufacturers have put it to use in name plates, escutcheons, dials and such. If your problems are similar, let us know.

> If the items discussed here seem unrelated to your immediate interests, we still may have what you need at our fingertips. We'd count it a pleasure to hear from you.

Corning means research in Glass

CORNING GLASS WORKS

30-6 Crystal Street, Corning, N. Y.

Please send me Bulletin B-91 on the VYCOR brand glasses.

Name________________ Title________

Company________________

Address________________

City__________ Zone_____ State______

American Astronomical Society by Bernard F. Burke and Kenneth L. Franklin.

Wandering Poles

A British astrophysicist, Thomas Gold, has come to the conclusion that the earth may have rolled over several times during its history: that is, it may have turned over its axis so that points formerly near the geographic poles are now near the Equator. He believes that such shifts would most easily account for the drastic changes that have taken place in the earth's climate and in the direction of its magnetic field.

Gold discussed the complex motions of our planet in an article in *Nature.* A perfect sphere of uniform density, he pointed out, would have no stable spin axis. If the earth were such an object, the smallest beetle crawling on its surface could roll it over. The lopsided earth tends to rotate around a line that gives the maximum rotational inertia. Because of certain poorly understood disturbances, it oscillates very slightly around that line so that every point on the surface is continually shifting in latitude. The range of variation is less than a thousandth of a degree.

Any change in the distribution of mass throughout the planet would change the preferred axis, and the earth would slowly begin to move around to bring this new line into the north-south direction. Gold estimates that a disturbance such as an upthrust of a continent could pull the earth around by as much as 90 degrees in a million years or so.

Except during the occasional major shifts in mass, Gold suggests, the earth's axis has been trapped in a narrow range by a kind of feedback action. For example, a melting glacier is a region of decreasing mass, and it will tend to move toward the axis of rotation. (Greenland, whose glacier is melting, seems to have moved a tiny fraction of a degree toward the North Pole in the past 50 years.) But as the glacier approaches the Pole, it freezes again, becomes heavier and reverses the motion.

Geologists have long realized that the earth's climate has undergone drastic changes. Some areas now in the tropics were once covered by glaciers. Recent measurements of "fossil" magnetism in rocks indicate that the magnetic north must have been in a different direction at times in the geologic past. To explain these facts, says Gold, we must assume either that the continents have drifted or that the whole earth has occasionally moved with respect to its axis, thus displacing the poles. Continental drift

would "imply new and surprising data about the earth and in particular its crust," he concludes, while wandering of the poles "would fit well with all that is known about the earth."

Progress

How a single technological "improvement" has come close to wrecking the simple economic and social system of the Aleutian Islands was related by Gerald D. Berreman, an Air Force anthropologist, in a recent article in the journal *Arctic*. The disastrous change was the introduction of dories in place of the Eskimos' traditional kayaks in an Aleutian fishing village.

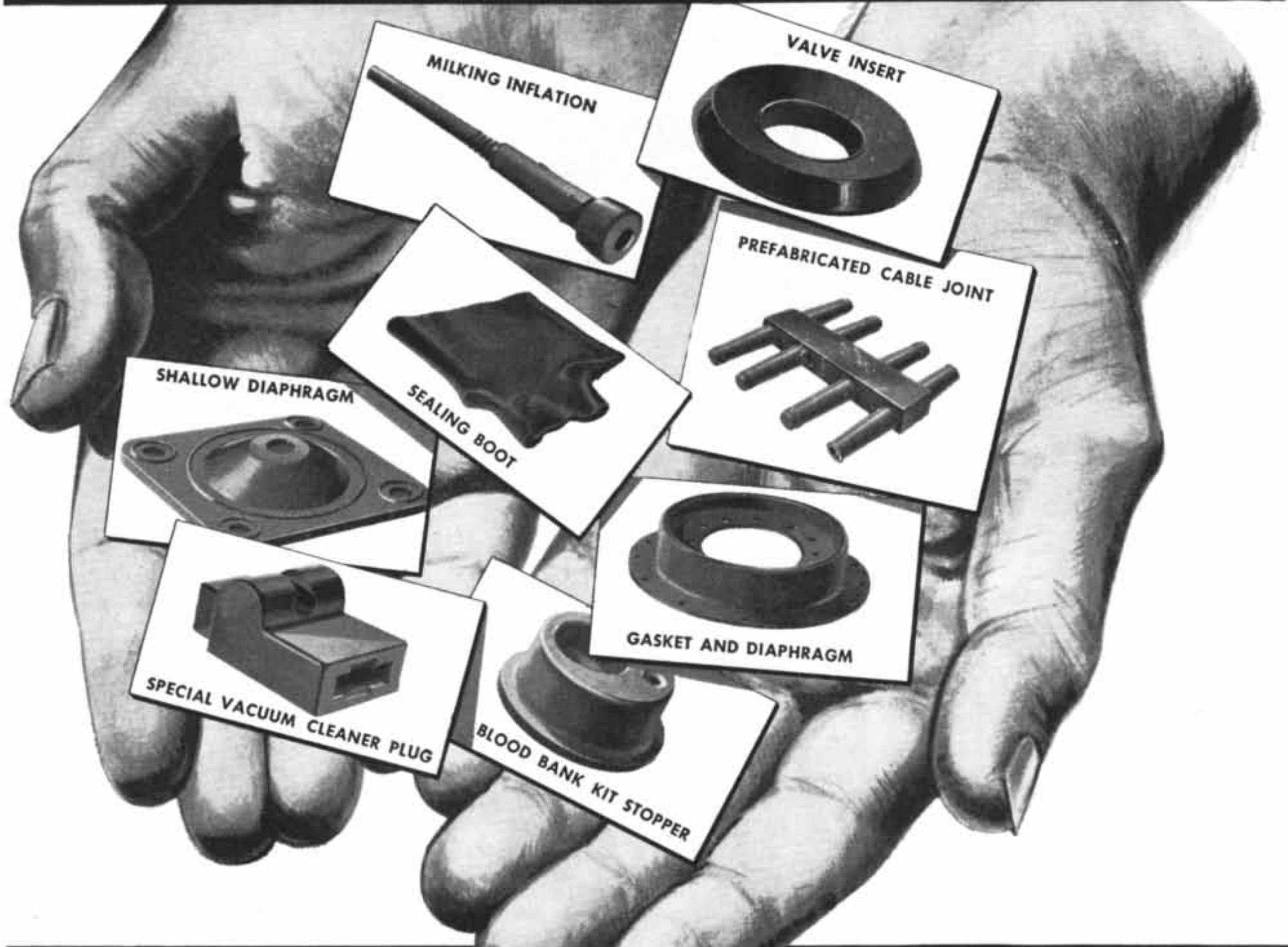
Forty years ago the Aleuts took a comfortable living entirely from the sea around them. They rode the waters in kayaks, harpooning salmon, seal and sea lions. The boats were made of driftwood frames and coverings of sea-lion skins, and the Aleutian men and women shared the task of building them.

The kayak is a one-man boat. Each family was self-sufficient and willing to share freely with the community. Male children were trained for many years by their fathers in the intricate arts of seamanship, fishing and boat-building. During their long apprenticeship the boys also absorbed the community traditions and culture from their elders.

Then, in the 1920s, dories were introduced from the U. S. These vessels were simpler to maintain and operate, larger and sturdier than kayaks. The islanders adopted them enthusiastically. But since they could not build dories, they had to hire out at jobs to get money to buy them. They also had to buy rifles and ammunition to shoot their sea game, because the noisy, clumsy dory cannot get close enough to the animals to harpoon them.

Now the Aleutian fishermen must leave their village every summer, the best fishing season, to work for money at a government sealing station. All summer the women and children are almost alone in the village. Family stability is suffering. The unreliable cash income and the limited fishing are together barely enough to keep the village economy alive. The village population has fallen to 56, about half what it was 50 years ago. The women, whose status was never very high, are even worse off, since they have lost their economic role as kayak outfitters. The elders, who used to be venerated as teachers and kayak builders, are now out of date, impoverished and economically superfluous. The children are not acquiring the old com-

Rubber in the right hands



can do wonders!

AVAIL YOURSELF OF THE SKILL, ENGINEERING ADVICE, SPECIAL COMPOUNDS AND PRECISION MOLDING OF UNITED STATES RUBBER COMPANY.

★ **A maker of milking inflations picked "U. S." molded rubber—because of its flexing characteristics (up to 400 hours in a flexing cycle test—where normal requirement is a 100 hour test.)**

★ **A utility company selected "U. S." molded rubber cable joints because "U. S." could fabricate an entirely *uniform* wall thickness in an extremely complex design. The high dielectric resistant compound provides top safety.**

★ **A lawn mower manufacturer cut labor time of treading from 7 minutes to 49 seconds—just by specifying "U. S." molded-drive roller rubbers.**

These are only a few of the hundreds of applications wherein U. S. Rubber's molded rubber works wonders. In the hands of "U. S." technicians, molded rubber becomes a basic material that will *do jobs no other material can do*. "U. S." research stockpiles, nationwide facilities and laboratories are joined with "U. S." experts in tackling any molded rubber goods problem quickly—and from every angle. Let "U. S." show you what it can do with molded rubber.

Get in touch with United States Rubber Company's Molding and Extrusions Department through address below.

US RUBBER

"U. S." Research perfects it . . . "U. S." Production builds it . . . U. S. Industry depends on it.

UNITED STATES RUBBER COMPANY

MECHANICAL GOODS DIVISION • ROCKEFELLER CENTER, NEW YORK 20, N. Y.

Hose • Belting • Expansion Joints • Rubber-to-metal Products • Oil Field Specialties • Plastic Pipe and Fittings • Grinding Wheels • Packings • Tapes Molded and Extruded Rubber and Plastic Products • Protective Linings and Coatings • Conductive Rubber • Adhesives • Roll Coverings • Mats and Matting munity culture and see no future in the village. At the time that Berreman was there, every child over the age of nine intended to emigrate as soon as possible.

Brain Cells and Intelligence

Is the intelligence of an animal related to the number or size of the cells of its brain? A recent experiment at Princeton University has yielded a strong clue to the answer of this classical question.

For some years Gerhard Fankhauser, professor of biology, has raised salamanders whose cells contain more than the usual number of chromosomes. This he has done by heating or cooling the animal's fertilized egg. The body cells of a normal salamander are diploid: they have two sets of chromosomes. The body cells of Fankhauser's experimental salamanders are triploid: they have three sets of chromosomes. The cells of triploid salamanders are proportionately larger than those of diploid salamanders. The remarkable thing is that diploid and triploid salamanders are the same size. The triploid animals have bigger cells but fewer of them. This also applies to their brain cells.

Fankhauser suggested to Jack A. Vernon, assistant professor of psychology, that they compare the learning ability of diploid and triploid salamanders. An experiment was planned that was elaborated and performed by two students, Warner V. Slack and William H. Frank. Their subjects were four diploid and four triploid salamander larvae which were closely comparable in physical performance. Each larva was placed in a Y-shaped maze and stimulated to move with a small probe. If the larva turned into the "incorrect" arm of the Y, it was subjected to the compound punishment of continued tactile stimuli and a bright light. If it turned into the "correct" arm, it was given a brief rest. The procedure was then repeated. The learning ability of the salamanders was measured by the number of trials it took for each animal to make 10 consecutive "correct" choices.

The mean number of trials that the four diploid salamanders needed was 38.75. The mean number for the triploid animals was 125.25. Clearly the salamanders with more brain cells learned more rapidly.

The Princeton workers plan to continue with other experiments. In the long run they hope to test the retentiveness of salamanders with four and even five sets of chromosomes, which have proportionately larger and fewer brain cells.

For product improvement . . . for production efficiency

FIND THE ANSWER

. . . with Celanese* Chemicals

Even backyard gardeners know how well hormone weed killers attack crabgrass. But the farmer has reaped the most from this chemical spray, in time and labor saving, and in increased crop yields. ACETIC ANHYDRIDE—a major ingredient in herbicides—is one of the acetyl chemicals which Celanese produces in volume, and whose uses Celanese has helped to develop over the years.

The plastics industry is meeting the tremendous demands for television parts—from cabinets to control knobs—with highly efficient low-cost mass molding methods. By making FORMALDEHYDE available in four specialized forms for the production of the plastic resins. Celanese is contributing to an outstanding industry-wide record for performance.

Today's "horn of plenty" for industry lies deep below the earth's surface, where trillions of cubic feet of natural gas represent a virtually inexhaustible supply of hydrocarbons.

Celanese Corporation of America has based its integrated petrochemical operation on this vast storehouse of natural wealth, employing specially developed processes to synthesize organic chemicals for use in nearly every major field of production. It is an operation that can supply industrial materials of greater uniformity, higher purity and improved reactivity. It can offer manufacturers the continuity and selectivity they are looking for from their basic supplier. When your production problem is chemical—and basic—Celanese organic chemicals can be the answer. Celanese Corporation of America, Chemical Division, Dept. 582-F, 180 Madison Avenue, New York 16, N. Y.

BASIC REASONS........... ....FOR IMPROVED PRODUCTS

Acids
Alcohols
Aldehydes
Anhydrides
Esters

Glycols
Hydraulic Fluids
Ketones
Oxides
Polyols

Plasticizers
Salts
Solvents
Synthetic Oils
Vinyl Monomers

Celanese* CHEMICALS
*Reg. U.S. Pat. Off.

In textiles, plastics, agriculture, paper, surface coatings, electrical and building materials and equipment, pharmaceuticals.

James Clerk Maxwell

In the same year that Einstein was born, the man who was perhaps his greatest immediate predecessor died. Generally regarded as an abstract theoretician, Maxwell relied heavily on mechanical models

by James R. Newman

James Clerk Maxwell, the greatest theoretical physicist of the 19th century, opened a new epoch of science, and much of what distinguishes our world from his is due to his work. Because his most spectacular discoveries were the fruits of theoretical rather than experimental researches, he is often cited as an outstanding example of a scientist who built his systems entirely with pencil and paper. This notion is false. Maxwell combined a profound physical intuition with a formidable mathematical capacity to gain insights into physical phenomena, never losing sight of the observations to be explained. This blending of the concrete and the abstract was the chief characteristic of almost all his researches.

ENGRAVING OF MAXWELL appears in *The Collected Papers of James Clerk Maxwell*. This illustration and those appearing on the next three pages are from the Burndy Library.

Maxwell was born in Edinburgh on November 13 in 1831, the same year Michael Faraday announced his famous discovery of electromagnetic induction. Descended of an old Scots family whose members were distinguished no less for their individuality, "verging on eccentricity," than for their talents (they included eminent judges, politicians, mining speculators, merchants, poets, musicians), he was the only son of a member of the Scottish bar who took little interest in the grubby pursuits of an advocate but instead managed his small estates, took part in county affairs and gave loving attention to the education of his son. Maxwell's father was a warm and rather simple man with a nice sense of humor and a practical interest in mechanical contrivances. His mother is described as having a "sanguine, active temperament."

Jamesie, as the boy was called, passed his early childhood on the family estate at Glenlair, two days' carriage ride from Edinburgh. He was a nearsighted, lively, affectionate little boy, as persistently inquisitive as his father and as fascinated by machines. To discover of anything "how it doos" was his constant aim. "What's the go of that?" he would ask, and if the answer did not satisfy him, he would add, "But what's the *particular* go of that?" His own first creation was a set of figures for a "wheel of life," a scientific toy which produced the illusion of continuous movement; he was fond of making things with his hands, and in later life knew how to design models embodying the most complex motions and other physical processes.

When Maxwell was nine, his mother died of cancer, the disease that was to kill him 40 years later. Her death brought the father and son even more closely together. The boy began his schooling a year later as a day student at the Edinburgh Academy. His early school experiences were painful. The master, a dryish Scotsman whose reputation as a pedagogue derived from a book he had written on the irregular Greek verbs, expected his students to be orderly, well-grounded in the usual subjects and unoriginal. Maxwell was deficient in all these departments. He created something of a sensation because of his clothes, which had been designed by his strong-minded father and included such items as "hygienic" square-toed shoes and a lace-frilled tunic. The boys nicknamed him "Dafty" and mussed him up, but he was a stubborn child and in time won the respect of his classmates even if he continued to puzzle them.

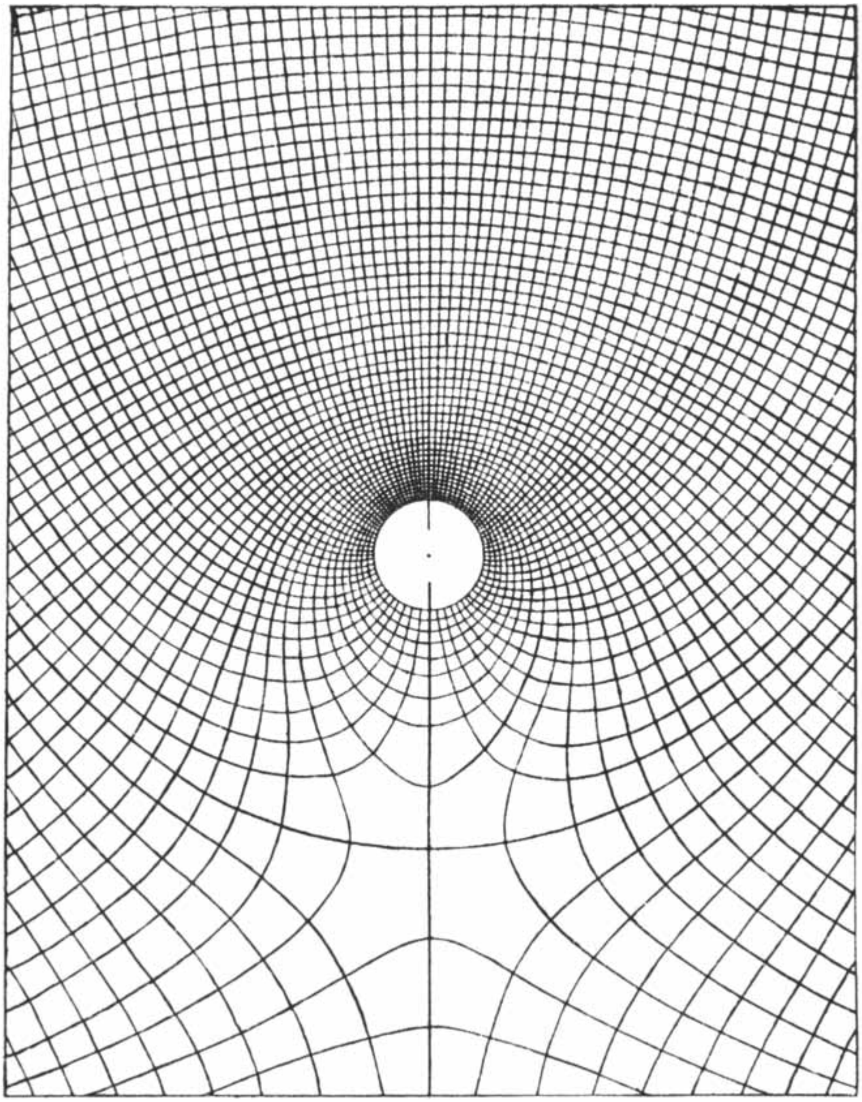
Mathematical Years

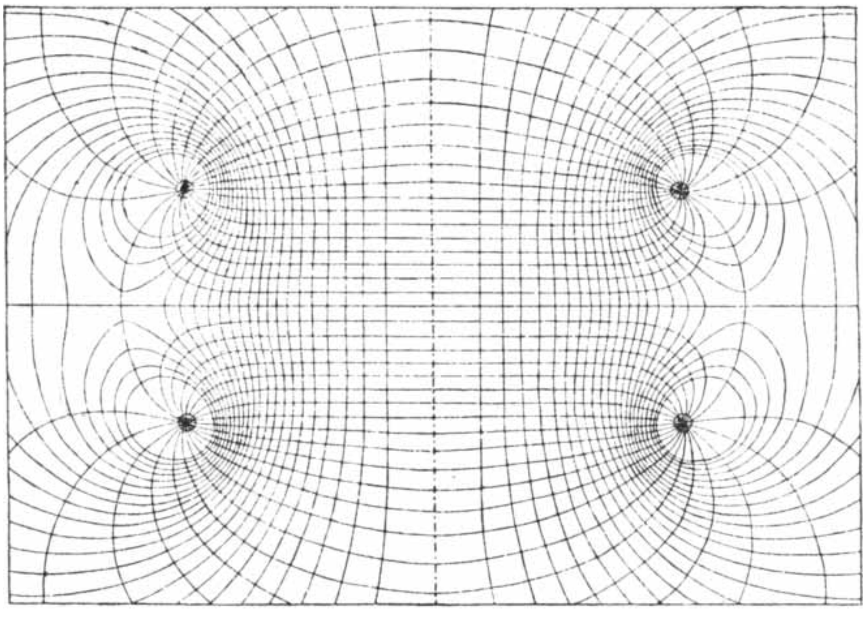
At school Maxwell experienced a gradual awakening of mathematical interests. He wrote his father that he had made a "tetra hedron, a dodeca hedron, and two more hedrons that I don't know the wright names for." In his 14th year he won the Academy's mathematical medal and wrote a paper on a method for constructing perfect oval curves with pins and thread. Another prodigious little boy, René Descartes, had anticipated him in this field, but Maxwell's contributions were original. It was a wonderful day for father and son when they heard the boy's paper on ovals read before the Royal Society of Edinburgh by Professor James Forbes. "Met," the father wrote of the event in his diary, "with very great attention and approbation generally."

After six years at the Academy Maxwell entered the University of Edinburgh. He was 16, a restless, enigmatic, brilliantly talented adolescent who wrote not very good but strangely prophetic verse about the destiny of matter and energy:

When earth and sun are frozen clods,
When all its energy degraded
Matter to aether shall have faded

His friend and biographer Lewis Campbell records that he was completely neat in his person, "though with a rooted objection to the vanities of starch and gloves," and that he had a "pious horror of destroying anything—even a scrap of writing paper." He read voraciously and passed much time in mathematical speculations and in chemical,





LINES OF FORCE appear in *Electricity and Magnetism*. **Top:** "Uniform magnetic field disturbed by an electric current in a straight conductor." **Bottom:** "Two circular currents."

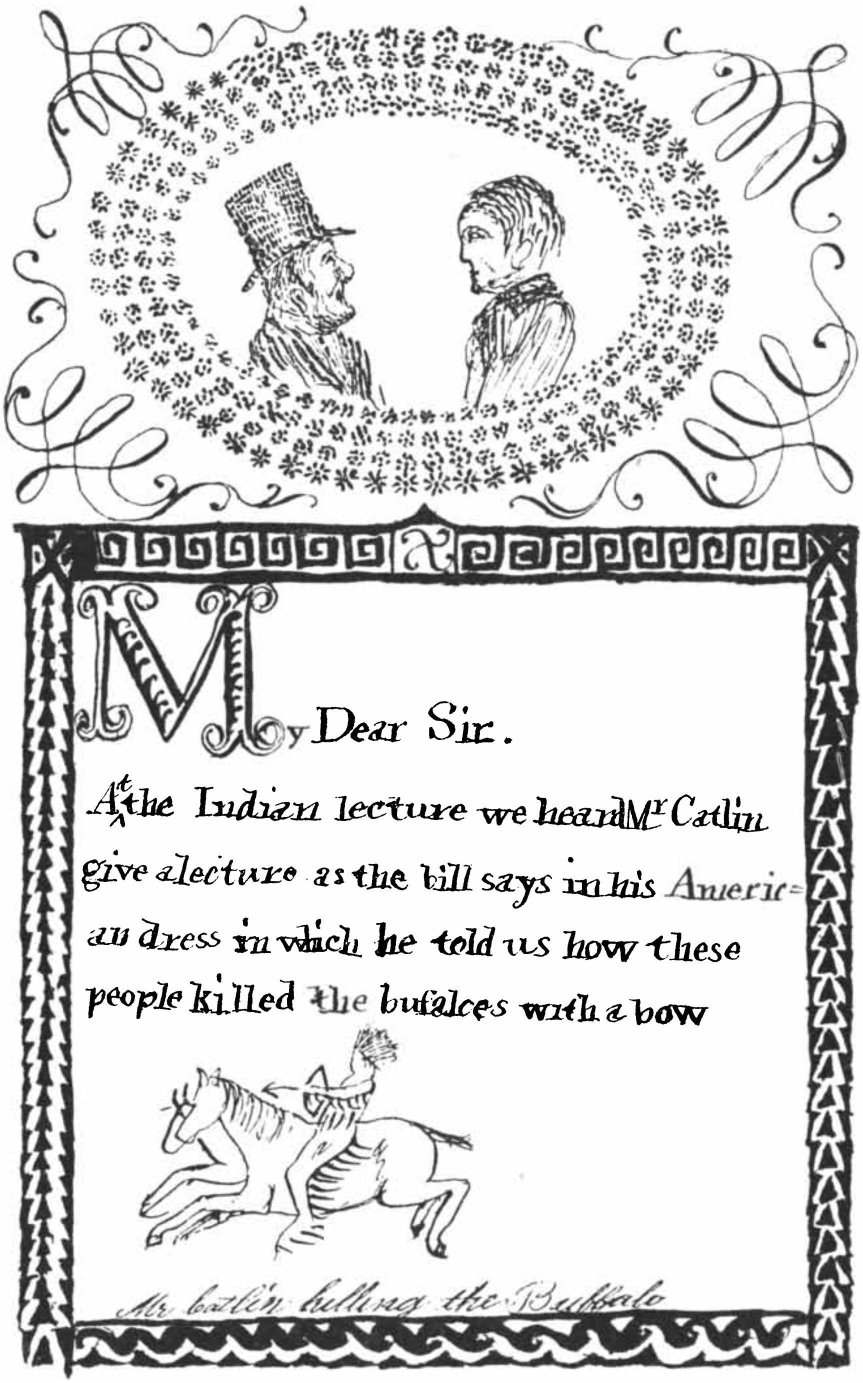
magnetic and optical experiments. "When at table he often seemed abstracted from what was going on, being absorbed in observing the effects of refracted light in the finger glasses, or in trying some experiment with his eyes—seeing around a corner, making invisible stereoscopes, and the like. Miss Cay [his aunt] used to call his attention by crying, 'Jamesie, you're in a prop [an abbreviation for mathematical proposition].' "

While at Edinburgh, Maxwell regularly attended meetings of the Royal Society, and two of his papers, "On the Theory of Rolling Curves" and "On the Equilibrium of Elastic Solids," were published in the *Transactions*. The papers were read before the Society by others, "for it was not thought proper for a boy in a round jacket to mount the rostrum there." During vacations at Glenlair he wrote long letters reporting his multifarious doings to friends. Many of his letters exhibit an intense interest in moral philosophy, reflecting his social sympathy, his Christian earnestness, the not uncommon 19th-century mixture of rationalism and simple faith. It was a period when men still believed that questions of wisdom, happiness and virtue could be studied as one studies optics and mechanics.

In 1850 Maxwell went on to the University of Cambridge. There he became a private pupil of William Hopkins, considered the ablest mathematics coach of his time, who prepared him for the mathematical tripos, the stiff competitive examinations in which the brightest students competed. Hopkins at once recognized the talents of the black-haired young Scotsman, describing him as "the most extraordinary man I have ever met," and adding that "it appears impossible for [him] to think incorrectly on physical subjects." Besides working hard on his studies, Maxwell joined fully in social and intellectual activities at the University. He was elected to the Apostles, a club of 12 members which for many years included the outstanding young men at Cambridge. A contemporary described Maxwell as "the most genial and amusing of companions, the propounder of many a strange theory, the composer of many a poetic *jeu d'esprit.*" Not the least strange of his theories related to economy of sleep. He would sleep from 5 in the afternoon to 9:30, read very hard from 10 to 2, exercise by running along the corridors and up and down stairs from 2 to 2:30 a.m. and sleep again from 2:30 to 7. The dormitory inhabitants were not pleased, but Maxwell persisted in his bizarre experiments. Another of his investigations was a study of the process by which a cat always lands on her feet. He demonstrated that a cat could right herself even when dropped upside down on a table or bed from a height of about two inches.

In the summer of 1853 a "sort of brain fever" seized Maxwell. For weeks he was totally disabled, and he felt the effects of his illness long afterward. This episode was undoubtedly an emotional crisis, but its causes remain obscure. All that is known is that his illness strengthened Maxwell's religious conviction—a deep, earnest piety, leaning to Scottish Calvinism yet never completely identified with any particular system or sect. "I have no nose for heresy," he used to say.

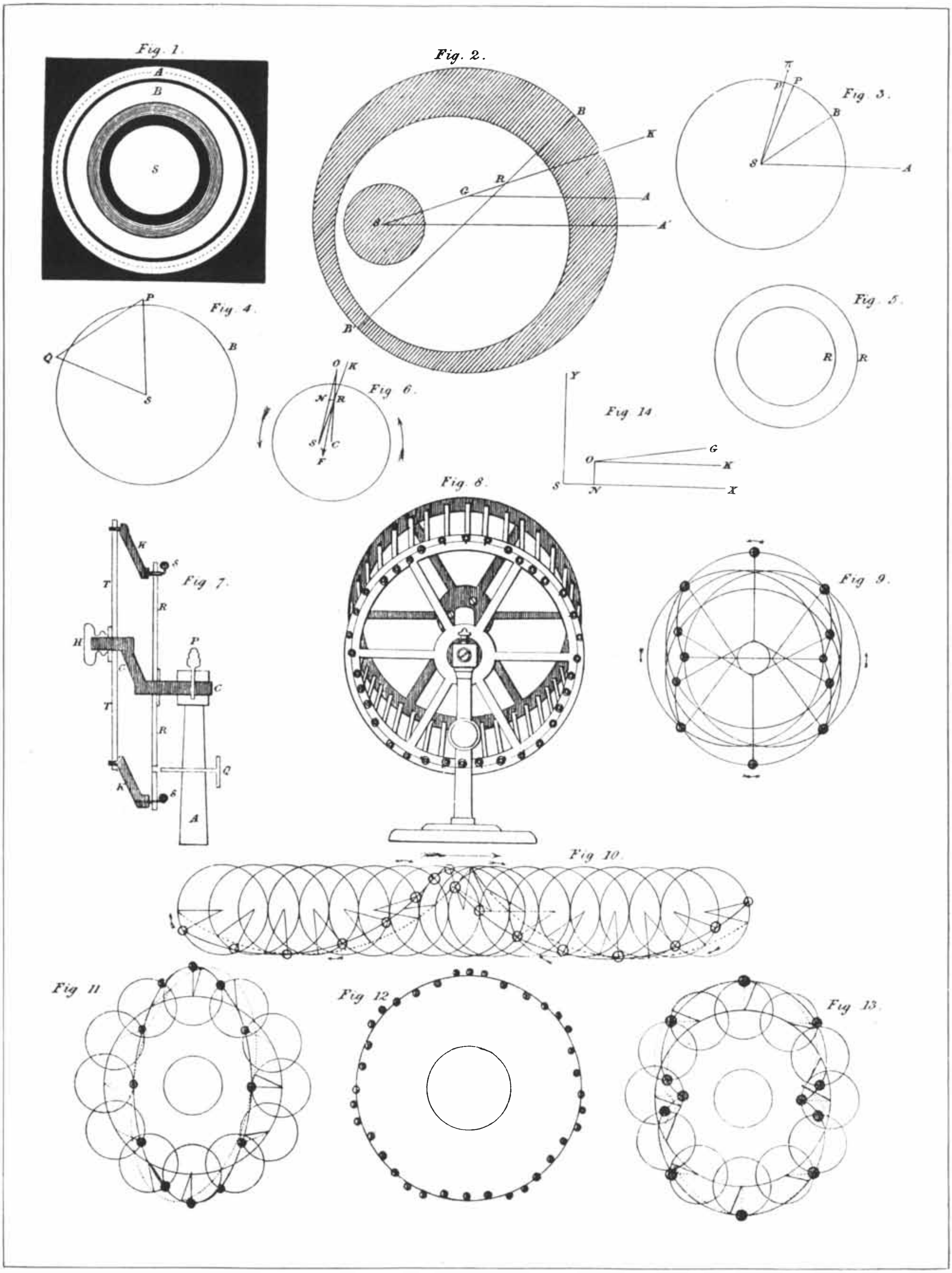
In January, 1854, Maxwell took the tripos in the Cambridge Senate House, with a rug wrapped around his feet and legs (as his father had advised) to mitigate the perishing cold. His head was


My Dear Sir.

At the Indian lecture we heard Mr Catlin give a lecture as the bill says in his Americ= an dress in which he told us how these people killed the bufalces with a bow

Mr Catlin killing the Buffalo

ILLUMINATED LETTER was written by Maxwell to his father in 1843, when the younger Maxwell was 11. The letter refers to a lecture by the American frontier artist George Catlin.



MECHANICAL MODEL is depicted in Figure 7 and Figure 8 of this page from Maxwell's essay "On the Stability of the motion of Saturn's Rings." In this essay Maxwell demonstrated that the rings were neither liquid nor solid but were composed of particles.

warm enough. He finished second wrangler behind the noted mathematician Edward Routh. (In another competition at Cambridge, for "Smith's prize," where the subjects were more advanced, Maxwell and Routh tied for first.)

Questions and Answers

After getting his degree Maxwell stayed on for two years at Trinity, studying, lecturing, taking private pupils and doing some experiments in optics. He designed a top with colored paper disks to study the mixing of colors, and he was able to show that suitable combinations of three primary colors—red, green and blue—produced "to a very near degree of approximation" almost every color of the spectrum. For this work in color sensation he later won the Rumford medal of the Royal Society.

Maxwell's most significant activity during the two postgraduate years at Trinity, however, was his reading of Faraday's *Experimental Researches* and entrance upon the studies of electricity which were to lead to his greatest discoveries. Before he left Trinity, he published his first major contribution, the beautiful paper "On Faraday's Lines of Force." In 1856 Maxwell was appointed to the chair of natural philosophy at Marischal College in Aberdeen; he had applied for the post partly to be near his father, whose health had been failing, but his father died a few days before he obtained the appointment. It was an irreparable personal loss to Maxwell; they had been as close as father and son could be. At Aberdeen Maxwell continued his work on electricity. His teaching load was rather light. Although he took teaching seriously, it cannot be said that Maxwell was a great teacher. With classes that were "not bright" he found it difficult to hit a suitable pace. He was unable to heed himself the advice he once gave a friend whose duty it was to preach to a country congregation: "Why don't you give it them thinner?"

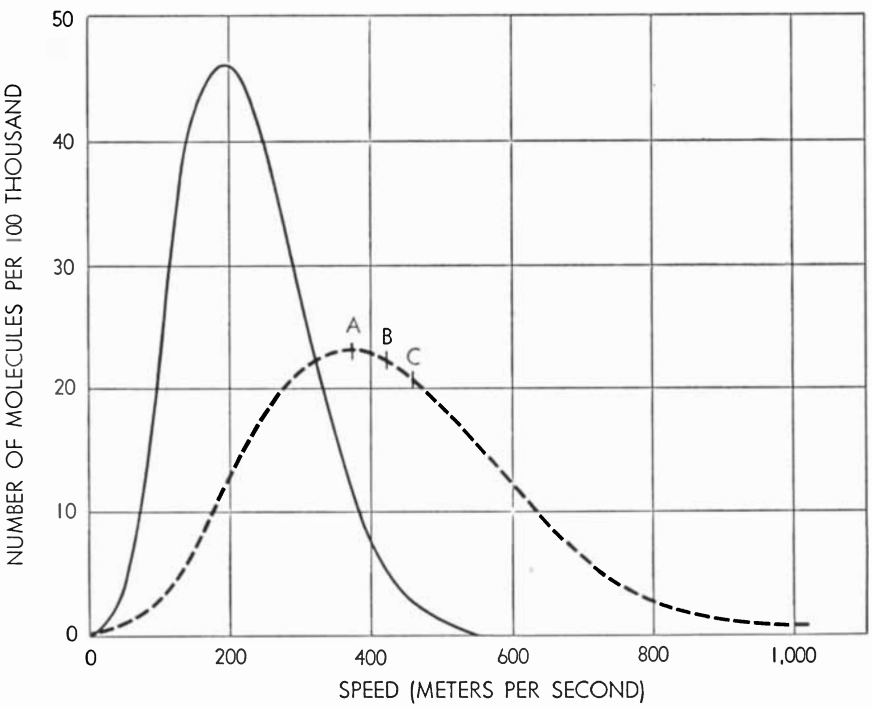
Maxwell's electrical studies at Aberdeen were interrupted by a task which engrossed him for almost two years. He entered a competition for a University of Cambridge prize on the subject of Saturn's rings. Were the rings solid? Were they fluid? Did they consist of masses of matter "not mutually coherent?" The problem was to demonstrate which type of structure adequately explained the motion and permanence of the rings. In a brilliant 68-page essay which Sir George Airy, the Astronomer Royal, described as one of the most remarkable applications of mathematics he had ever seen, Maxwell demonstrated that the only stable structure would be one composed of disconnected particles. His essay won the prize and established him as a leader among mathematical physicists.

His research on Saturn excited his interest in the kinetic theory of gases. Maxwell's predecessors in this field—Rudolf Clausius, Daniel Bernoulli, James Joule and others—had been successful in explaining many of the properties of gases, such as pressure, temperature and density, on the hypothesis that a gas is composed of swiftly moving particles. However, in order to simplify the mathematical analysis they had assumed that all the particles of a gas move at the same speed. Maxwell realized that this was an altogether implausible assumption, for collisions among the molecules must give them various velocities. If the science of gases was to be developed on "strict mechanical principles," it was necessary, he said, to incorporate this fact into the mathematical formulation of the laws of motion of the particles.

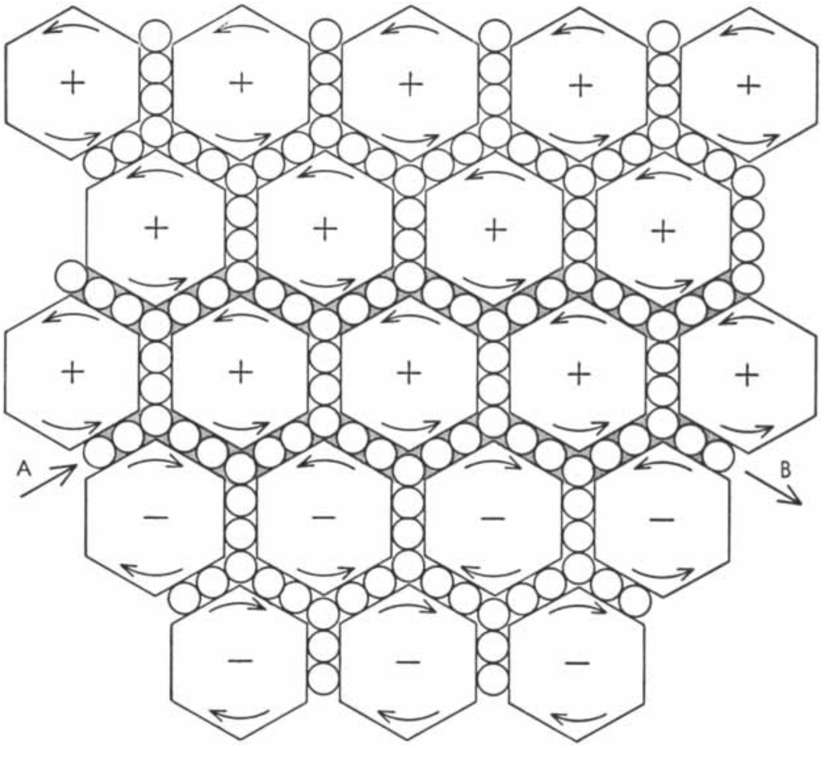
Maxwell's Law of Gases

Maxwell proceeded to examine mathematically the behavior of an assemblage of colliding particles as if they were "small, hard and perfectly elastic spheres acting on one another only during impact." Since the many molecules could not be treated individually, he introduced the statistical method for dealing with them. He supposed that the distribution of velocities among the molecules in a gas would follow the famous bell-shaped frequency curve, which applies to so many phenomena, from the pattern of shots on a target to groupings of men according to height. Thus while the velocity of an individual molecule might elude description, the velocity of a crowd of molecules would not. Having arrived at a quantitative description of the speeds of molecules composing a gas, Maxwell was able to write a precise formula for gas pressure. Curiously enough this expression did not differ from that based on the assumption that the velocity of all the molecules was the same, but at last the right conclusion had been won by correct reasoning. Moreover the generality and elegance of Maxwell's mathematical methods led to the extension of their use into almost every branch of physics.

Maxwell went on to consider another factor which needed to be determined for precise formulation of the laws of gases: namely, the distance a molecule travels, on the average, between colli-



MAXWELL DISTRIBUTION is plotted for the molecules in a gas at 200 degrees centigrade (*solid curve*) and at 0 degrees centigrade (*broken curve*). Each point on the curves indicates the number of molecules in the gas moving at that speed. The speed corresponding to Point A is the most probable velocity of the molecules. The speed corresponding to Point B is the average velocity. The speed corresponding to Point C is the root mean square velocity.



MODEL OF AN ELECTROMAGNETIC FIELD used by Maxwell visualized "molecular vortices" rotating in space. In this illustration the vortices are slender cylinders seen from the end. (Maxwell gave the cylinders a hexagonal cross section to simplify the geometry of the model.) Between the vortices are small "idle wheels." If a row of the idle wheels is moved from A toward B, they cause the adjacent vortices to rotate in opposite directions.

sions—*i.e.*, its mean free path. He reasoned that the mean free path of molecules in a given gas could be measured by the viscosity of that gas. Assume that a gas is composed of groups of molecules with different velocities which slide over one another, thus creating friction. This would account for the viscosity of gases. Now the mean free path of molecules would be related to viscosity in the following way. Imagine two layers of molecules sliding past each other. If a molecule passing from one layer to the other travels only a short distance before colliding with another molecule, the two particles do not exchange much momentum, because near the boundary the difference of velocity between the two layers is small. But if the molecule penetrates deep into the other layer before a collision, the velocity differential will be greater; hence the exchange of momentum between the colliding particles is greater. This amounts to saying that in any gas with high viscosity the molecules must have a long mean free path. Maxwell deduced further the paradoxical fact that the viscosity of a gas is independent of its density, for the increased probability of collisions in a dense gas is offset by the fact that in such a gas a molecule will not travel far into a different layer before colliding. On balance, then, the momentum conveyed across each unit area per second remains the same regardless of density.

Thus Maxwell constructed a mechanical model of a gas as an assemblage of crowds of particles "carrying with them their momenta and their energy," traveling certain distances, colliding, changing their motion, resuming their travels, and so on. His picture made it possible to account in precise quantitative terms for a gas's various properties—viscosity, diffusion, heat conduction. Altogether it was a scientific achievement of the first rank. The model has since been criticized, on the grounds, for example, that molecules are not hard nor perfectly elastic, like billiard balls, nor is their interaction confined to the actual moment of impact. Yet despite the inadequacies of the model and errors of reasoning, the results, which, as Sir James Jeans said, "ought to have been hopelessly wrong," turned out to be exactly right, and Maxwell's law for the behavior of gases is in use to this day.

The German physicist Ludwig Boltzmann, who recognized at once the significance of these discoveries, set to work refining and generalizing Maxwell's proof. He showed that the Maxwell distribution of velocities was the only possible equilibrium state of a gas. This equilibrium state, as both men realized, is the thermodynamic condition of maximum entropy—the most disordered state, in which the least amount of energy is available for useful work.

The concept of entropy led Maxwell to one of the celebrated images of modern science, namely that of the sorting demon. Increasing entropy is man's fate because we are not very bright. But a demon more favorably endowed could sort out the slow- and fast-moving particles of a gas, thereby changing disorder into order and converting unavailable into available energy. Maxwell imagined one of these small, sharp fellows "in charge of a frictionless, sliding door in a wall separating two compartments of a vessel filled with gas. When a fast-moving molecule moves from left to right, the demon opens the door; when a slow-moving molecule approaches, he (or she) closes the door. The fast-moving molecules accumulate in the right-hand compartment, and slow ones in the left. The gas in the first compartment grows hot and that in the second cold." Thus the demon would thwart the second law of thermodynamics. Living organisms, it has been suggested, achieve an analogous process; as Erwin Schrödinger has phrased it, they suck negative entropy from the environment in the food they eat and the air they breathe.

Maxwell and Boltzmann, working independently and in a friendly rivalry, at first made notable progress in explaining the behavior of gases by statistical mechanics. After a time, however, formidable difficulties arose. For example, they were unable to write accurate theoretical formulas for the specific heats of certain gases (the quantity of heat required to raise the temperature of a body of the gas by a given amount). Explanation of the discrepancies they found had to await the development of quantum theory, which showed that the spin and vibration of molecules were restricted to certain values. But neither quantum theory nor relativity, nor the other modes of thought constituting the 20th-century revolution in physics, would have been possible had it not been for the brilliant labors of these natural philosophers in applying statistical methods to the study of gases.

Marriage

In February, 1858, Maxwell wrote his aunt, Miss Cay: "This comes to tell you that I am going to have a wife." "Don't be afraid," he added, "she is not mathematical, but there are other things besides that, and she certainly won't stop mathematics." His bride was Katherine Mary Dewar, daughter of the Principal of Marischal College. Their union became very close: they enjoyed doing things together—horseback riding, reading aloud to each other, traveling—and he even found useful tasks for her in his experimental work. The marriage was childless, but this very fact increased the couple's dependency and devotion.

In the summer of 1860 Maxwell moved to London as professor of natural philosophy at King's College. He remained there for five years. Living in London offered him the opportunity to see something of Faraday, with whom, up to this time, Maxwell had had only correspondence, and to make the acquaintance of other scientists. He was no solitary. "Work is good, and reading is good, but friends are better," he wrote to his friend Litchfield. Despite social distractions and arduous teaching duties at King's, the five years in London were the most productive of Maxwell's life. He continued his work on gases. In the large garret of his house in Kensington he measured the viscosity of gases and obtained practical confirmation of his theoretical work. (To maintain the necessary temperature a fire had to be kept up in the midst of very hot weather and kettles kept boiling to produce steam which would be allowed to flow into the room. Mrs. Maxwell acted as stoker.) But his major work was in the theory of electricity, from which he had been diverted and to which he now returned.

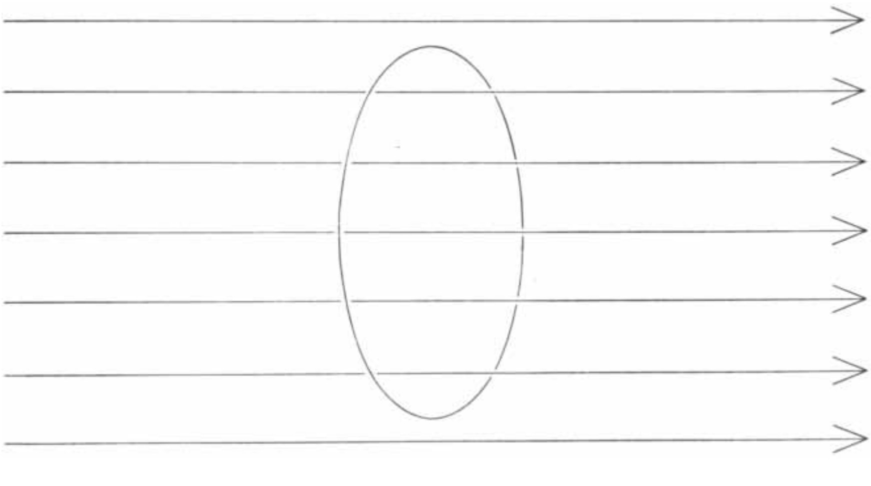
A Model for Electricity

Faraday's experiments had crowned a century of researches (by Coulomb, Oersted, Ampère and others) which had established many facts about the behavior of electricity and its link with magnetism. They had shown that electric charges attracted and repelled each other according to a law like that of gravitation (in proportion to the product of the charges and in inverse proportion to the square of the distance between the charges); that a current produces a magnetic field, and a moving magnet produces a current; that an electric current in one circuit can induce a current in another.

What absorbed Maxwell was the attempt to explain these phenomena. What was a field? How did electricity and magnetism exert their influence through space? Faraday had suggested a new concept to answer these questions, and it was his idea that excited Maxwell's interest.

Most theorists had pursued the analogy of electricity to gravitation and had sought to explain the phenomena in terms of "action at a distance." They imagined a charge (or mass) situated at one point in space mysteriously influencing a charge (or mass) at another point, with no linkage or connection of any kind between the charges (or masses). Faraday proposed to explain electricity as a mechanical system. He asserted that the instrumentality of electric and magnetic action was lines of force running through space—not merely imaginary lines but actual, physical entities, with properties of tension, attraction, repulsion, motion and so on.

Maxwell admirably summarized the cleavage between the two views: "Faraday, in his mind's eye, saw lines of force traversing all space, where the mathema-



CURL of Maxwell's equations is suggested by this diagram. The arrows are a moving magnetic field. The circle is the electric field which "curls" around the magnetic lines of force.

ticians saw centres of force attracting at a distance; Faraday saw a medium where they saw nothing but distance; Faraday sought the seat of the phenomena in real actions going on in the medium, they were satisfied that they had found it in a power of action at a distance impressed on the electric fluids."

Maxwell believed in Faraday's concept, and he set out to develop it. In his first paper, "On Faraday's Lines of Force," he tried to imagine a physical model, embodying Faraday's lines, whose behavior could be reduced to formulas and numbers. He did not suggest that the model represented the actual state of things, but he felt that it was important "to lay hold of a clear physical conception, without being committed to any theory founded on the physical science from which that conception is borrowed." Such a method would protect the investigator against being led into a blind alley of abstractions or being "carried beyond the truth by a favorite hypothesis."

Maxwell proposed a hydrodynamic model, in which he incorporated Faraday's lines of force in the form of "tubes of flow" carrying an incompressible fluid such as water. The fluid moving through the tubes represented electricity in motion; the form and diameter of the tubes gave information as to the strength and direction of the flow. The velocity of the fluid was the equivalent of electrical force; differences of fluid pressure were analogous to differences of electrical pressure or potential; pressure transmitted from tube to tube by way of the elastic tube surfaces furnished an analogue to electric induction. By applying the established equations of hydrodynamics to such a system, Maxwell was able to account for many of the observed facts concerning electricity.

It was a wonderful paper, and Faraday expressed his appreciation. "I was at first almost frightened," he wrote Maxwell, "when I saw such mathematical force made to bear upon the subject, and then wondered to see that the subject stood it so well." Other students, however, thought the subject stood it not at all well. Electricity was mysterious enough without adding tubes and incompressible fluids. But Maxwell, who had had good training in being considered queer, went on with the task of extending Faraday's ideas.

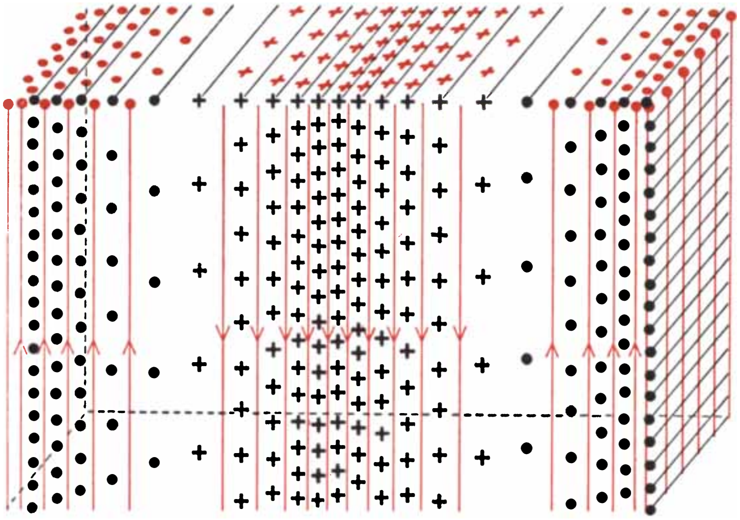
Cylinders and Balls

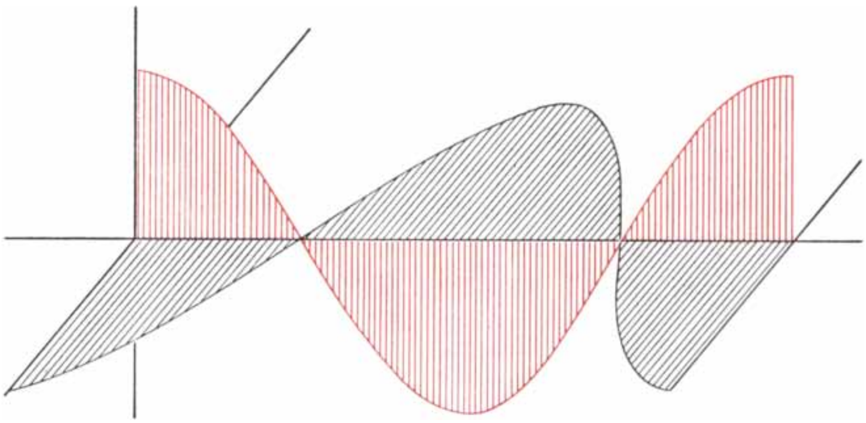
Maxwell's second great memoir, "On Physical Lines of Force," was published after he returned to the subject of electricity in London. He now constructed a more elaborate model to account not only for electrostatic effects but also for magnetic attraction and electromagnetic induction. In the new model "molecular vortices" rotating in space were the agents that produced magnetic fields. A molecular vortex may be thought of as a slender cylinder which rotates around the lines of magnetic force. The velocity of rotation depends on the intensity of the magnetic force. Two mechanical effects are associated with the cylinders: tension in the direction of the lines of force, and lateral pressure arising from the centrifugal force produced by the rotating cylinders. Combined, these effects mechanically reproduce magnetic phenomena: magnetism is a force exerted both along the axis and outward from the axis.

Maxwell proceeded to show how this curious arrangement might explain the production of a magnetic field by an electric current and of a current by a changing field. He supposed first that a uniform magnetic field consists of a portion of space filled with cylinders rotating at the same velocity and in the same direction "about axes nearly parallel." But immediately a puzzle confronted him. Since the cylinders are in contact, how can they possibly rotate in the same direction? As everyone knows, a rotating wheel or cylinder causes its neighbor to rotate in the opposite direction. Maxwell hit upon a pretty idea. He supposed that rows of small spheres, like layers of ball bearings, lay between the cylinders and acted as gears (in Maxwell's words, "idle wheels"). Thus the cylinders all rotated in the same direction.

And now, as just reward for his ingenuity, Maxwell found that the spheres could be made to serve another even more valuable purpose. Think of them as particles of electricity. Then by purely mechanical reasoning it can be shown that their motions in the machine of which they are a part serve to explain many electrical phenomena.

Consider these examples. In an unchanging magnetic field the cylinders all rotate at the same constant rate. The little rotating spheres keep their position; there is no flow of particles, hence no electric current. Now suppose a change in the magnetic force. This means a change in the velocity of rotation of the cylinders. As each cylinder is speeded up, it transmits the change in velocity to its neighbors. But since a cylinder now rotates at a slightly different speed from its neighbor, the spheres between them are torn from their positions by a kind of shearing action. This





ELECTROMAGNETIC WAVE was visualized by Maxwell as a moving disturbance which tended to separate positive (*plus sign*) and negative (*dot*) charges. In the drawing at the top magnetic lines of force (*arrows*) lie at right angles to the direction in which the disturbance is moving. The drawing at the bottom depicts the two components of the electromagnetic wave. The electrical component is shown in black; the magnetic component, in color.

motion of translation of the particles is an electric current.

Observe now how the model begins to live a life of its own. Though designed primarily to demonstrate how magnetic changes produce electric currents, it also suggested to Maxwell a mechanism whereby a change in electric force might produce magnetism. Assume the spheres and cylinders are at rest. If a force is applied to the spheres of electricity, causing them to move, the cylinders of magnetism with which they are in contact will begin to rotate, thereby producing a magnetic force. Moreover, the model holds up even as to details. Take a single illustration. An examination of Maxwell's model shows that the cylinders will rotate in the direction perpendicular to the motion of the spheres, thus bearing out the observation that a magnetic field acts at right angles to the flow of a current!

"I do not bring it forward," Maxwell wrote of his system, "as a mode of connection existing in Nature. . . . It is, however, a mode of connection which is mechanically conceivable and easily investigated, and it serves to bring out the actual mechanical connections between the known electromagnetic phenomena." Among the other "mechanical connections" Maxwell was able to demonstrate were electrical repulsion between two parallel wires carrying currents in opposite directions (ascribed to the centrifugal pressures of the revolving cylinders on the electrical particles in the model) and the induction of currents (the result of communication of rotary velocity from one cylinder to another).

Maxwell was not done with the model. It had yet to pass the supreme test: that is, to supply a mechanical explanation of the origin of electromagnetic waves. To orient ourselves in this matter we must examine briefly the question of condensers and insulators.

Faraday in his experiments had come upon a curious fact. The type of insulating material used in a condenser made a considerable difference in the condenser's capacity to take or to hold a charge. This was difficult to understand if all insulators were equally impermeable to an electric current. With the help of his model, Maxwell advanced a bold hypothesis. In an insulating material the little electrical particles somehow are unable to move freely from cylinder to cylinder; hence no current can flow. However, it was known that "localized electric phenomena" did occur in insulators. Maxwell suggested that these phenomena were currents of a special kind. When an electric force acts on an insulator, the particles of electricity are "displaced" but not torn loose; that is, they behave like a ship riding at anchor in a storm. They move only a limited distance, to the point where the force pushing them is balanced by the resistance of the elastic cylinders. As soon as the impelling force ceases to act, the particles snap back to their original positions. When a particle snaps back, it overshoots and oscillates about its fixed position. The oscillation is transmitted through the insulator as a wave. Thus for a brief instant a displacement current flows, for the wave is the current. If the electric force applied to the insulator is varied continually, it will produce a continually varying displacement wave: in other words, a continuing current.

Maxwell next arrived at an epoch-making conclusion. It had to do with the relation of the velocity of the displacement wave, or current, to that of light. For the point of departure we must go back to earlier work by the German physicists Wilhelm Weber and Friedrich Kohlrausch on the relationship between electrostatic and electrodynamic forces. The electrostatic unit of charge was defined as the repulsion between two like unit charges at unit distance apart. The electrodynamic unit was defined as the repulsion between two measured lengths of wire carrying currents "which may be specified by the amount of charge which travels past any point in unit time." In order to compare the repulsion between static charges with that between moving charges, a factor of proportionality must be introduced, since the units are different. This factor turns out to be a velocity, for since the length of the wires is fixed, and the number of units of electricity passing a given point in a given time can be measured, what the investigator must consider is length divided by time, or velocity. Weber and Kohlrausch had found that the velocity of propagation of an electric disturbance along a perfectly conducting wire was close to 3×10^{10} centimeters per second. This was an astonishing coincidence, for the figure was about the same as the velocity of light, determined a few years earlier.

Maxwell pursued the coincidence. He himself confirmed the Weber-Kohlrausch results, using an ingenious torsion balance to compare the repulsion between two static charges and two wires carrying currents, and at about the same time he calculated the velocity of displacement currents in a dielectric (nonconductor). The resulting values tallied closely. In other words, currents in a wire, displacement currents in a dielectric, and light in empty space (which of course is a dielectric) all traveled with the same velocity. With this evidence at hand Maxwell did not hesitate to assert the identity of the two phenomena—electrical disturbances and light. "We can scarcely avoid the inference," he said, "that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena."

Maxwell's Equations

Maxwell now had to outgrow his model. In "A Dynamical Theory of the Electromagnetic Field," published in 1864, he displayed the architecture of his system, as Sir Edmund Whittaker has said, "stripped of the scaffolding by aid of which it had first been erected." The particles and cylinders were gone; in their place were the field and the aether, a special kind of "matter in motion by which the observed electromagnetic phenomena are produced." The matter composing the aether had marvelous properties. It was very fine and capable of permeating bodies; it filled space with an elastic medium. It was the vehicle of "the undulations of light and heat."

For all its refinements and subtleties the aether was no less a mechanical rig than the cylinders and balls. It could move, transmit motions, undergo elastic deformations, store potential (mechanical) energy and release it when the deforming pressures were removed. As a mechanism, Maxwell said, it "must be subject to the general laws of dynamics, and we ought to be able to work out all the consequences of its motion, provided we know the form of the relation between the motions of the parts." Applying himself to this task, he devised the famous Maxwellian equations of the electromagnetic field. In their most finished form they appear in his *Treatise on Electricity and Magnetism,* which presents the results of 20 years of thought and experiment.

Maxwell based the equations on four principles: (1) that an electric force acting on a conductor produces a current proportional to the force; (2) that an electric force acting on a dielectric produces displacement proportional to the force; (3) that a current produces a magnetic field at right angles to the current's lines of flow and proportional to its intensity; (4) that a changing magnetic field produces an electric force proportional to the intensity of the field. The third and fourth principles exhibit a striking symmetry. The third is Faraday's law of electromagnetic induction, according to which "the rate of alteration in the number of lines of magnetic induction passing through a circuit is equal to the work done in taking unit electric charge round the circuit." Maxwell's complementary law, the fourth principle, is that "the rate of alteration in the number of lines of electric force passing through a circuit is equal to the work done in taking a unit magnetic pole round it."

On this foundation two sets of symmetrical equations can be erected. One set expresses the continuous nature of electric and magnetic fields; the second set tells how changes in one field produce changes in the other.

How does the concept of the field enter the theory? We have followed Maxwell as he stripped his model of its particles and cylinders and reduced it to an aethereal medium. Now he robs the medium of almost all its attributes other than form. Its properties are all purely geometric. The grin is left but the cat is gone. It is a perfect example of mathematical abstraction.

The aether is a thing that quivers when it is prodded, but does nothing on its own. An electromagnetic field consists of two kinds of energy: electrostatic, or potential, energy, and electrodynamic, or kinetic, energy. The aether, like a universal condenser, may be conceived as storing energy—in which case, being elastic, it is deformed. Since the aether fills all space and therefore penetrates conductors as well as dielectrics, it no longer makes any difference whether we deal with a conduction current or a displacement current; in either case the aether is set in motion. This motion is communicated mechanically from one part of the medium to the next and is apprehended by us as heat, light, mechanical force (as in the repulsion between wires) or other phenomena of magnetism and electricity. The ruling principle of all such phenomena, it should be observed, is that of least action. This is the grand overriding law of the parsimony of nature: every action within a system is executed with the least possible expenditure of energy. It was of the first importance to Maxwell that electrical phenomena should satisfy the principle, for otherwise his mechanical explanation of the phenomena would not have been possible.

Div and Curl

With these points in mind, we may examine a set of Maxwell's equations in a form which describes the behavior of an electromagnetic field in empty space. No conductors or free charges are present; the source of the field is some other region of space.

The first equation then reads:

$$\text{div}\, E = 0$$

E represents the electric field strength, which varies in time and from place to place. Div is an abbreviation for divergence. It signifies a mathematical operation which gives a rate of change. The equation says that the number of electric lines of force (representing the field strength) which enter any tiny volume of space must equal the number leaving it. That is, the rate of change in the number of lines is zero, and they can neither be created nor destroyed.

The second equation reads:

$$\text{div}\, H = 0$$

It makes the same assertion for the magnetic field H as the first equation makes for the electric field.

The third equation is:

$$\text{curl}\, E = -\frac{1}{c}\frac{\partial H}{\partial t}$$

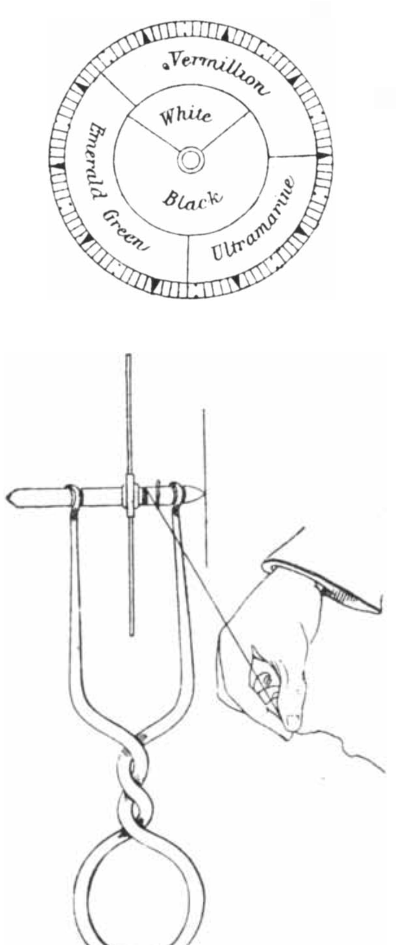
This is Maxwell's statement of Faraday's law of induction: it describes what happens in a changing magnetic field. The expression $\partial H/\partial t$ simply states the rate of change of the magnetic field. The changing magnetic field creates an electric field, and this fact is expressed on the left side of the equation, where the term "curl" signifies a mathematical operation dealing with rotation. The equation is more than analytic; it actually gives a picture of the event. A simple diagram may help make it clear [*see illustration on page 64*]. Suppose the existence of a magnetic field uniform over a region of space. A bundle of parallel lines represents the intensity and direction of this field. If the field is changed (by motion or by increase or reduction of strength), it produces an electric field which acts in a circle around the lines of magnetic force. By summing the work done in moving unit electric charge around the circle we obtain what is called the net electromotive force around the circle. If the circle were made of wire, the changing magnetic lines would of course induce the flow of a current; but even without a wire a force would be induced. Dividing this force by the area enclosed by the circle gives the net electromotive force (per unit area) which "curls" around the circle. Now imagine the circle growing smaller and smaller and shrinking finally to the point P. By this limiting process we obtain a limiting value of the net electromotive force per unit area: this is curl E at P. Thus the equation says that the limiting value of electromotive force per unit area equals the rate of change of H at the point P, multiplied by the tiny negative fraction, $-1/c$. The symbol c here stands for the ratio of the electrostatic to the electromagnetic units of electricity. It is required to translate E (an electrostatic phenomenon) and H (an electrodynamic phenomenon) into the same system of units. The equation explains how Maxwell was able to connect electrical and magnetic phenomena with the velocity of light, for c is in fact that velocity.

The last equation is:

$$\text{curl}\, H = \frac{1}{c}\frac{\partial E}{\partial t}$$

It says that except for the change of algebraic sign (which has to do with the directions of the fields), the roles of E and H in the preceding equation may be reversed. At any given point and instant the magnetic force per unit of area created by a changing electric field is equal to the time rate of change of the electric field multiplied by the tiny positive fraction $1/c$. Now this rate of change is none other than Maxwell's displacement current. For since the changes are taking place in the dielectric known as empty space, the only currents that can flow are displacement currents. Prior to Maxwell it was thought that a magnetic field could be produced only by currents which flowed in wires. It was Maxwell's great discovery, deduced mechanically from his model and expressed mathematically in this equation, that a time-varying electric field produced a magnetic force even in an insulator or empty space.

According to Maxwell's theory the introduction of a time-varying electric force in a dielectric produces displacement waves with the velocity of light. These periodic waves of electric displacement are accompanied by a periodic magnetic force. The wave front itself comprises electric vibrations at right angles to the direction of propagation, and a magnetic force at right angles to the electric displacement. The compound disturbance is therefore called an electromagnetic wave. A light wave (a displacement wave), as Henri Poincaré later elaborated, is "a series of alternating currents, flowing in a dielectric, in the air, or in interplanetary space, changing their direction 1,000,000,000,000,000 times a second. The enormous inductive effect of these rapid alternations produces other currents in the neighboring



COLOR WHEEL is depicted in Maxwell's essay "Experiments on Colour, as perceived by the Eye, with remarks on Colour-Blindness." The wheel is shown at the top. The apparatus for rotating it is at the bottom.

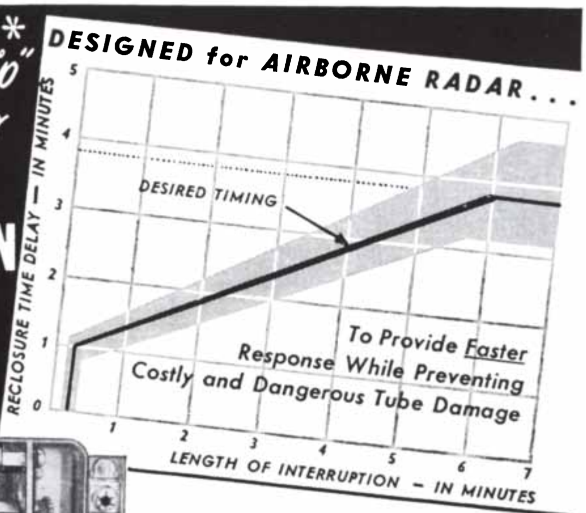
portions of the dielectric, and thus the light waves are propagated from place to place."

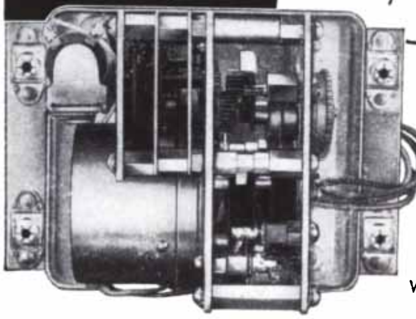
The electromagnetic theory of light was testable experimentally, and stood up remarkably well in laboratory trials. There were also other ways of testing Maxwell's theory. If his reasoning was correct, different sources of disturbance should produce other electrical waves at frequencies different from those of light. They would not be visible; yet it should be possible to detect them with appropriate instruments. Maxwell did not live to see their discovery, but 10 years after his death Heinrich Hertz won the race to demonstrate their existence. In a series of brilliant experiments he succeeded in generating electric radio waves. He concluded that the connection "between light and electricity . . . of which there were hints and suspicions and even predictions in the theory, is now established. . . . Optics is no longer restricted to minute aether waves, a small fraction of a millimetre in length; its domain is extended to waves that are measured in decimetres, metres and kilometres. And in spite of this extension, it appears merely . . . as a small appendage of the great domain of electricity. We see that this latter has become a mighty kingdom."

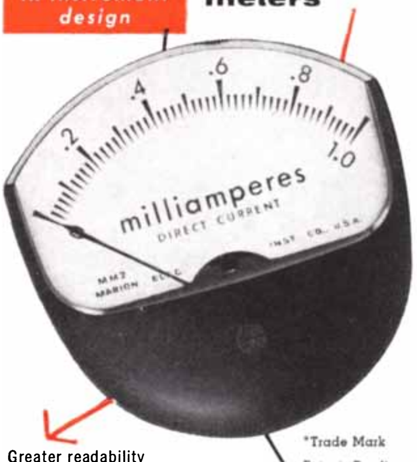
Construction Work

Maxwell completed his great work on electromagnetic theory while "in retirement" at Glenlair. It drew only part of his energy. As a "by-work" during the same period he wrote a textbook on heat and a number of papers on mathematics, color vision and topics of physics. He maintained a heavy scientific and social correspondence, enlarged his house, studied theology, composed stanzas of execrable verse, rode his horse, went on long walks with his dogs, visited his neighbors and played with their children, and made frequent trips to Cambridge to serve as moderator and examiner in the mathematical tripos.

In 1871 a chair in experimental physics was founded at Cambridge. It is hard to realize that at the time no courses in heat, electricity and magnetism were being taught there, and no laboratory was available for the pursuit of these arcane matters. The University, as a contemporary scholar delicately observed, "had lost touch with the great scientific movements going on outside her walls." A committee of the faculty began to bestir itself, a report was issued, and the lamentable facts fell under the gaze of the Duke of Devonshire,







chancellor of the University. He offered the money for the building and furnishing of the famous Cavendish Laboratory. Maxwell, though at first reluctant to leave Glenlair, yielded to the urging of his friends to offer himself as a candidate for the chair. He was promptly elected.

He now devoted himself to the task of designing and superintending the erection of the laboratory. His aim was to make it the best institution of its kind, with the latest apparatus and the most effective arrangements for research. He presented to the laboratory all the apparatus in his own possession and supplemented the Duke's gift by generous money contributions. With so many details to be taken care of, the structure and its appointments were not completed until 1874. The delay, while inevitable, was inconvenient. "I have no place," wrote Maxwell, "to erect my chair, but move about like the cuckoo, depositing my notions in the Chemical Lecture Room in the first term, in the Botannical in Lent and in the Comparative Anatomy in Easter." His "notions" were the courses he gave on heat, electricity and electromagnetism.

Maxwell's classic *Matter and Motion,* "a small book on a great subject," was published in 1876. About this time he contributed articles on various subjects—"Atom," "Aether," "Attraction," "Faraday," among others—to the famous ninth edition of the Encyclopaedia Britannica. His public lectures include a charming discourse "On the Telephone," which, though delivered when he was already very ill, is not only as clear as his best expositions but filled with gay, amusing asides. Speaking of "Professor Bell's invention," he commented on "the perfect symmetry of the whole apparatus—the wire in the middle, the two telephones at the ends of the wire, and the two gossips at the ends of the telephones. . . ." Maxwell spent five years editing 20 packets of unpublished scientific papers of Henry Cavendish. This splendid two-volume work, published in 1879, did much to fix the reputation of the immensely gifted 18th-century investigator, whose important work on electricity was unknown to his contemporaries because the results were confided only to his manuscripts. Maxwell repeated Cavendish's experiments and showed that he had anticipated major discoveries in electricity, including Ohm's law.

Glenlair

As Maxwell grew older, friends remarked on his "ever-increasing soberness" of spirit. He continued to see his many friends, to write light verse and parodies, to promenade with his dog Toby, to play small practical jokes. But he became somewhat more reticent, and more and more concealed his feelings and reflections beneath an ironical shell. The tough, rational, Scotch commonsense cord of his nature had always been intertwined with threads of mysticism. He had faith in science; yet he was at bottom skeptical as to how much could be learned from science alone about nature and meaning. His contemporaries described him as both modest and intellectually scornful, tentative in his scientific opinions and dogmatic when others seemed to him to be immoderately self-assured.

The most striking of Maxwell's traits was his gentleness. An extraordinary selflessness characterized his relationship to those close to him. When his brother-in-law came to London to undergo an operation, Maxwell gave up the ground floor of his house to the patient and nurse and lived in a room so small that he frequently breakfasted on his knees because there was no room for a chair at the table. Mrs. Maxwell had a serious and prolonged illness in the last years of Maxwell's life, and he insisted on nursing her. On one occasion it is reported that he did not sleep in a bed for three weeks. But his work went on as usual and he was as cheerful as if he enjoyed the ordeal—which may indeed have been the case. Nor did he give the slightest sign of being downcast or show self-pity when his own fatal illness seized him.

In the spring of 1877 he began to be troubled with pain and a choking sensation on swallowing. For some strange reason he consulted no one about his symptoms for almost two years, though his condition grew steadily worse. His friends at Cambridge observed that he was failing, that the spring had gone out of his step. When he went home to Glenlair for the summer of 1879, he was so obviously weakening that he called for medical help. He was in terrible pain, "hardly able to lie still for a minute together, sleepless, and with no appetite for the food which he so required." He understood thoroughly that his case was hopeless, yet his main concern seemed to be about the health of his wife. On November 5 he died. "No man," wrote his physician, Dr. Paget, "ever met death more consciously or more calmly." When Maxwell was buried in Parton Churchyard at Glenlair, the world had not yet caught up with his ideas. Even today it has not fully explored the kingdom created by his imagination.

LEARNING IN THE CANARY

Concerning some engaging experiments in which these domestic pets demonstrate unexpected ability to perform such feats as placing one box on top of another to reach a pellet of grain

by Nicholas Pastore

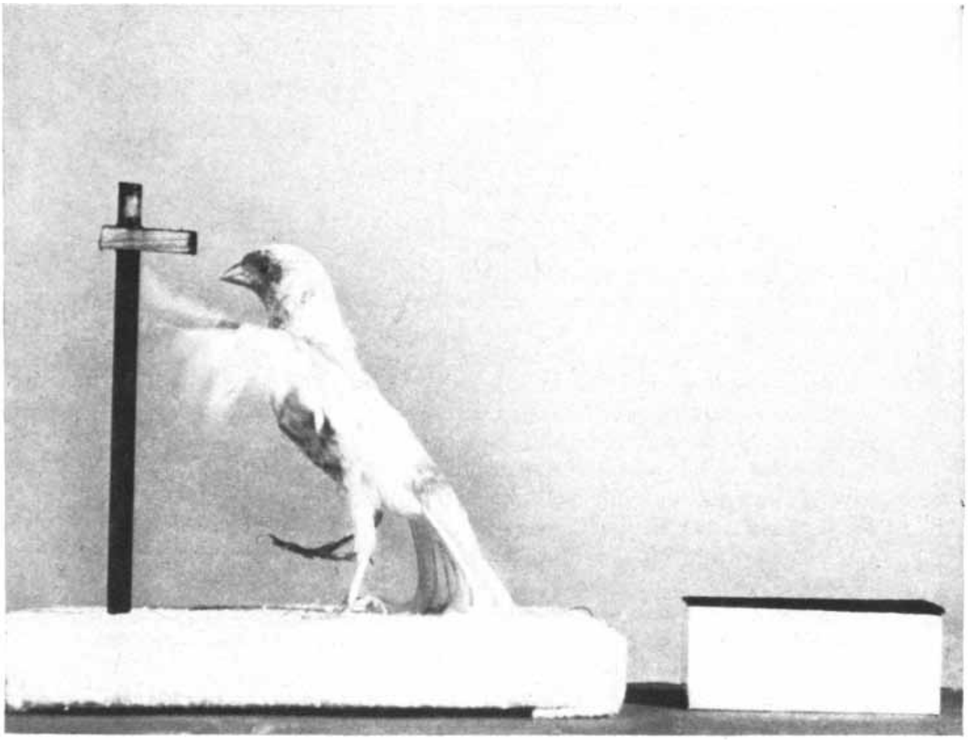
As subjects for laboratory experiments in learning, birds have not enjoyed high esteem among many psychologists. A bird is supposed to be incapable of learning a complex task, because its brain cortex is poorly developed. But the bird has at least one important advantage over the rat, a favorite laboratory animal for testing theories of learning. The bird has sharper vision; therefore it can respond more sensitively to a visual test or problem. Using complex tests of this kind, we have found that the avian brain has a surprising capacity for intelligent behavior.

In the department of psychology at Queens College in New York we have been investigating the ability of birds to solve visual problems and to form concepts. The subjects are nine female canaries. Three were 10 weeks old and the other six were a year old when the experiments began. The birds' secondary feathers were clipped so they would be easier to handle, and after they became used to their surroundings they were trained to perform tasks with a standard food reward.

The first task was a test of the birds' ability to identify the one object which differed from the others in a series. A row of nine food wells was set up next to the cage, all accessible to the canary. After the bird had been trained to push aside a covering object (initially a coin) to reach a pellet of grain in a well, a grain pellet was placed in one well and all nine were covered. The object covering the well with the food was a wood screw standing on its head; the eight empty wells were covered with aspirin tablets. The bird pushed aside the covering objects until it found the grain pellet. Then a pellet was placed in another well (chosen at random) and this time it was covered with an aspirin tablet, while wood screws covered the other eight. The test was continued in this way, with a screw or a tablet covering the grain (not always alternately), until the bird learned to select the unique object among the nine without error at least 15 times out of 20. Then the stimulus objects were changed from aspirin tablets and screws to some other pair: chess pawns, bolts and so on. The canary was trained on a total of 21 different pairs of objects.

Four canaries were put through this experiment, and the chart on page 74 summarizes the results: it shows the mean number of trials the four birds needed to master each problem. With each new version of the problem, their learning became more efficient. What they were learning to recognize was not the identifying object itself but its uniqueness. In anthropomorphic terms we may say the canaries learned the following: "Pay no attention to the actual physical attributes of the stimulus; instead select the stimulus which is different from all the others."

Next the birds were trained to select a stimulus which, though identical with others, was isolated from them. For in-



STACKING PROBLEM was solved by the author's most accomplished canary, the late Phyllis. Because her wing feathers were clipped, Phyllis could not reach a pellet of grain stance, on a given trial three aspirin tablets were grouped on the left side of a tray and one covering the food was set off to the right. On the next trial the position of the isolated stimulus was switched to the left, in order to prevent the bird from simply learning to go always to the left or to the right. After a bird had mastered the selection of the isolated stimulus for a given type of object, other objects were presented; all told there were seven. The learning of the four canaries was exceedingly rapid. In the first two problems of the series of seven the mean number of trials required was 45. Thereafter no further learning was necessary; in the following five problems the birds directly selected the isolated stimulus. They had learned how to respond to its perceptual distinctiveness.

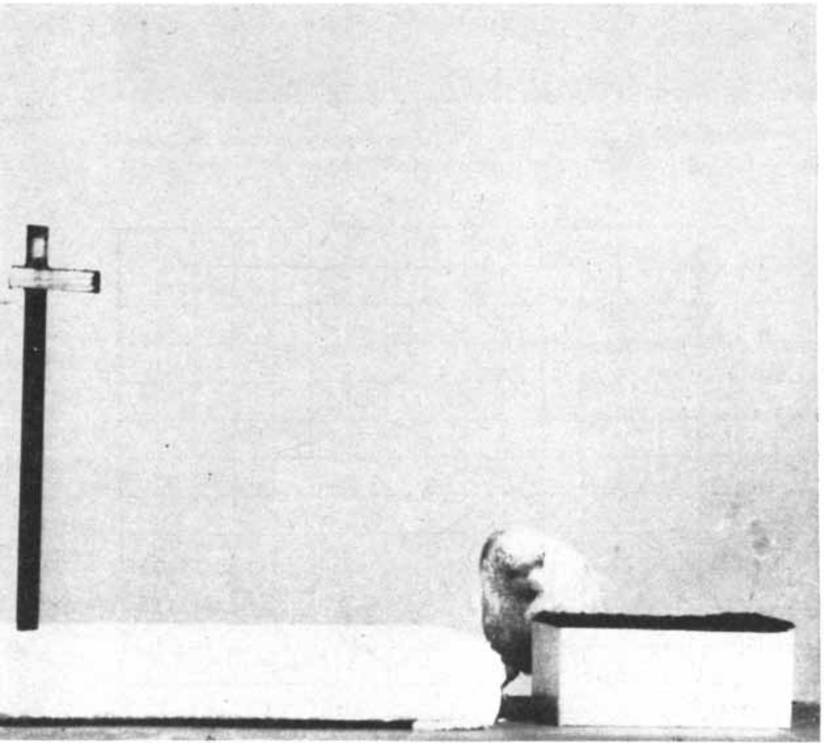
Let us consider a somewhat different question: Can a bird learn to respond to spatial relationships? Observation of birds under natural conditions suggests that it can: for example, a bird decelerates from full flight speed with precise timing when it alights on a perch or when it dives into the water in the pursuit of fish.

A series of experiments with our smartest canary, Phyllis, was inspired by Wolfgang Köhler's work with chimpanzees. Köhler showed that a chimpanzee could stack as many as four boxes in order to reach a food bait hanging overhead. Can a canary learn to perform a similar task? Of course the bird's physical limitations must be considered. Since its capacity to carry objects is severely limited, we first trained Phyllis to move objects by tugging on thread. A short length of thread was attached to a small wooden food tray on runners, placed outside the cage. The end of the thread lay inside the cage. The canary was permitted to feed directly from the tray, then the tray was placed slightly out of reach. In its efforts to reach the tray the canary seized the thread and, with a backward thrust of its head, brought the tray within reach. This performance was promptly repeated on the next and successive trials.

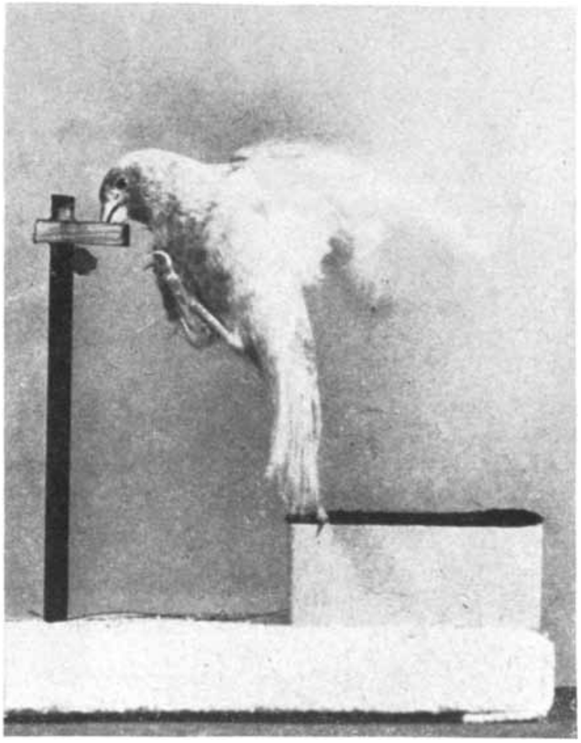
In the next phase the bird was fed from a fixed spot on the cage floor. This spot was then covered by a small cardboard prism to which a short length of thread was attached. The canary investigated the prism and finally tugged on the thread and exposed the pellet of grain. After that it readily pulled the thread. Then the canary was trained to feed from a bin. The bin was raised so that the bird could not reach it while standing on the cage floor, and the canary was taught to mount the prism to get access to the bin. At this point in the training the raised bin was placed away from the prism. The canary seized the thread and pulled the prism. When the prism happened to slide alongside the bin, the bird perched on the prism and reached for its reward. Apparently at first the canary merely tugged the prism to try to find grain under it. But after 25 trials the bird pulled the prism every time so that it was positioned next to the bin. Eventually it could haul the prism from a point as far as 16 inches away from the bin and position it properly. Later the height of the bin was increased and a box was placed beneath it. The canary learned to haul the prism alongside the box, mount the box, hoist the prism onto the box and perch on the prism to reach the food in the bin.

The canary must have been responding to spatial relationships, for the hoisting of the prism onto the box could not have been due to chance behavior. However, the bird was not able to stack both the box and the prism under the bin consistently when both were out of position, as a chimpanzee could do.

Since the manipulation of boxes by the canary offered mechanical difficulties, the experiment was modified. A small toy plastic truck was placed on a track. A length of string, attached to the truck, ran along a groove in the track and emerged through a piece of cardboard at



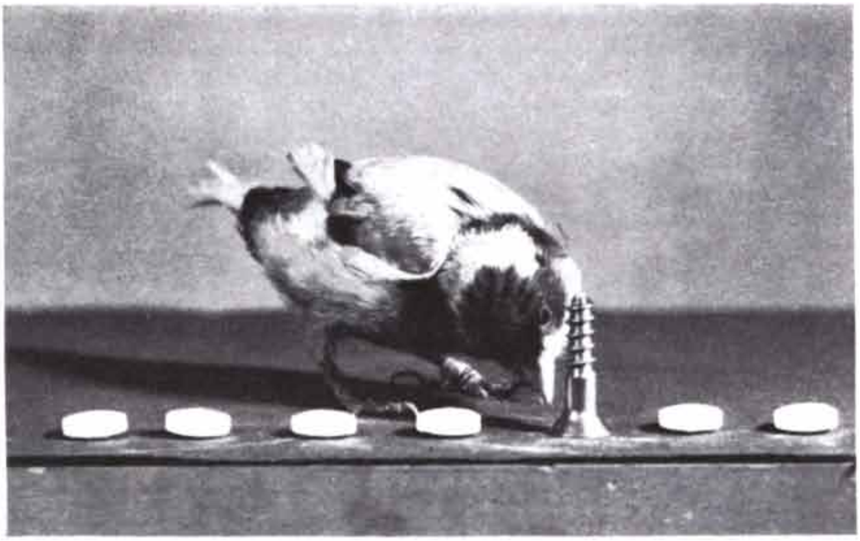
on a high post. But Phyllis learned to manipulate a small box placed out of reach up onto the platform next to the post. (A helpful string attached to the



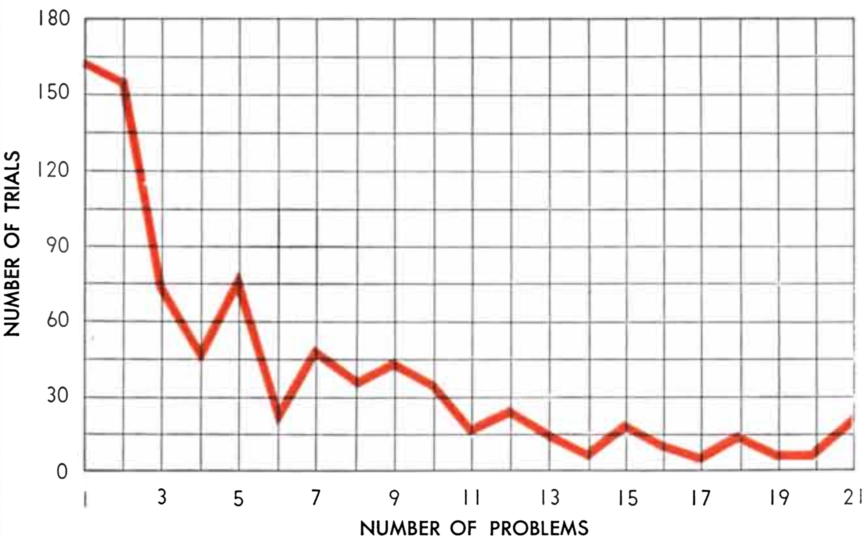
box is out of sight in the picture.) From the new vantage point atop the box Phyllis was able to obtain the pellet.

one end, so that when the canary tugged on it, the truck moved forward. The other piece of apparatus was a food bin mounted on a post, which we could place anywhere alongside the track. Phyllis readily tugged on the string until the truck was aligned with the post, perched on the truck and seized her reward—a pellet of grain in the bin atop the post. Phyllis did not overshoot the post, nor did she tug when the post was placed next to the truck. Sometimes the bird mounted the truck before she had hauled it far enough, but then she jumped off again to tug some more. Sometimes the bird would look alternatingly at the truck and the bin from its tugging position, as if judging the distance between the two. These results show that the crucial variable was the spatial relationship of the truck to the post. Separation of the truck from the post served as a cue for tugging; the conjunction of truck with post served as a cue for not tugging.

The canary, then, can learn perceptual and spatial relationships. Can it form concepts, that is, can it take an appropriate action when the rewarding stimulus itself is not in sight (*e.g.*, a cover on food)? This was the second main question that interested us. Admittedly it is a controversial area in experimental psychology. The "behaviorists" are loath to use terms such as concept, insight, purpose and memory in



UNIQUE-STIMULUS PROBLEM is solved. There is a pellet of grain beneath the screw, and no pellets beneath the aspirin tablets. The canary learns to choose the unique object.



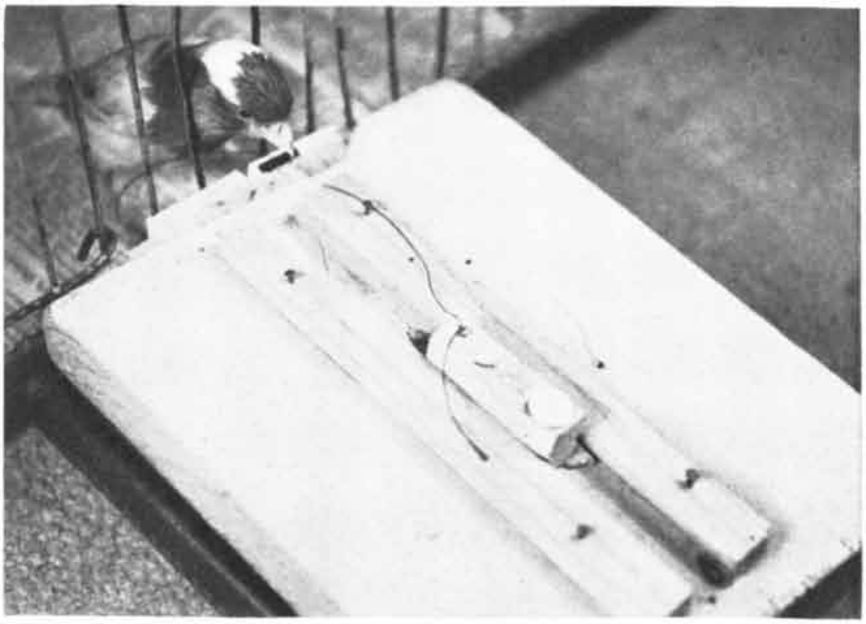
TWENTY-ONE UNIQUE-STIMULUS PROBLEMS were given. Each point on this curve represents the number of trials needed for a canary to pick the unique object 15 times out of 20. The curve is the mean for four birds. Ability of birds improved with each problem.

describing behavior. On the other hand, the Gestalt psychologists lean to this approach. Without becoming involved in these differences of theory, let us consider some experiments.

The four birds which had solved the unique-stimulus problem were tested on a more subtle form of it. Twenty screws and one aspirin (the unique stimulus) were equally spaced along the circumference of a circle. Inside the circle was a large cylinder which obstructed a canary's view so that it could not see the unique stimulus. The canary, instead of responding to the grouped stimuli visible to it, hopped around the obstacle until it found the unique object. It did this even though the location and physical characteristics (screw or aspirin) of the unique object were changed from trial to trial. The mean number of trials required to master this problem for all four birds was only 120. A plausible inference is that the canary's original response in learning to select the unique stimulus (the first problem discussed in this article) involved something more than a response to a perceptual relationship. The canary had formed a concept of uniqueness. The development of such a concept would explain the increased efficiency that the canary displayed in selecting the odd stimulus as new configurations were presented to it.

The next experiment employed the truck and the food bin mounted on a post. An opaque partition was placed between the canary and the track, so that she could not see when she had pulled the truck alongside the post. In the first step of this experiment the post was placed at one of two distances from the truck: at one distance a single tug on the thread sufficed to position the truck beside the post; at the other distance, two tugs were necessary. Phyllis first was taught to tug only once, receiving a reward if she did so. Then the truck and post were placed at the distance which required two tugs. After tugging once, the canary went behind the partition for her reward but found the truck was not in position. She then resumed her tugging. Gradually Phyllis learned to tug twice or three times before leaving the partition for her reward.

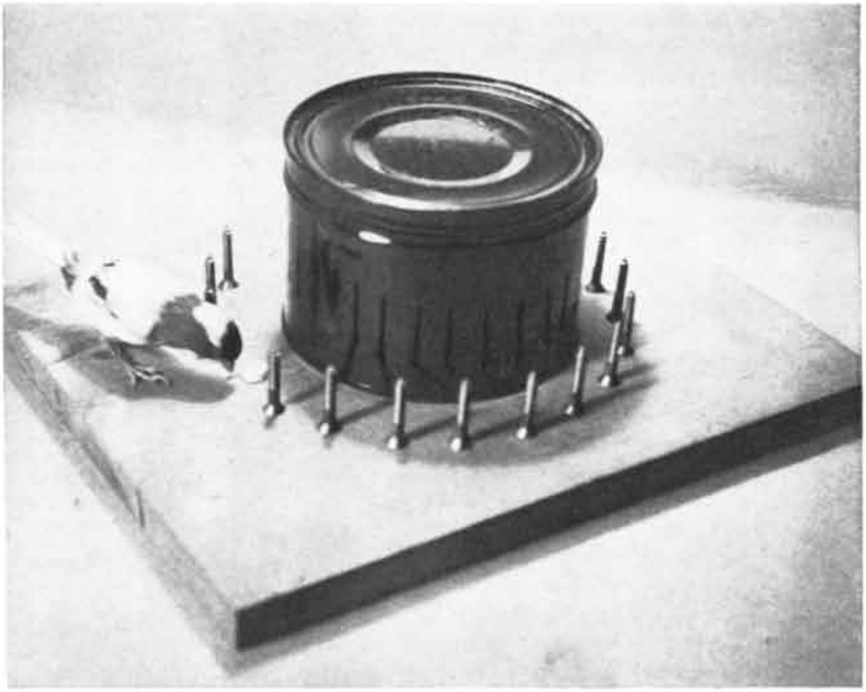
In the next series of trials the two distances were interspersed. Now Phyllis had to look at the distance for the cue to the appropriate number of tugs. After 2,600 trials she learned to match the two different distances with the required number of tugs. Subsequently, after 6,000 trials, she learned to correlate as many as four types of tugging responses



CANARY TUGS THREAD to bring a tray up to its cage. The tray bears food and is mounted on runners. This and similar experiments demonstrated spatial perception in the canary.

(one, two, three and four or more consecutive tugs) to four different distances.

The successful solution of the four-distance problem shows that the bird discriminated among four different distances, retained a given discrimination while tugging behind the partition, discriminated among four different types of tugging responses and, finally, correlated the four types of tugging responses to the four distances. In ordinary language we would say that the bird was able to remember the amount of separation between truck and bin and could then produce a tugging response on the basis of that memory of the situation. And, still within the scope of ordinary language, we would say that insofar as the bird could utilize memory to pro-



DELAYED RESPONSE to a unique stimulus was demonstrated by four birds which had solved the previous problems. When the view of the unique stimulus was obstructed, the bird would circle the can until it found the aspirin tablet that covered the grain pellet.

Complete coverage,

highest quality,

outstanding value

OSCILLATORS

0.008 cps to 10 MC

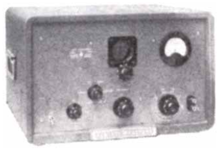
Hewlett-Packard, pioneer of the now-standard resistance capacity or RC oscillator circuit, today offers 11 stable, wide range, RC oscillators covering all frequencies 0.008 cps to 10 MC. Each instrument is a precision, quality built equipment guaranteeing you highest stability, long term trouble free operation, and the convenience of compact size and wide frequency range. Brief specifications are given here; for complete details see your *-hp-* representative or write direct.

Instrument	Primary Uses	Frequency Range	Output	Price
-hp- 200AB	Audio tests	20 cps to 40 KC	1 watt/24.5 v	$120.00
-hp- 200CD	Audio and ultrasonic tests	5 cps to 600 KC	160 mw/20 v open circuit	150.00
-hp- 200 I	Interpolation, frequency measurements	6 cps to 6 KC	100 mw/10 v	225.00
-hp- 200T	Telemetry, carrier current tests	250 cps to 100 KC	160 mw or 10 v/600 ohms; 20 v open circuit	350.00
-hp- 201B	High quality audio tests	20 cps to 20 KC	3 w/42.5 v	250.00
-hp- 202A	Low frequency measurements	.008 to 1200 cps	20 mw/10 v	465.00Δ
-hp- 202B	Low frequency measurements	½ cps to 50 KC	100 mw/10 v	365.00Δ
-hp- 205AG	High power tests, gain measurements	20 cps to 20 KC	5 watts	440.00Δ
-hp- 206A	High quality, high accuracy audio tests	20 cps to 20 KC	+ 15 dbm	565.00Δ
-hp- 233A	Carrier test oscillator	50 cps to 500 KC	3 w/600 ohms	475.00
-hp- 650A	Wide range video tests	10 cps to 10 MC	15 mw/3 v	490.00Δ

3 of 11 famous *-hp-* oscillators

***-hp-* 200CD, 5 cps to 600 kc.** Probably America's fastest selling precision audio oscillator. Offers highest stability, constant output, year after year dependability. 5 ranges, frequency response ±1 db, distortion less than 0.5%. Compact, weighs only 22 lbs. 300° logarithmic dial, 60″ effective scale length. $150.00.

***-hp-* 202A Low Frequency Function Generator.** Convenient, highly stable, multi-purpose source of transient-free test voltages from 0.008 cps to 1,200 cps. 5 bands, distortion less than 1%, provides sine, square or triangular waveforms. 30 volts peak output, frequency response flat within 0.2 db. $465.00Δ.



***-hp-* 650A Test Oscillator.** Provides fast, accurate tests from 10 cps to 10 MC. Extreme stability; output flat within 1 db full range. Voltage range 0.00003 volts to 3 volts. Output impedance 600 ohms. No zero set, no adjustment during operation. Output voltage attenuator, self-contained VTVM. $490.00Δ.

ΔRack mounted instrument available for $15.00 less.

HEWLETT-PACKARD COMPANY

3336S Page Mill Road • Palo Alto, California, U.S.A.
Cable "HEWPACK"

Field Representatives in all principal areas

Data subject to change without notice

PLEASE SEND INFORMATION ON MODEL________OSCILLATOR

Name____________________

Company____________________

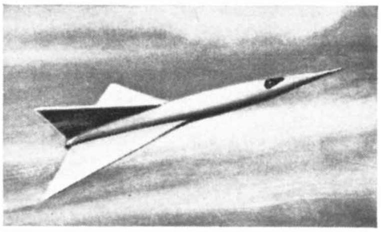
Street____________________

City__________ Zone____ State________

ELECTRONIC MEASURING INSTRUMENTS

experience

plays a vital role in every success



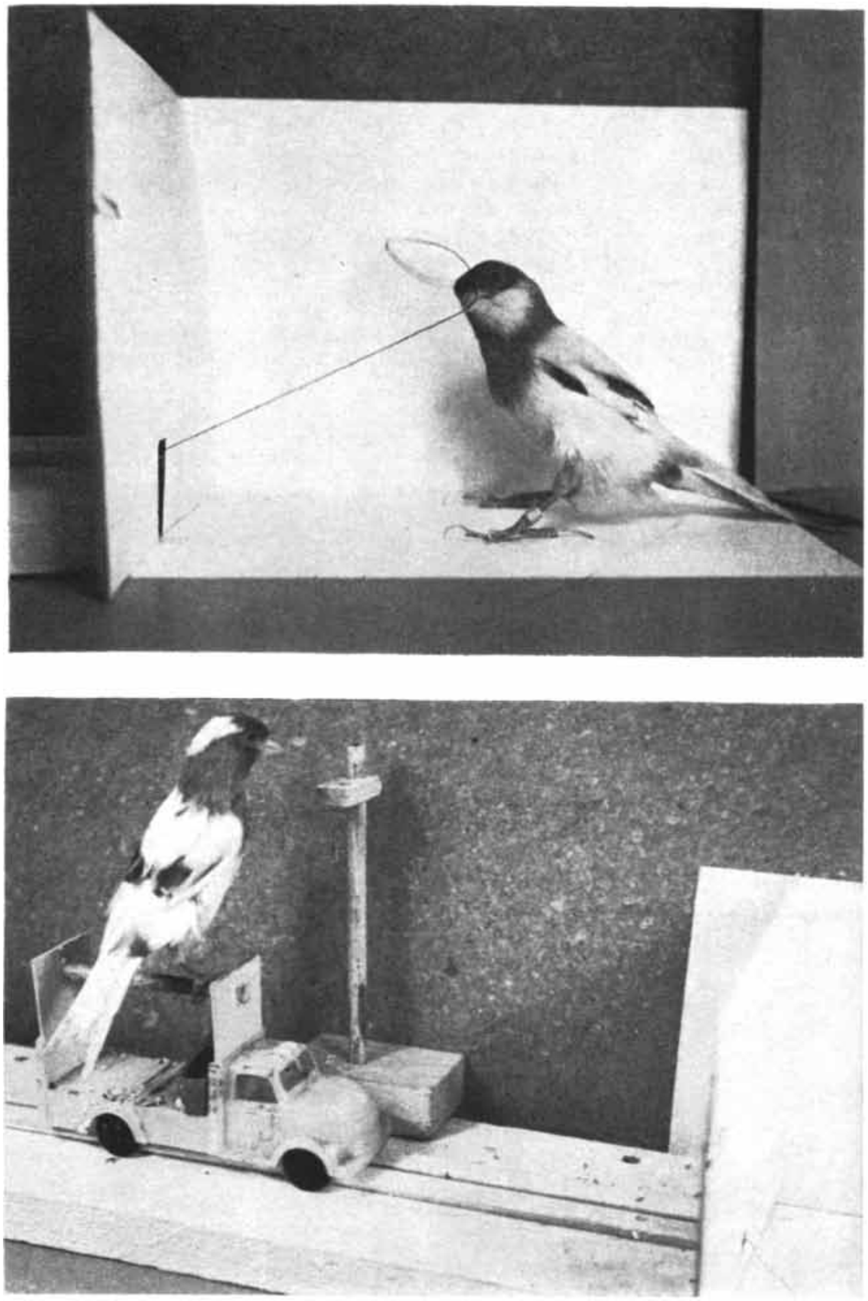
Pressure actuated switches for every requirement from zero absolute to 12,000 psi. Meletron switches are used by every major aircraft manufacturer.

Great progress has been made in high fidelity recording. Microphones, amplifiers, discs, tapes and speakers have been greatly improved. Knowledge of audio principles alone could not create high quality recording. It was knowledge, plus years of experience, that made high fidelity sound reproduction a reality.

In the precision instrument field, we are constantly improving techniques and testing new materials. This research is productive, but real progress is gained only through experience; *experience* that's acquired only through the production of more than a million pressure switches.

MELETRON® CORPORATION
950 NORTH HIGHLAND AVENUE, LOS ANGELES 38, CALIFORNIA

J M. WALTHEW CO., Boeing Field, Seattle 8, Wash. THOMSON ENGINEERING SERVICE, 554 So. Summit St., Fort Worth 4, Texas and 307½ Laura St., Wichita, Kansas. ROUSSEAU CONTROLS Ltd., 2215 Beaconsfield Ave., Montreal 28, Canada. JOSEPH C. SORAGHAN & ASSOCIATES, 1612 Eye St., Northwest, Washington 6, D. C.



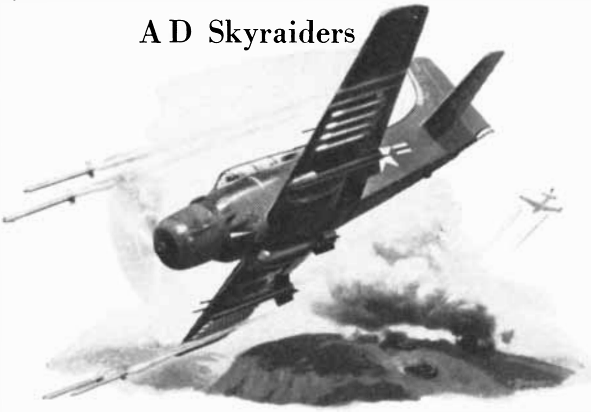
DIFFICULT PROBLEM is solved by a canary. In the top picture the bird tugs at a thread behind a cardboard screen. At the other end of the thread is the small truck shown in the bottom picture. The canary learns how many tugs are needed to pull the truck up to the post.

duce a sensible response, it exhibited insight into the needs of the situation.

Observers who saw Phyllis perform have commented on her "eagerness" and "deliberateness." One observer suggested that the bird had formed a concept of number. This interesting suggestion is not actually proved by the experiments. The bird might have learned four different types of motor or muscular rhythms. In an analogous situation, a musician runs off an appropriate series of notes without, of course, counting individual notes.

Our experiments demonstrated two things: that a canary can learn to respond to perceptual and spatial relationships, and that it is capable of insightful or conceptual behavior. Evidently a bird's visual discrimination in some respects matches that of a human being. Further, the low esteem in which a bird's capacity for intelligent behavior is held is not justified. In the light of the foregoing experiments, we must admit either that the brain cortex of a bird is capable of more complex performances than has generally been conceded or that its subcortical centers can carry on complex activities usually assigned to the cortex.

A D Skyraiders

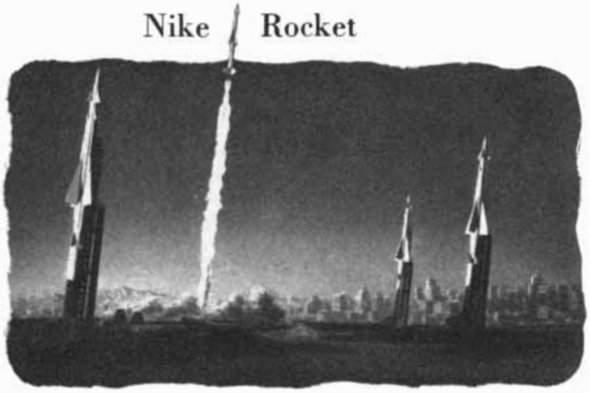


Called world's most versatile aircraft

C-118 A—R 6 D

Air Force and Navy versions of the DC-6A

Nike Rocket

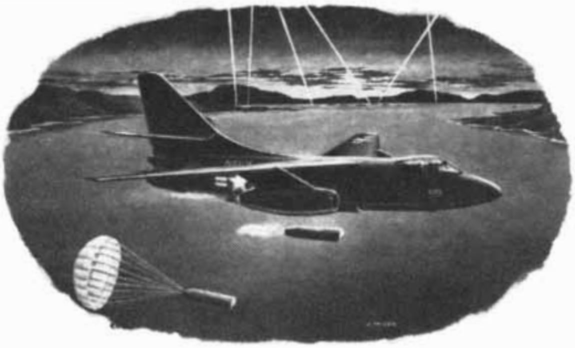


Supersonic anti-aircraft missile already in service

D 558-2 Skyrocket

First plane to fly double speed of sound

A 3 D Skywarrior



Navy's largest carrier-based bomber

R B-66

Versatile Air Force reconnaissance bomber

F 3 D Skyknight

Twin-jet, radar-guided night fighter

Depend on

DOUGLAS

First in Aviation

Antibiotics against Plant Diseases

Antibiotics have already been used to preserve food and to promote the growth of farm animals. Recent experiments show that they also control rot, blight, smut, wilt, mold and mildew in certain plants

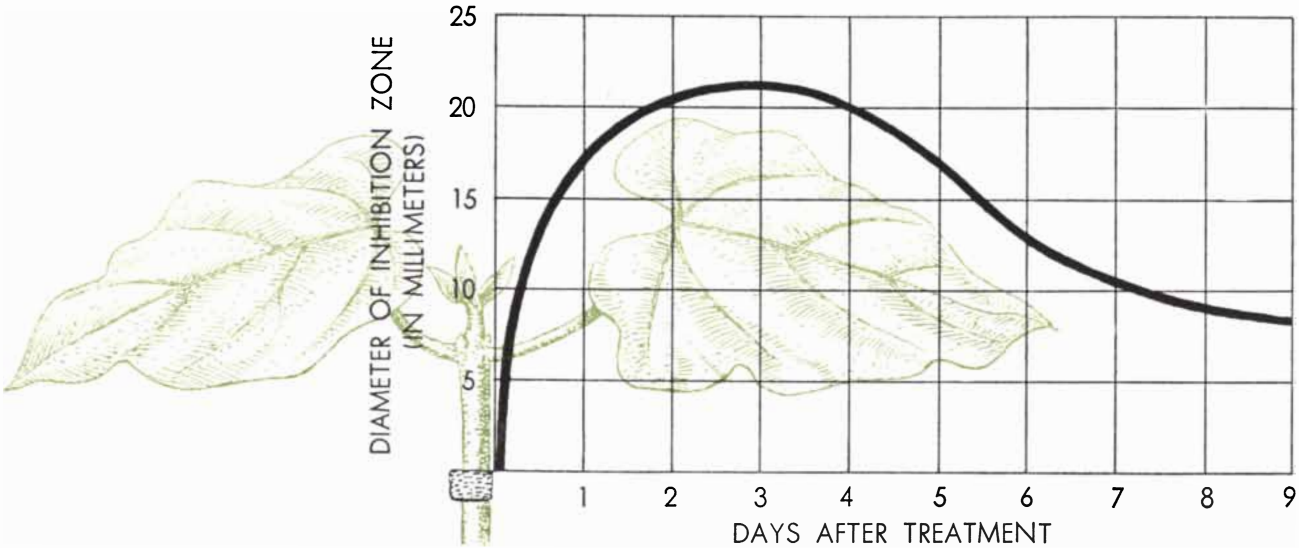
by David Pramer

Antibiotics have been a great gift not only to medicine but also to agriculture. They are used today to promote the growth of pigs and chickens, to prevent spoilage of vegetables, dairy products and sea foods, to delay deterioration of beef, even to preserve food by incorporation in the ice used to chill it.

During the past year the possibility of using antibiotics to control plant diseases was explored in many laboratory and field studies. The results reported by agricultural experiment stations throughout the country are most promising. This new and intriguing approach to the problem of reducing plant disease losses has given rise to questions of fundamental importance to the microbiologist and plant physiologist, as well as to the plant pathologist.

In the U. S. plant diseases are attacked in four ways: exclusion, eradication, plant breeding and chemical treatment. The Federal Government, most states and some counties take steps to prevent diseased plants and animals from crossing their borders, and an outbreak of disease may be localized by quarantining the infected area. Eradication of an established disease may be achieved by destroying infected plants, by crop rotation, by elimination of alternate host plants or by soil management which discourages growth of the infective organisms. Breeding is used to produce disease-resistant crop varieties. And more than 200 million pounds of chemicals, costing $35 million, are expended in the U. S. each year to fight plant diseases.

The poisons most commonly employed for preventing plant disease are



ABSORPTION AND TRANSLOCATION of streptomycin from the stem to the leaves of bean seedlings were demonstrated simply. First streptomycin sulfate was applied to the stem of each test seedling in a lanolin carrier. Leaves from the plants were collected at intervals during the nine days following treatment. The juice squeezed from them was placed in cylinders on an agar medium supporting a growth of the bean blight organism *Xanthomonas phaseoli*. The streptomycin that had been translocated to the leaves diffused out of the cylinders, inhibiting the growth of the bacteria. The curve shows the antibiotic concentration in the leaves.

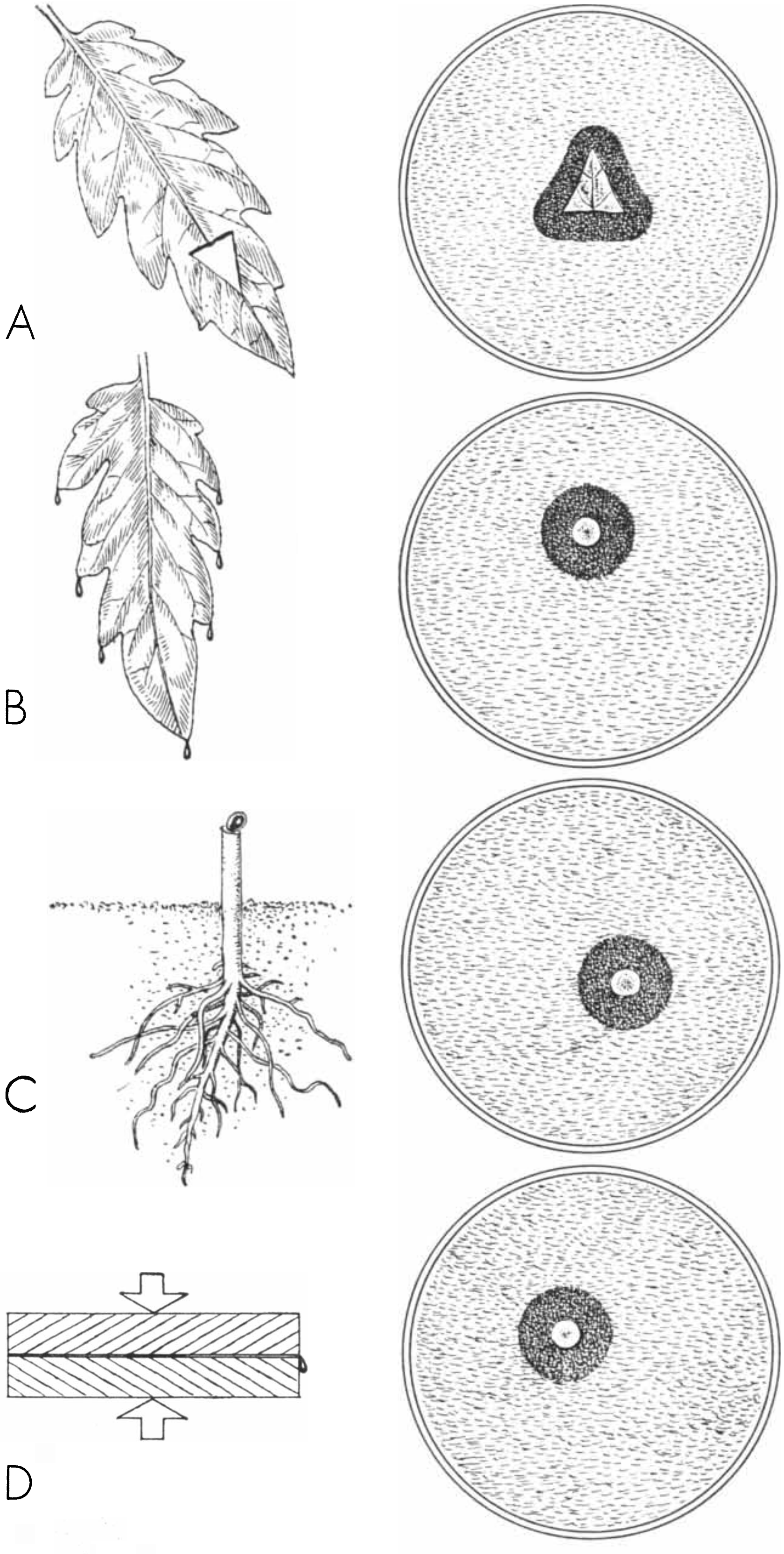
compounds of sulfur, copper and mercury, with carbamates and certain other chemicals recently added to the arsenal. In general these defenses protect plants only at the surface. It has been difficult to find chemicals which will destroy specific bacteria or fungi within a plant without injuring the plant's tissues also. Now the antibiotics have made such attack possible.

One of the most promising experimental successes of the antibiotics has been against the bacterial disease of apple and pear trees known as fireblight, long the despair of orchardists. The fireblight damage to orchards is estimated to be millions of dollars annually, and it is responsible for the marked decline of pear culture in our eastern and central states. The disease is spread by pollen-gathering and nectar-sucking insects as they move from infected to healthy blossoms. Once in the blossoms, the fireblight bacteria multiply rapidly. The blossoms, leaves and branches turn brown or black, as though seared by fire. The infection lies dormant in the woody portion of trees throughout the winter and reappears the following spring. Copper sprays and dusts have been used against it, but they are only moderately effective and damage the fruit and foliage.

Among the groups that tested antibiotics against fireblight was R. N. Goodman and his associates at the University of Missouri Agricultural Experiment Station. They applied various antibiotic-containing sprays to the foliage of year-old fruit trees that were extremely susceptible to fireblight. To help the drugs penetrate into the leaf tissues they added methyl Cellosolve, a cuticle solvent, to the spray. Twenty-four hours after the spray was applied, the trees were infected by inoculation of the shoots with fireblight bacteria. The experimenters discovered that a spray containing streptomycin and terramycin could give almost complete protection against fireblight. The drugs acted to suppress the bacteria inside and at the surface.

Orchard experiments on naturally infected trees confirmed these greenhouse results, and so did tests at various other stations throughout the country. Antibiotics promise to become a routine treatment for the control of fireblight.

Many other workers investigated the potency of antibiotics against diseases of vegetable crops. At the Bureau of Plant Industry of the U. S. Department of Agriculture, J. W. Mitchell and W. J. Zaumeyer collaborated in treating bacterial blight of beans. This embraces a



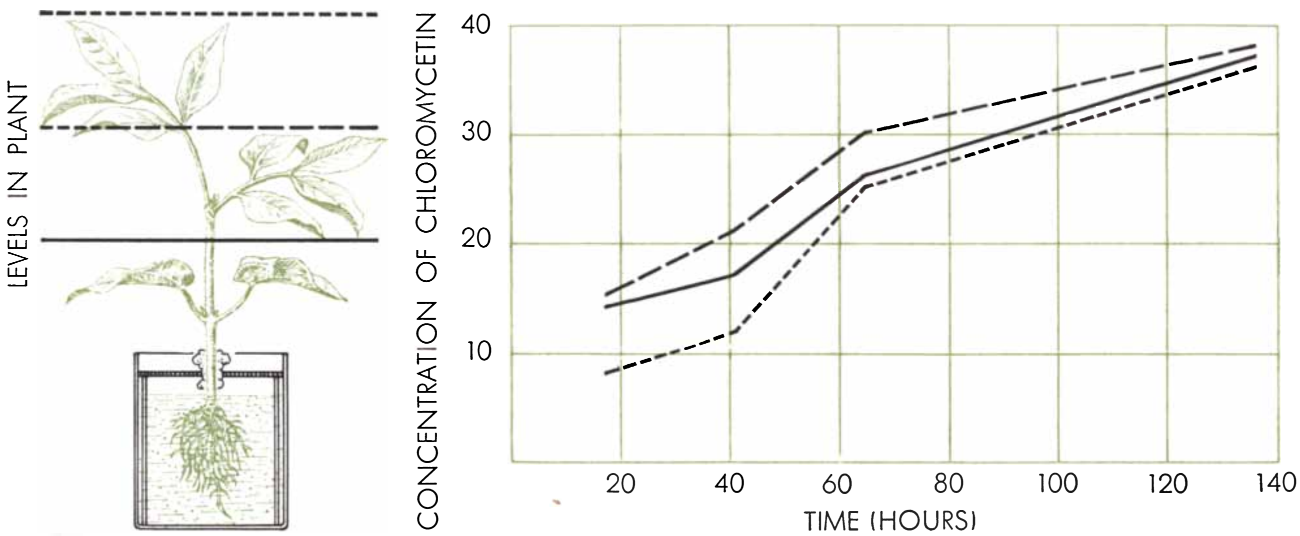
AGAR-PLATE TECHNIQUE is used to measure concentration of antibiotic in parts of plants. The part is either removed and placed on an agar plate covered with bacteria, or filter paper which has absorbed fluid from the part is placed on the plate. The area of bacterial growth inhibited indicates the antibiotic concentration. Shown here are tests on a leaf section (A), fluid exuded by a leaf (B), fluid from a stem (C) and sap extracted by pressure (D).

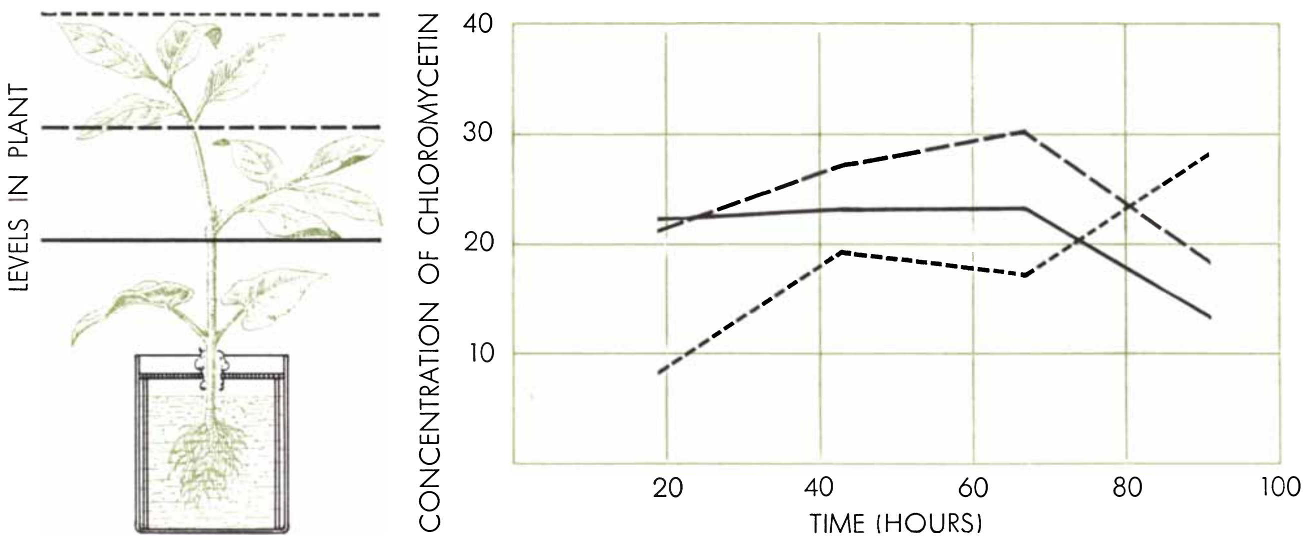
group of diseases: common blight, fuscous blight and halo blight, each caused by a different bacterium. They are promoted by a rainy season. Water-soaked spots appear on the leaves and pods of infected plants. The spots enlarge and turn brown, and the dying leaves may become covered with a bacterial ooze. The bacteria enter the plant through the stomata in leaves, stems and pods.

Mitchell and Zaumeyer prepared a paste of streptomycin mixed with a lanolin carrier and applied the paste in a thin layer on the stems of bean plants. The stems absorbed the drug and passed it on to the leaves: measurable amounts of the antibiotic were detected in leaves within eight hours. This treatment was completely successful in preventing blight in bean plants inoculated with the halo blight organism.

A farmer cannot be expected to go through acres of bean plants treating each stem individually, as the experimenters did in this laboratory test. Mitchell and Zaumeyer therefore proceeded to spray fields of beans with a preparation containing one tenth of 1 per cent of streptomycin. Four sprayings completely prevented the blight. The streptomycin spray was able to suppress the disease even after infection appeared, if the spray was applied within two days of the infection.

At the Wisconsin Agricultural Experiment Station C. Leben and G. W. Keitt worked with a new antibiotic called helixin. It is primarily a fungicide, and the experimenters demonstrated that it could control a fungus-incited disease of tomato plants known as early blight. The blight first produces small brown spots on the leaves and then causes the leaves to turn yellow. Much of the foliage dies. Helixin, sprayed on the plants, reduced infection by more than 95 per cent. It acts only on the plant surface: immersing the roots of tomato plants in



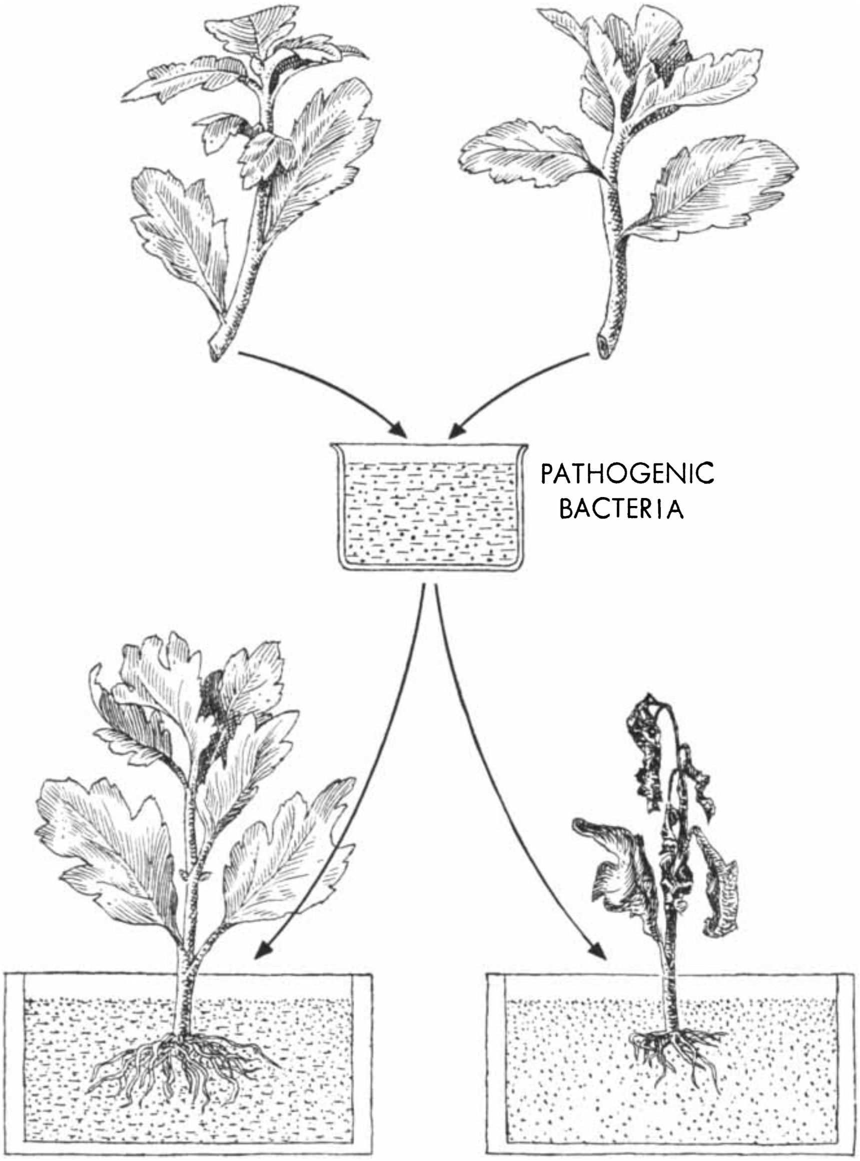


ACCUMULATION OF ANTIBIOTICS by broad-bean plants was found to follow a gradient up the plant. Plants were grown in solutions of chloromycetin and assayed periodically. After 17 hours the bottoms of the two plants contained more antibiotic than the tops, but this gradient disappeared after 137 hours (*top graph*). When the plants were grown for 19 hours in the antibiotic solution, then removed to solutions without antibiotic, the gradient was again evident but reversed itself after 72 hours (*bottom graph*).

solutions of the antibiotic had no effect on the infection.

At the Imperial Chemical Industries laboratories in England P. W. Brian and his associates investigated griseofulvin, an antibiotic which destroys molds. Griseofulvin, not commercially available, is endowed with a number of desirable characteristics. It is relatively nontoxic to plants, has some solubility in water, is chemically stable and is very active against various fungi. Brian grew oat seedlings with their roots immersed in nutrient solutions containing the antibiotic. In a cool and humid atmosphere drops of fluid exuding from the plant collected at the tip of each leaf, and these drops were found to contain griseofulvin, which had been absorbed by the plant roots and had traveled to the leaves. After this demonstration of the antibiotic's absorption, Brian's group tested the drug against the gray mold disease of lettuce seedlings and later against early blight of tomato plants, mildew on barley and the chocolate-spot disease of the broad-bean plant. The treatment gave high percentages of control over all these infections. In each case the antibiotic was applied to the roots. It is interesting that griseofulvin shows systemic activity against early blight of tomato, whereas helixin is inactive systemically but highly effective as a surface protectant.

Antibiotics have also scored successes against certain diseases of flower plants. A study of their usefulness for control of bacterial wilt of chrysanthemums was undertaken at the New Jersey Agricultural Experiment Station. Bacterial wilt, a new menace to chrysanthemums, has become serious in commercial nurseries. The infection is believed to have been spread throughout the country in cuttings, the usual form in which chrysanthemums are propagated. The infecting bacterium invades the plant's sap vessels, causes them to turn a reddish color and eventually may produce a black, soft rot of the stem and leaves. Streptomycin, aureomycin and terramycin proved to be most active against this bacterium, but the latter two were toxic to the plants. The effectiveness of streptomycin against plant infection was then tested in the following manner. Cuttings were infected by dipping their open ends into a water suspension of the bacterium. The disease was allowed to develop for six hours, and then the infected cuttings were placed in water solutions of streptomycin. After six hours of contact with the antibiotic, the cuttings were removed and inserted in sand



CHRYSANTHEMUM CUTTINGS were infected by dipping their stems into a suspension of pathogenic bacteria. Some infected cuttings were treated by dipping them into a solution of streptomycin; others were left untreated. Treated and untreated cuttings were transplanted to sand, where after 24 hours the untreated ones succumbed to the disease. The cuttings treated with streptomycin were completely protected and not injured by the antibiotic.

for rooting. Within 24 hours all cuttings that had been infected but not treated with streptomycin had succumbed to the disease and were transformed into a mass of black, soft rot. Cuttings that had received streptomycin showed varying degrees of resistance, depending upon the concentration of antibiotic used. Complete control was obtained with concentrations of streptomycin which in no way influenced the vigor or rooting of cuttings. This was a very impressive demonstration of antibiotic chemotherapy in plants.

Streptomycin also was just as effective as a protective measure when applied to cuttings before infection. And it gave a high degree of control and protection against the disease when the antibiotic was applied to the sand in which the cuttings were grown instead of to the cuttings themselves. Thus streptomycin, which at the current price is not appreciably more expensive than some sprays commonly used in greenhouses, seems to be a practicable means of prevention and treatment of bacterial wilt of chrysanthemums. It is up to 80 per cent effective even against severe infections and does not set back the plants.

These are only examples taken from what is rapidly becoming a voluminous literature on the usefulness of antibiotics against plant diseases. In almost every test the results have been most promising. Two large pharmaceutical firms have announced that they will market antibiotic plant sprays this year.

The unusual ability of antibiotics to enter the plant system has provided an opportunity for some interesting basic studies of the migration of substances in plants. The writer made a series of such studies during a two-year stay as visiting investigator at the Butterwick Research Laboratories of the Imperial Chemical Industries in England. The experimental procedures employed were relatively simple. Plant roots or cuttings were immersed in antibiotic solutions, and the amount of antibiotic taken up was then determined by measuring the concentration in sap pressed out of the leaves.

In one experiment cucumber seedlings were used to study the uptake and movement of five antibiotics. The seedlings absorbed no aureomycin, neomycin or terramycin, so far as we could tell. They absorbed considerable chloromycetin, but the level in the leaves never reached that in the solution in which the roots were immersed. Streptomycin, on the other hand, was so effectively absorbed and stored that the concentration in the leaves was actually higher than that in the solution feeding the roots. It may be that both drugs were absorbed equally but streptomycin was accumulated because it is stable, while chloromycetin is relatively unstable. In general we must take account of the possibility that the failure of an antibiotic to appear in the leaves does not necessarily mean none was absorbed through the roots: it may merely have failed to travel to the leaves or may have been transformed by the plant to another substance.

Working with broad-bean and tomato plants, we found that absorption depends on the concentration of antibiotic in the nutrient solution. In the case of chloromycetin the amount that reached the leaves varied directly with the amount supplied to the roots. In the case of streptomycin none of the drug could be detected in leaves until the amount in the solution was at a rather high level; thereafter the amount passing to the leaves was in direct proportion to the supply to the roots.

Tomato plants absorb more streptomycin than bean plants. Cut shoots (with the roots removed) absorb much more than intact plants, especially in the case of the bean. In both bean and tomato plants the older tissues (the lower leaves) took up more antibiotic than the upper leaves; this contrasts with the uptake of regular nutrients such as phosphorus and calcium, which migrate mainly to the young leaves where growth is most rapid. As the roots continue to absorb antibiotic, the concentration in the young leaves rises. Antibiotics travel in the plant more slowly than minerals or plant hormones. Their absorption and rate of migration in the plant seem to be linked with the evaporation of moisture from leaf surfaces (transpiration). This is of practical interest, for it indicates that the effectiveness of antibiotics in plants may be profoundly influenced by atmospheric or weather conditions.

It must be emphasized that the effects described are all specific for the antibiotic or the plant: they cannot be generalized. Plants differ physiologically, and antibiotics differ greatly in their physical and chemical properties; for example, penicillin is acidic while streptomycin is a base.

There is indirect evidence that some antibiotics will penetrate into a plant when they are applied to the surface in a spray. But that is a separate subject which still needs much more study.

How do the antibiotics act to halt disease in a plant? The answer may seem obvious (by attacking the microbe), but actually it is still largely unknown. One of the mysteries is that infectious organisms which resist an antibiotic in the test tube succumb to it in a plant. For instance, streptomycin has little or no activity against fungi *in vitro*, but it unexpectedly controls blue mold of tobacco, loose smut of barley and rot of sugar beets—all fungus diseases. Likewise streptothricin and terramycin suppress two plant virus diseases—tobacco ring spot and tobacco mosaic—although they show little effect on viruses in the test tube.

Evidently the effects of the antibiotics in these cases must be indirect. Do they increase the plants' resistance to infection by altering their metabolism? We know that changes in the sugar and nitrogen content of plants will influence their susceptibility to disease. But so far there is no experimental evidence that antibiotics alter the biochemical composition of plant tissue. Does the plant itself convert the antibiotic to a substance toxic to the infecting organisms? Again

there is no evidence that this happens: antibiotics recovered from plant leaves apparently are in no respect altered from the substances originally applied to the roots. Yet different plants do respond differently to an antibiotic: in some the drug may suppress a given infection while in others it has no effect on the very same pathogenic organism. These different effects, produced by the same antibiotic on the same pathogen in different hosts, indicate a complex interrelationship among the three factors.

R. S. Robison and R. L. Starkey, who did the work on bacterial wilt of chrysanthemums in New Jersey, investigated a suggestion by the writer for testing whether antibiotics act independently of the plant. The suggestion was to try the antibiotic on strains of an organism that had developed resistance to the drug in the test tube. If the antibiotic suppressed such a resistant strain in the plant, then it must be interacting in some way with the plant. The experimenters found that strains of the chrysanthemum bacterium which were resistant to streptomycin in the test tube were also resistant in the plant. It was concluded that in this case the antibiotic must act directly and independently on the sensitive bacteria.

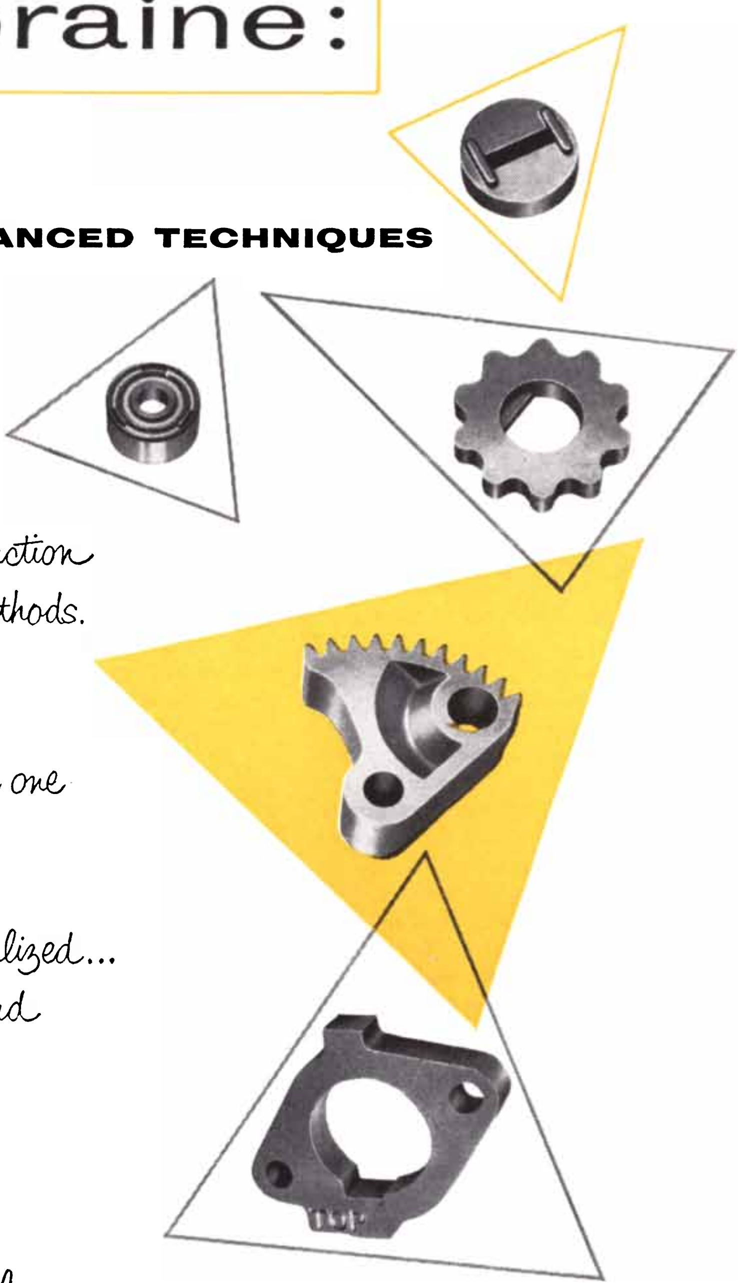
Although we know little about how antibiotics work, we do know that they can be remarkably effective against plant diseases. Two major difficulties stand in the way of their commercial application. One is economic—the cost of antibiotics. However, the one antibiotic that is the best choice against almost all the diseases is streptomycin, which is also the least expensive. J. C. Dunegan of the U. S. Department of Agriculture has estimated that at its present price of 20 cents per gram commercial use of streptomycin to control fruit diseases approaches feasibility. No estimate has been made as to whether it is economically practicable for vegetable and floral crops.

The second difficulty involves public health. If the crops we eat contain antibiotics, we must be concerned about whether they will contribute to developing resistant strains of bacteria in our bodies, so that the antibiotics will be less effective in controlling human infections. The use of antibiotics for treating human diseases is more important than their use in controlling plant diseases. It will be necessary for the U. S. Department of Agriculture and the Food and Drug Administration to establish permissible tolerances for antibiotic residues in food crops.

from moraine:

METAL POWDER PARTS

THAT REPRESENT ADVANCED TECHNIQUES



Here are only a few of the many parts that might be production problems if made by ordinary methods. Moraine, however, makes them from metal powder in quantity, every day—to close tolerances—in one press operation. Through our cooperation with the customer, many important benefits are realized... among them—lower unit costs, and improved product performance. More and more industries are taking advantage of Moraine's design and engineering experience with metal powders... Moraine's ability to deliver on schedule.

Five metal powder parts from the wide variety Moraine makes for the automotive, appliance, and other industries.

moraine products

DIVISION OF GENERAL MOTORS, DAYTON, OHIO

Other Moraine products include Moraine-400 bearings, toughest automotive engine bearings ever made—M-100 engine bearings and Moraine conventional bi-metal engine bearings—Self-lubricating bearings—Moraine friction materials—Moraine porous metal parts—Moraine rolled bronze and bi-metal bushings—Moraine power brakes—Delco hydraulic brake fluids, Delco brake assemblies, master cylinders, wheel cylinders and parts.

COMPUTER MEMORIES

A large mathematical machine must be able to store information and refer to it. This requirement has stimulated the evolution of information-storage units based on various physical effects

by Louis N. Ridenour

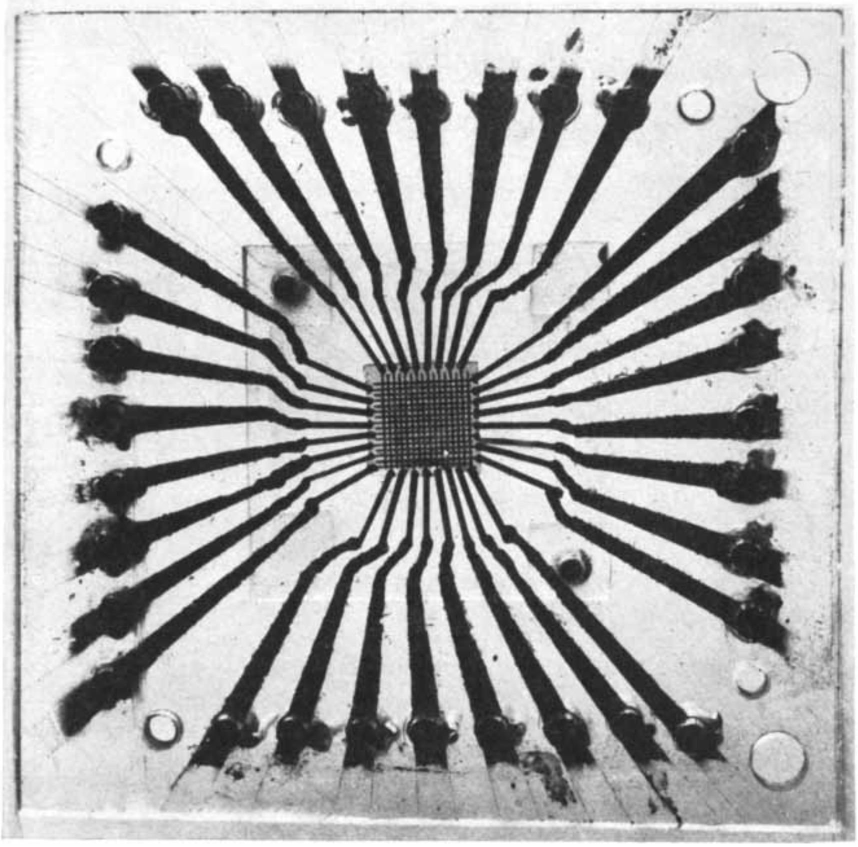
A computing machine capable of solving problems must possess a "memory" or, less poetically, an "information-storage unit." The recent history of improvements in computing machines has been largely a history of improving memory devices. No ideal system has yet been found, but there has been a great deal of progress within the past decade, and several promising new developments are on the horizon.

When we speak of the "memory" of a machine, we are using the term in a rather different sense from the usual one involving human mental activity. In a computer the component labeled "memory" serves the functions of storing instructions, data put into the machine and results of computations which are held until they are needed for successive operations. To clarify what we mean by the machine's memory, let us compare the machine with a human computer, say a man preparing his tax return.

His program of instructions is set forth in the income tax form and amplified in books prepared by professional tax advisers. The "input data" are available in certain records: income payments to him, the amount withheld for the Internal Revenue Service by his employer, checkbook stubs testifying to his deductible expenses and contributions, and so on. The taxpayer processes these data (performing addition, subtraction, multiplication and division) according to the program of instructions and enters the results as "output data" on the form. During most of the work the man is not employing his memory: he reads the instructions from the form or a book and the input data from his records, and he stores partial results of his calculations as he goes along by jotting them on a scratch-pad. Almost the only way his memory comes into play is in his use of learned skills—adding, multiplying, reading and writing.

In the case of the computing machine, reading and writing are the province of input and output devices rather than the memory, and the rules for multiplication and addition are wired into the machine at the time of its construction. Thus the computer's memory is used in a quite different way: it must hold the jottings on the scratch-pad, the program of instructions set forth on the tax form (and, if possible, their fuller explanation by J. K. Lasser), files of receipted bills and canceled checks, information from the looseleaf notebook used to keep a budget, and the like.

We must therefore compare computer



FERROELECTRIC-CRYSTAL MEMORY made at Bell Telephone Laboratories is built around a thin crystal only a quarter of an inch square (*center*). On one side of the crystal is a set of parallel electrodes; on the other side is a second set of electrodes at right angles to the first. When a current flows across the intersection of two electrodes, information is stored by a change in the electrical properties of the crystal. This crystal stores 256 "bits."

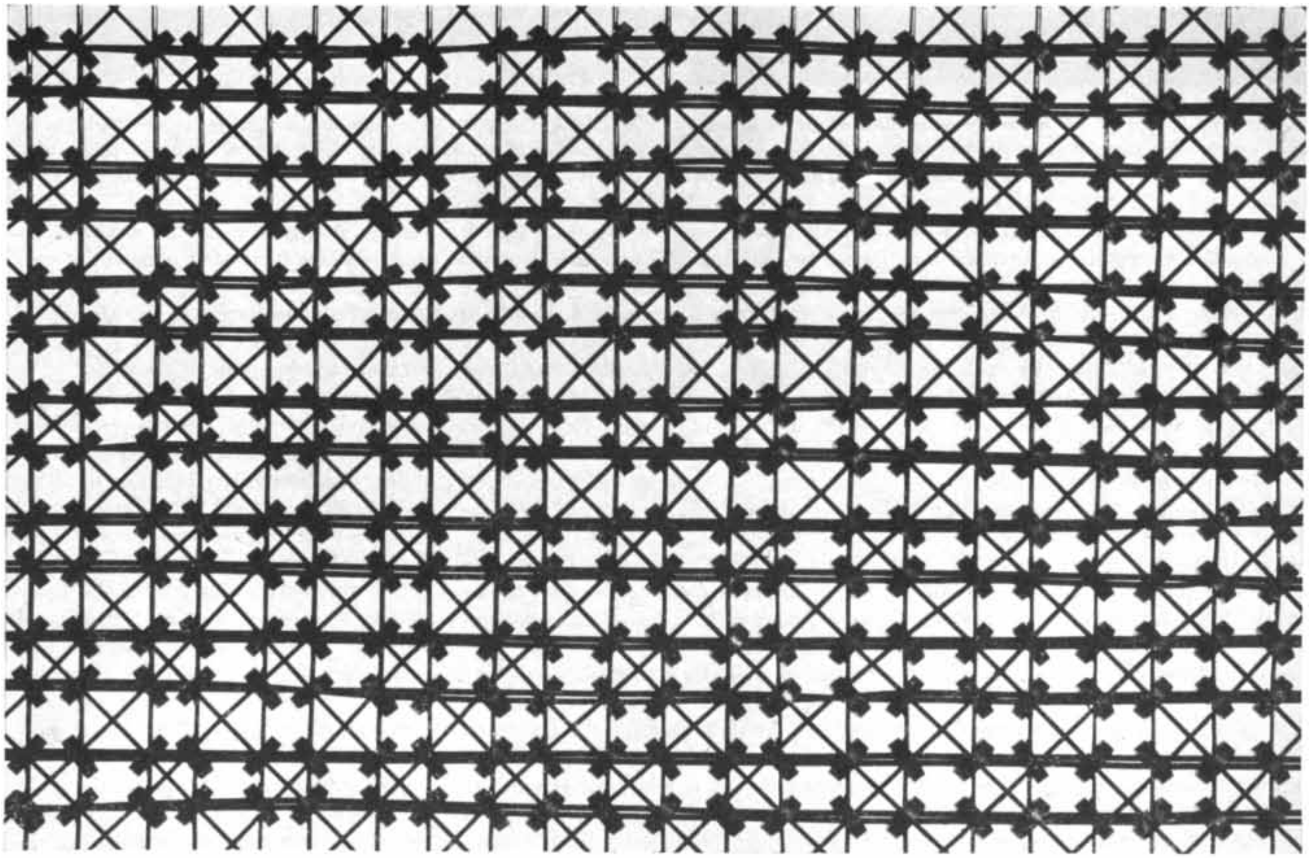
memory devices not with the memory functions of the human brain, but rather with the physical information-storage devices used by men—the scratch-pad, notebooks and other current records, books and other permanent references.

Next we have to consider the form in which the information is stored, or, to put it another way, the language of the memory. Human language is composed of 10 digits (the decimal system), 26 letters of the alphabet (in English) and various punctuation marks and other symbols. But in an electronic computer it is essential to translate all information into a simpler code, and the most convenient is the binary system, using just two symbols: 0 and 1.

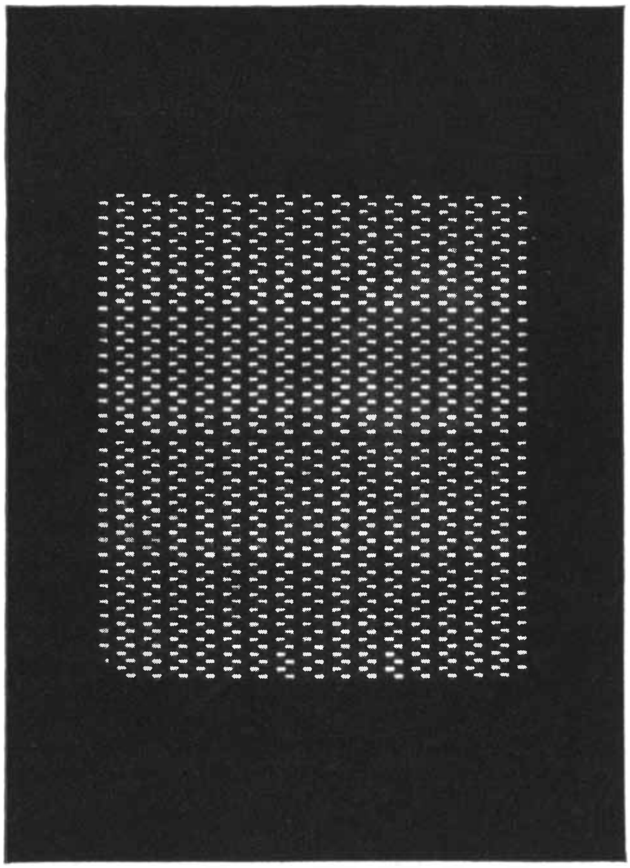
The binary system is peculiarly appropriate to the nature of an electronic machine; if it had not existed, computer designers would have had to invent it. Its two symbols can be expressed simply by the "on" and "off" states of a vacuum tube (or its potential replacement, the transistor). In the logical circuits of a modern computer the memory units commonly consist of pairs of vacuum tubes connected in a circuit which is called a "toggle" because of its analogy with a toggle switch. Once turned on, a toggle remains on until an explicit action is taken to turn it off. The toggle circuit is so connected that when one tube of the pair is carrying current, the other cannot carry current. Upon receiving an appropriate signal voltage, the toggle reverses; the tube formerly carrying current is abruptly cut off, and the tube formerly not carrying current now passes a large current. A toggle is either on or off; it has no other stable states. It can switch from on to off or *vice versa* in considerably less than a millionth of a second.

These two states, then, can represent the binary symbols, and a combination of those symbols in turn can represent a character of a richer alphabet. Thus numbers or words of ordinary English text can be stored in the machine's memory as sequences of on-or-off signals. It takes five binary symbols to express a single letter of the English alphabet.

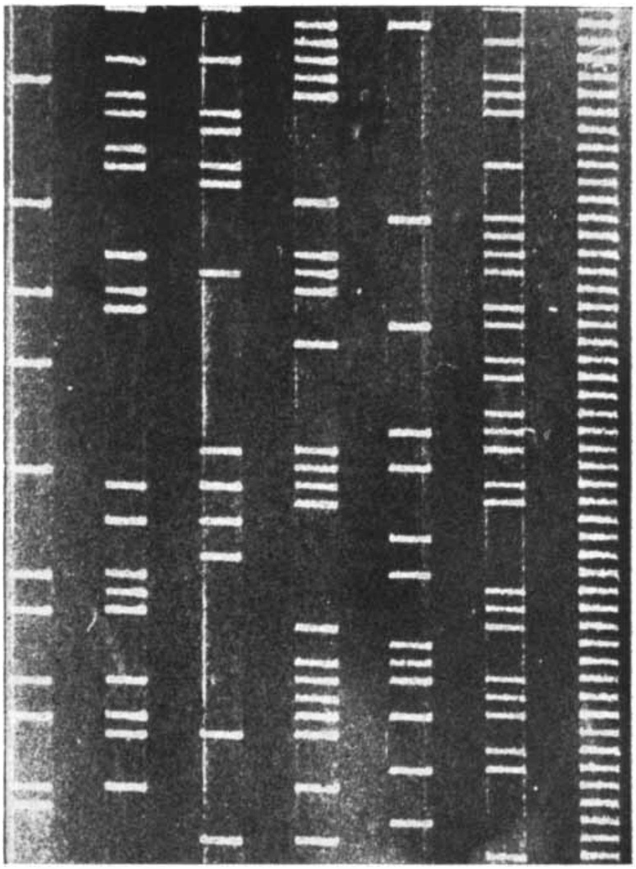
A big difficulty lies, of course, in the fact that the language of men must be translated into this language of the machines. At the output end the machine itself can perform the translation, but on the input side men usually have to do the translating to the machine. Moreover, there is a serious discrepancy between men and machines in operating speed. Even the primitive machines we now know how to build can perform any unit operation between a thousand and a million times faster than a human being could. If the machines are to be very useful in doing man's clerical work, some way must be found to match the speed of input to the speed of the machine's operation. A straightforward solution would be to let tens or even hundreds of human key-punch operators provide a single machine with its input data. This also suggests how the problem of translation can be approached. The single operation of pressing a key labeled *A* could cause the machine to type the letter *A* on a page, select the matrix necessary to cast an *A* in a linotype slug, punch the binary representation of the letter *A* in a paper tape, punch the holes representing that letter in a



MAGNETIC-CORE MEMORY consists of tiny rings or cores of magnetic material threaded by wires. In this small section of a memory made by the International Business Machines Corporation each core is penetrated by four wires. If a current simultaneously passes through two of the wires, the core is magnetized in one direction, representing 1. The number may later be "read" by passing a second current through the same two wires, which gives rise to a current on a third wire. The second current also magnetizes the core in the opposite direction, representing 0. The fourth wire is used to inhibit magnetization for special problems of storage.



CATHODE-RAY-TUBE MEMORY uses an electron beam to store information as charged spots on the face of the tube. The spots are read by scanning them with the beam. This tube was made by IBM.



MAGNETIC-TAPE MEMORY magnetized spots on the tape. In this section of a tape made by the Raytheon Manufacturing Company the spots are made visible by dusting them with powdered iron.

business-machine card, and so on. Thus the operation would simultaneously produce two kinds of copy, one legible to human beings, the other to the machine. (In fact, the teletype page printer already does this: it types copy in English text and at the same time perforates a paper tape which can be read by a machine.)

Once a given set of data has been recorded in machine language, no human operator should ever again have to perform the same key-punch operation, because machines could always reproduce the data from the transcript. All information needed for reference should be preserved in machine-readable form.

These, then, are the requirements and general problems in designing machine memories. Now let us look at the memory devices themselves. It is useful to distinguish three classes of memories. The first is the inner or high-speed memory of the machine. This is the machine's analogue to the scratch-pad; it is used to store the data and instructions in current use. There are two important requirements of the inner memory: it must permit rapid access to its data and it must be erasable. Because the elements of a rapid access system are costly, the inner memory of a machine usually is small, with a capacity of some 1,500 to 6,500 English words. (We shall use words instead of "bits"—binary digits—as the measure of memory capacities in this article.) It must therefore be supplemented with an intermediate-speed memory—the analogue to a human computer's notebooks and files of documents. This memory may take as much as a thousand times longer than the fast inner memory to look up an item of information, but it can transfer a large block of data at once. Its total storage capacity is typically in the range from 10,000 to 100,000 English words. Like the inner memory, it must be erasable. The third class of machine memory corresponds to books and similar large repositories of the knowledge of mankind. Such a memory is required in any application where the machine is to keep large files: for instance, the subscription and promotion lists of a mass-circulation magazine, which may call for the storage of an amount of information equivalent to 100 million English words. To achieve this vast increase in storage capacity at reasonable money cost we must pay the price of slower access to the stored information, sacrifice of rapid erasability or some combination of the two.

Up to the present time most of the attention of designers has been focused on the high-speed inner memory of computing machines. Several different forms have been developed. One device is the vacuum-tube toggle circuit already mentioned. This was used for the inner memory of the ENIAC, the first of the modern high-speed computers. Since vacuum-tube circuits are complicated and expensive, the ENIAC memory was very small by present standards; its capacity was equivalent to only 27 words of English text.

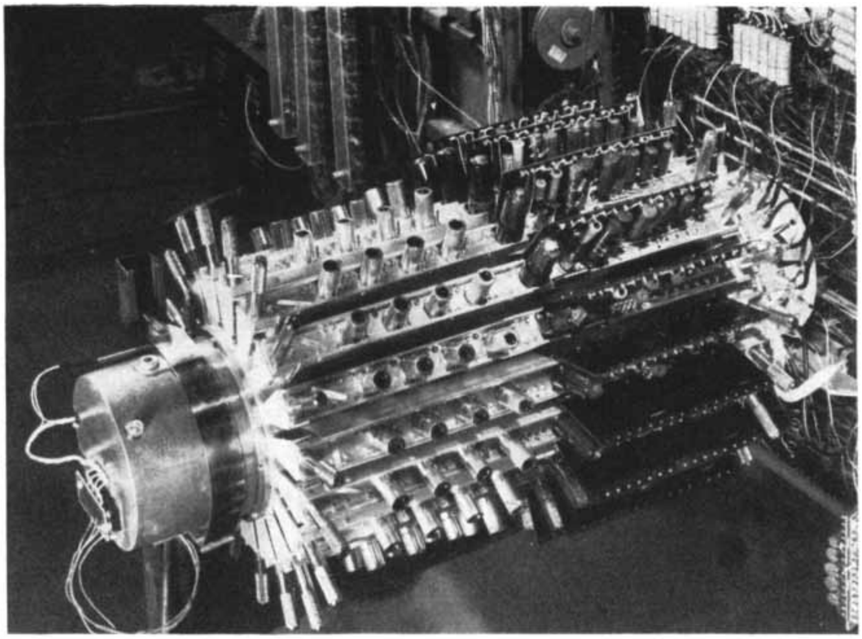
The expense of a vacuum-tube toggle as a memory element made it evident that an entirely different memory system would be required if large storage was to be achieved. Designers turned to the idea of storing information in a delay tank of mercury, where the information is cycled in the form of ultrasonic sound waves. The electrical pulses representing information "bits" are converted by crystals to sound waves, which travel so much slower than electricity or light that a given length of path can hold a vastly greater amount of information. A mercury delay tank with a two-foot sound path permits the storage of about 400 pulses, or bits, spaced one microsecond apart. The pulses are amplified and recirculated through the tank repeatedly.

A number of practical computing machines using this type of high-speed memory have been built. The best known is UNIVAC, whose inner memory has 100 parallel acoustic channels and a storage capacity of 2,800 English words.

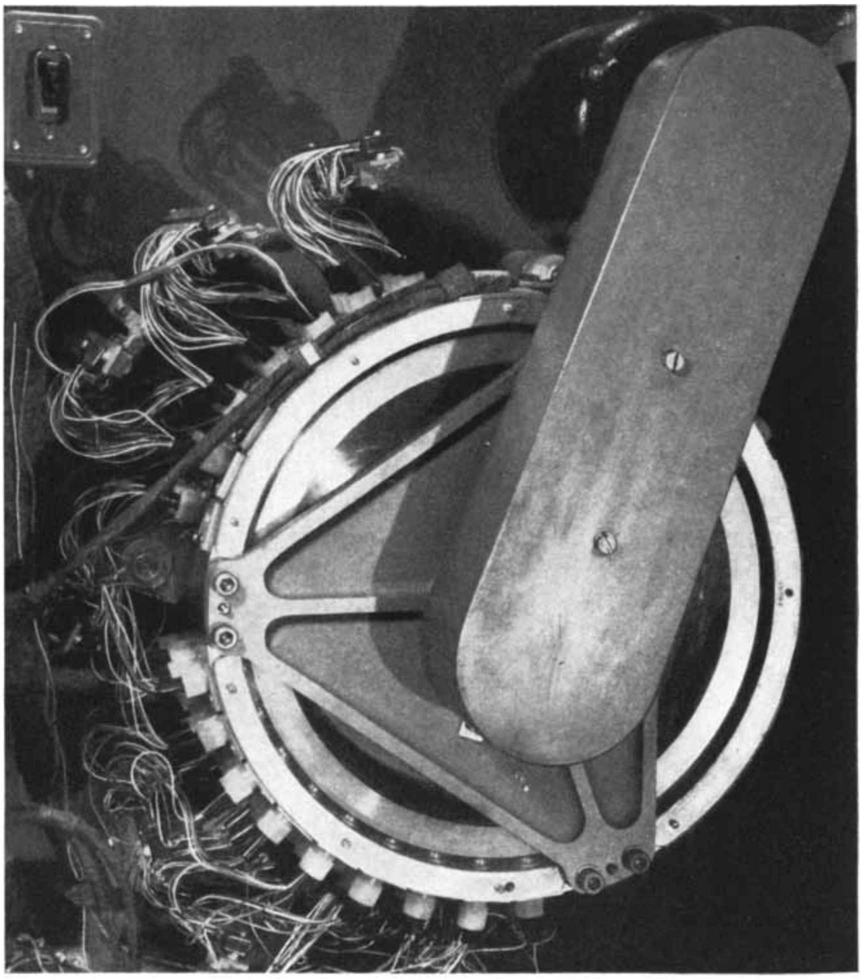
The chief objection to the acoustic-delay memory is its rather long access time. While signals are traveling through the mercury as sound pulses, they are unavailable to the computer. To refer to items of the stored information, the machine must wait until the wanted information reaches the receiving crystal and is turned back into electrical pulses. On the average this entails a delay of one half the total delay introduced by the mercury tank, or about 200 microseconds in a typical case. This is a long time compared to a modern computer's speed of calculation.

The next idea developed was an electrostatic memory system using a cathode-ray tube in principle like a television picture tube. Information is recorded as patterns of charge ("dots" or "dashes") produced by an electron beam at spots on the screen. The information stored in a given spot can be read by directing a beam of electrons to the chosen spot; electron emission produces output signals identifying the stored information. A typical electrostatic memory has 40 storage tubes, each with a pattern of 32 by 32 storage positions on its face; this corresponds to storage sufficient for about 1,350 English words. It takes only about 12 to 20 microseconds to deliver an information "bit" from its memory. The main virtue of the electrostatic memory is that the electron beam can very quickly pick out any part of the stored information. But its big drawback is that it almost doesn't work; the system is so delicate and so subject to external interferences that it is extremely difficult to maintain accurate operation.

More promising than any of the foregoing is a new type of memory just recently developed. It depends on magnetic effects. The units in the system are tiny rings of magnetic material, called "cores" [*see photograph on page 93*]. Information is stored in a core by applying



MERCURY-DELAY LINE stores ultrasonic pulses which oscillate in a tank of mercury. This apparatus made by Remington Rand Inc. is now being supplanted by magnetic cores.



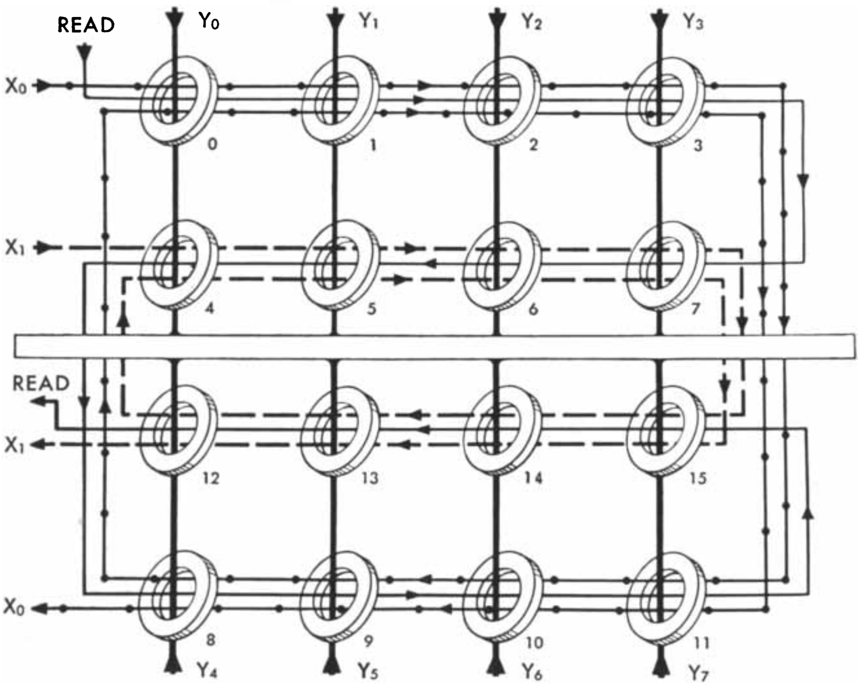
MAGNETIC DRUM places magnetized spots on the surface of a rotating drum. In this apparatus made by IBM the edge of the drum is visible as the smaller of the two metal rings.

a magnetic field; when it is magnetized in one direction, its state represents the digit 1; in the opposite direction, it represents 0. The core is a permanent magnet which "remembers" its magnetic state after the applied magnetic field is turned off; thus the core can store information as long as may be desired. Now when a magnetic field is applied again, the behavior of the core will depend on its magnetic state. If, for example, a field is applied to urge the core in the magnetic direction signifying 1, and the stored magnetism in the core happens to be in the direction signifying 0, the field will change the core's magnetic state. This change produces a signal current in a wire threading the core. Thus the generation of the current shows that the core was storing a 0. On the other hand, if the core happened to be storing the digit 1, the same applied field would produce no change in its magnetic state, and there would be no signal; the absence of a signal would show that the stored information was the digit 1.

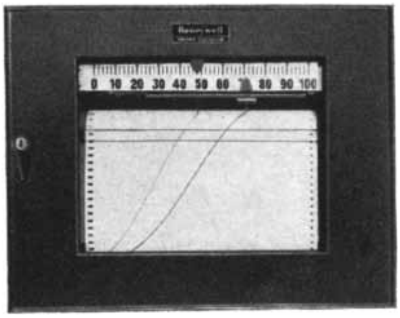
The system uses an array of cores arranged in rows and columns [*see photograph*]. The magnetic field is applied by means of two current-carrying wires passing through each core at right angles to each other. The system exploits a peculiar property of the new magnetic materials called ferrites: namely, the fact that some cling to their magnetic state and cannot be changed from it by an opposing magnetic field until the field is stronger than a certain threshold value. In the scheme shown in the diagram on this page, the magnetic field produced by a current in a single wire, say Y_1, is not sufficient to change a core's magnetic state; only when two currents are added together at an intersection, as at Y_1-X_1, does the magnetic field become strong enough to reverse the core's state. In this manner it is possible to read the information stored in any individual core. The information is read as a signal on another wire winding which can link all the cores in the array, since only one core is consulted at a time in reading.

The magnetic-core memory produces stronger signals than an electrostatic memory, is relatively immune to unwanted electrical disturbances and uses simpler circuitry.

Another promising type of high-speed memory is in laboratory development. It involves the use of a ferroelectric material, which has the property of "remembering" the direction of an electric field applied to it. This behavior is exactly analogous to that of the magnetic cores just described: the cores remember their magnetic history, while the ferroelectric crystal remembers its electric history. The main practical difference between the two systems is that the ferroelectric memory requires much less electric power. The material used in the experimental ferroelectric memory sys-



DOUBLE-SIDED MAGNETIC-CORE MEMORY made by the International Telemeter Corporation is unfolded in this diagram. Here there are two sets of X wires and one set of Y wires. Each core may be energized by a current passing through both an X and a Y wire.

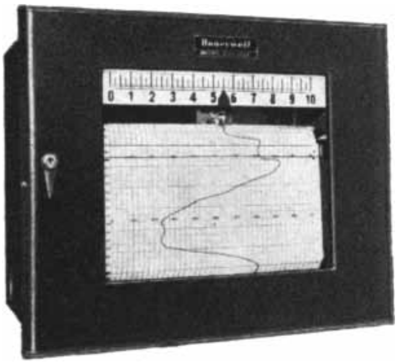


DUPLEX RECORDER

Simultaneously plots two continuous data curves vs. time. Has two independent measuring systems, each with any desired range.

See Data Sheet 10.0-6.

Get *better* test data *quicker* – with *ElectroniK* research instruments



½ SECOND PEN SPEED RECORDER

Pen traverses full 11-inch calibrated width of chart in only ½ second. Precise recording of variable changes without overshoot or hunting. Full accuracy, even on spans as narrow as 3 millivolts.

Request Data Sheet 10.0-13.

BROWN-RUBICON PRECISION INDICATOR

Combination of high-precision potentiometer and automatic *ElectroniK* indicator, for highly accurate small voltage measurements and for calibrating meters, bridges and similar equipment . . . with minimum operator fatigue.

See Data Sheet 10.0-2.

Research men everywhere are finding that specialized *ElectroniK* instruments can save them many precious hours of lab time, by automatically taking over much of the routine burden of gathering, recording and plotting data.

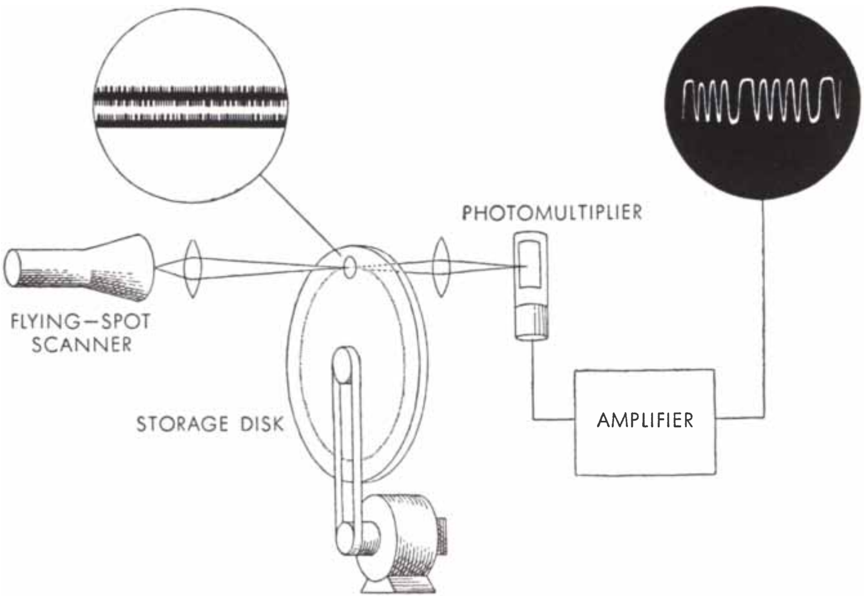
In addition to the models pictured here, Brown instruments for research include *ElectroniK* Function Plotters, in single pen and double pen types . . . *ElectroniK* Extended Range Recorder and Adjustable Span Recorder . . . the *ElectroniK* Null Indicator, modern successor to the galvanometer . . . and a family of precision-made servo components. For a discussion of how these can help in your own research program, call your nearby Honeywell sales engineer.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

H HONEYWELL

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

First in Controls



PHOTOSCOPIC-DISK MEMORY is experimental. The circle at upper left is an enlargement of a small section of three information tracks on the disk. The symbols on each track are vertical marks. In the circle at upper right is the voltage output from one of the tracks.

tems is barium titanate. A single small crystal of this material can store 256 "bits" or eight English words.

For the larger, intermediate-speed memory of a computer the favorite device at present is the magnetic drum. The drum's outer surface is coated with a ferromagnetic material like that used in magnetic tape recorders. On this surface, which can be rotated at high speed, information is recorded in the form of magnetized areas "written" in circular tracks as the drum rotates. The writing and reading are done by electromagnet "heads" mounted close to the recording surface. The tracks, in present practice, are laid down about a tenth of an inch apart and can store about 80 digits per inch. Thus a drum four inches in diameter and 12 inches long can store some 4,000 English words. Larger drums, storing up to 100,000 English words, have been built.

From the standpoint of access to the stored information the magnetic drum suffers from the same kind of limitation as the ultrasonic delay tank. The computer must wait until the desired information on the drum comes under the reading head. Even on the fastest-rotating drums this waiting time may be 10 to 20 thousandths of a second. Moreover, the magnetic-drum memory requires substantial vacuum-tube circuitry, and hence is not particularly economical.

Magnetic-core arrays may provide an answer to the intermediate-speed memory problem as they have for computers' inner memories. At present only their cost stands in the way of their use for this larger memory, and they may soon be fully competitive with the magnetic drum, even in the largest practicable sizes—around 200,000 English words.

So far comparatively little work has been done on the third type of memory required by computers—the large-capacity storage of information corresponding to the human library of printed books. Many electronic computers still are tied to punched cards, which at present computer operating speeds are an anachronism. The inner memory of a computer can be read at six million English words per minute. The intermediate-speed memory can be read at the rate of 400,000 words per minute per reading head, and information is often read from several heads in parallel to increase this rate. But punched cards at best can be read no faster than 20,000 words per minute. In addition, the sheer physical bulk of a large file of punched cards makes access to an item of stored information slow and difficult. We must search through the many drawers of cards, choose the drawer containing the entry of interest, carry the cards in that drawer to the reader and read through the deck until we have found what we want. This may take minutes.

Most designers of the newer computers have adopted the magnetic tape as the best available improvement over punched cards for large storage capacity. By paralleling several channels on a single tape, by using several tapes in paral-

PROGRESS THROUGH ANACONDA METALS

The cable that keeps coal coming

THE PROBLEM: Everywhere in a coal mine the vital power link is electrical cable. Whenever cable fails, mining stops. Machines stand idle. Men sit and wait. Costs go up.

The cable is always fighting for its life. Rock slivers prick tiny holes. On wet mine floors, water may get inside and short the cable. Machines snap it like a whip and pinch it against mine walls, breaking the conductors. To survive takes a stout heart. The cable must be engineered as carefully as the massive machines it powers.

THE SOLUTION: Engineers of Anaconda Wire & Cable Company checked thousands of cables to see why they failed; then they developed the cable in the picture above. It's considered the toughest "shuttle car" cable ever made—greatly cuts down those costly failures. Neoprene, nylon and copper give it new *inner* and *outer* strength. Hundreds of tests proved its longer life. *This cable keeps the coal coming!*

THE FUTURE: Mechanization calls for better and better wires and cables. In keeping pace, Anaconda's experience with metals and cable engineering is finding dependable answers — *often first!* The Man from Anaconda can focus this experience on your problem . . . to save you time, trouble and money. *Anaconda, 25 Broadway, New York 4, N. Y.* 55222

ANACONDA®

lel and by using great lengths of tape, information storage of almost any desired total capacity can be realized. But tape has several serious drawbacks. Access to items on the tape is slow; the time is proportional to the length of the tape. Far more important is the difficulty of making corrections or additions to the information stored. To add a new entry to an ordered file we must either have provided empty spaces between each two original entries in the file, or else we must rewrite the entire file, putting the new entry in its correct location. Neither of these possibilities is attractive. Leaving blank spaces in the original file means that we are using the store in a highly wasteful way, with no guarantee that our blank spaces will be properly arranged for the additions we shall later have to make. Rewriting the whole file to make additions and changes is costly and lends itself to the commission of errors.

Two millennia ago human beings had just the same difficulties with scrolls—the ancients' counterpart of books. The scroll form was dictated by the need for protecting the edges of their brittle papyrus; the scroll left only two edges exposed. Shortly after the tougher parchment was introduced, the book form was invented, either in Greece or in Asia Minor. Called the codex, it was originated primarily for law codes, so that pages could be removed or added as statutes changed.

Reels of magnetic tape are the scroll stage in the history of computing machines. It remains for someone to invent the machine's analogue of the codex. A promising beginning has been made by Gilbert W. King. He has undertaken to exploit the great density of information storage that is possible through the use of high-resolution photographic emulsions. With his "photoscopic" technique information can be stored at densities more than a hundred times as great as those possible in magnetic media. This permits not only a more compact storage system—on a disk the size of a 12-inch phonograph record more than half a million words can be stored—but also faster reading rates per reading station, more information accessible to a single reading station for a given access time, and other advantages.

The first practical applications of photoscopic storage are just beginning. It is too soon to say how important this new technique may ultimately prove to be. There are indications that we shall now be able to give the computing machine a storage system having the capacity and flexibility of a library of books.

"...business helps itself by promoting thrift among its own people."

EDWARD C. BALTZ
President
Perpetual Building Association
Washington, D. C.

"Expanding the regular sales of U. S. Savings Bonds is essential to the continued success of our Government's sound money policy. Savings Bonds help people build security for themselves and stability for the nation's economy. A reserve in Bonds gives them the assurance to spend current income on homes, cars and other substantial purchases. Meanwhile, regular Bond buying goes on adding to their future buying power. Thus business helps itself by promoting thrift among its own people. The surest way to encourage an employee to save regularly right where he works is to sign him up on the Payroll Savings Plan."

Let's point up this statement by Mr. Baltz, head of one of the nation's outstanding thrift institutions and volunteer chairman of the District of Columbia Savings Bond Committee, with a few facts and figures:

● currently, more than 45,000 companies, large and small, representing every classification of industry and business, are encouraging national thrift through the Payroll Savings Plan.

● every month, 8,500,000 Payroll Savers in these 45,000 companies invest more than $160,000,000 in Savings Bonds.

● largely as the result of employer-encouraged thrift the cash value of Savings Bonds held by individuals on July 31, 1954, totaled more than 37.5 billion dollars.

● never before has America had such a reserve of future purchasing power.

● invested in America, these 37.5 billion dollars in Savings Bonds Dollars are a most effective check on inflation and a very important contribution to economic stability and a sound dollar.

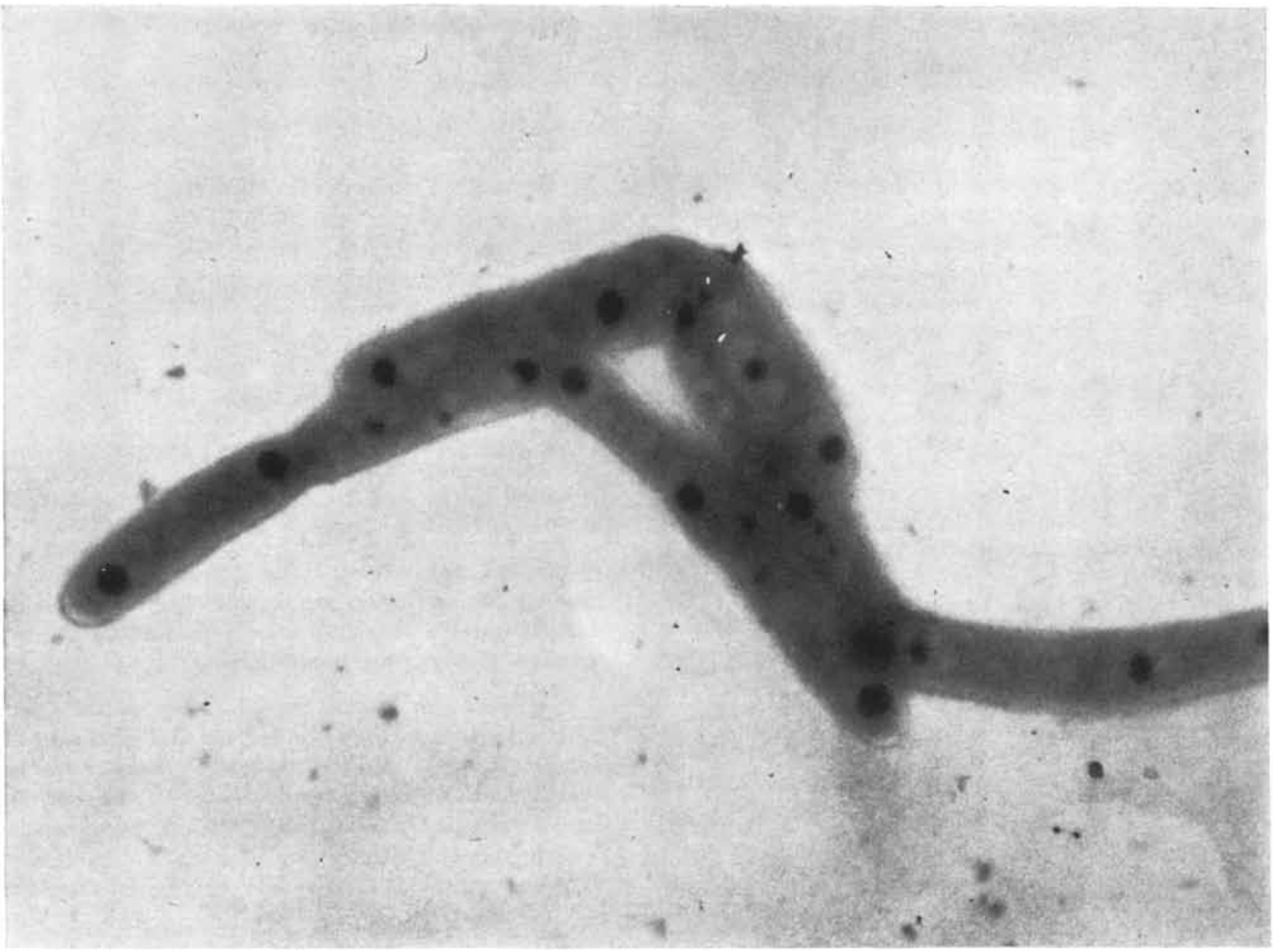
A million new Payroll Savers by the end of 1954! That's the goal of those who believe that what is good for Americans is good for business. To do your part in reaching this objective, phone, wire or write today to Savings Bonds Division, U. S. Treasury Department, Washington, D. C. Your State Director, U. S. Treasury Department, will show you how easy it is to build a successful Payroll Savings Plan.

THE GERM OF TUBERCULOSIS

The biology of the tubercle bacillus is studied to control its multiplication in man. Out of these investigations have come encouraging advances in the treatment of the disease

by Esmond R. Long

A mouse, an elephant, a bird or a butterfly is a complicated subject, but man has managed to learn a great deal about these fellow creatures. We can describe their natural history, their foods and habitats, their movements and behavior, their physiology and illnesses, their procreation and death; we know enough about them to breed, destroy, train or frustrate them at will. It will be a great day for mankind when we become equally knowledgeable about the lives of microbes. Like their larger cousins, microorganisms have a natural history, preferences in food and habitat, characteristic life cycles and points of vulnerability. But it has taken more than half a century of work by a tremendous number of microbiologists, inventing elaborate and ingenious tools to explore their tiny world,



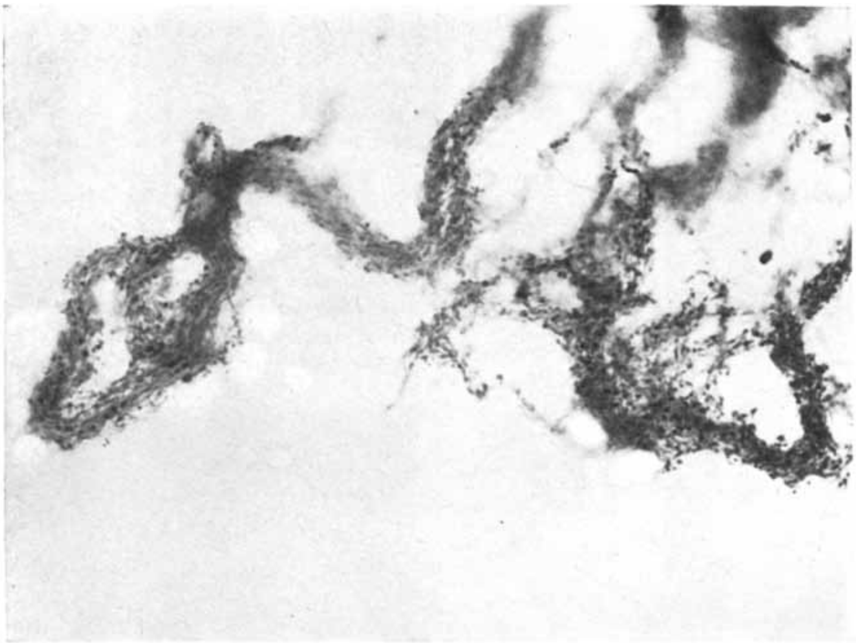
TUBERCLE BACILLI from a bird are enlarged 44,000 diameters in this electron micrograph by Georges Knaysi of Cornell University. Avian tubercle bacilli are closely related to those that infect man. Within the bacilli several small round granules are visible.

to learn something about the natures of these creatures.

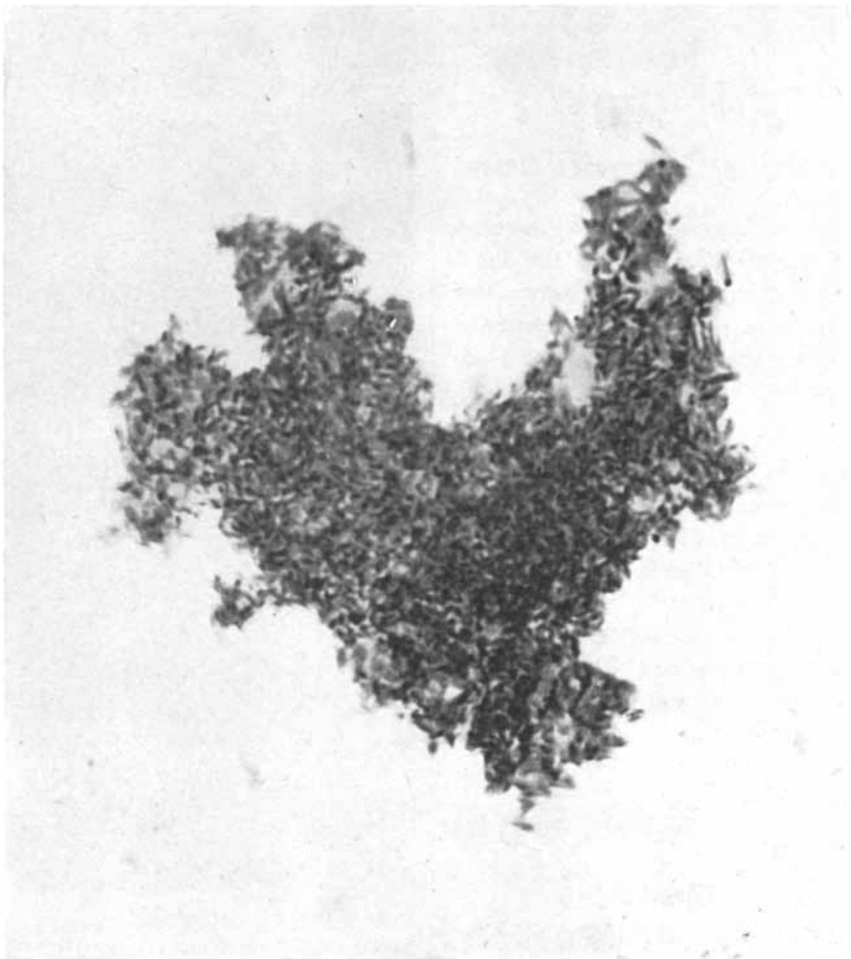
This article will review briefly what is known about the bacillus of human tuberculosis and its life in its habitat—man. The tubercle bacillus has been one of the most intensively studied of all microorganisms. It was first brought to light by Robert Koch in Germany in 1882. A colorless bacterium, it is unusually difficult to stain, and Koch had to apply special methods, including heat and a series of dyeing operations, to make it visible under the microscope. Koch found the bacillus in body tissues, in sputum and in urine. He was able to grow the microbe in an artificial culture, to reproduce tuberculosis by injecting it into new animals and to recover it again from the infected tissue—a procedure which has become standard for connecting a given disease with a germ and is known by the name Koch's Laws.

The tubercle bacillus belongs to a genus called mycobacteria, the members of which are classed together simply on the basis of their peculiar staining property. Though difficult to stain, once stained they hold the dyes tenaciously, refusing to give them up to a strong destaining agent such as acid; hence they are described as "acid-fast." The mycobacteria are a fairly large group. Besides the true tubercle bacillus, different types of which infect men, cattle and birds, they include the germ of leprosy, a germ causing the wasting Johne's disease in cattle, and microbes producing diseases like tuberculosis in fish, frogs, turtles, snakes and other cold-blooded animals. In addition there are many harmless acid-fast bacilli; they appear on grass, in butter and in animal skin secretions such as earwax.

Our concern here is the bacillus that lives in man. It is of average size, as microbes go, but six million tubercle bacilli could lie end to end in the space of one inch. To the naked eye a mass of the bacteria looks motionless; actually it is a seething colony of activity. Each bacillus breathes, absorbs food and carries on an astonishingly complex metabolism. It takes up oxygen and gives off carbon dioxide. It absorbs minerals and organic compounds and builds them into proteins, fats and carbohydrates. In a test-tube culture it can synthesize the complex materials it needs for growth from very simple substances. For example, tracer studies with radioactive carbon 14 have shown that the microbe will break down glycerin, burn some of it for energy and use its carbon to make



VIRULENT BACILLI of tuberculosis growing in a liquid medium tend to adhere side by side, forming characteristic sinuous chains. The photomicrograph is by Hubert Bloch of the Rockefeller Institute for Medical Research. It enlarges the bacilli 1,175 diameters.

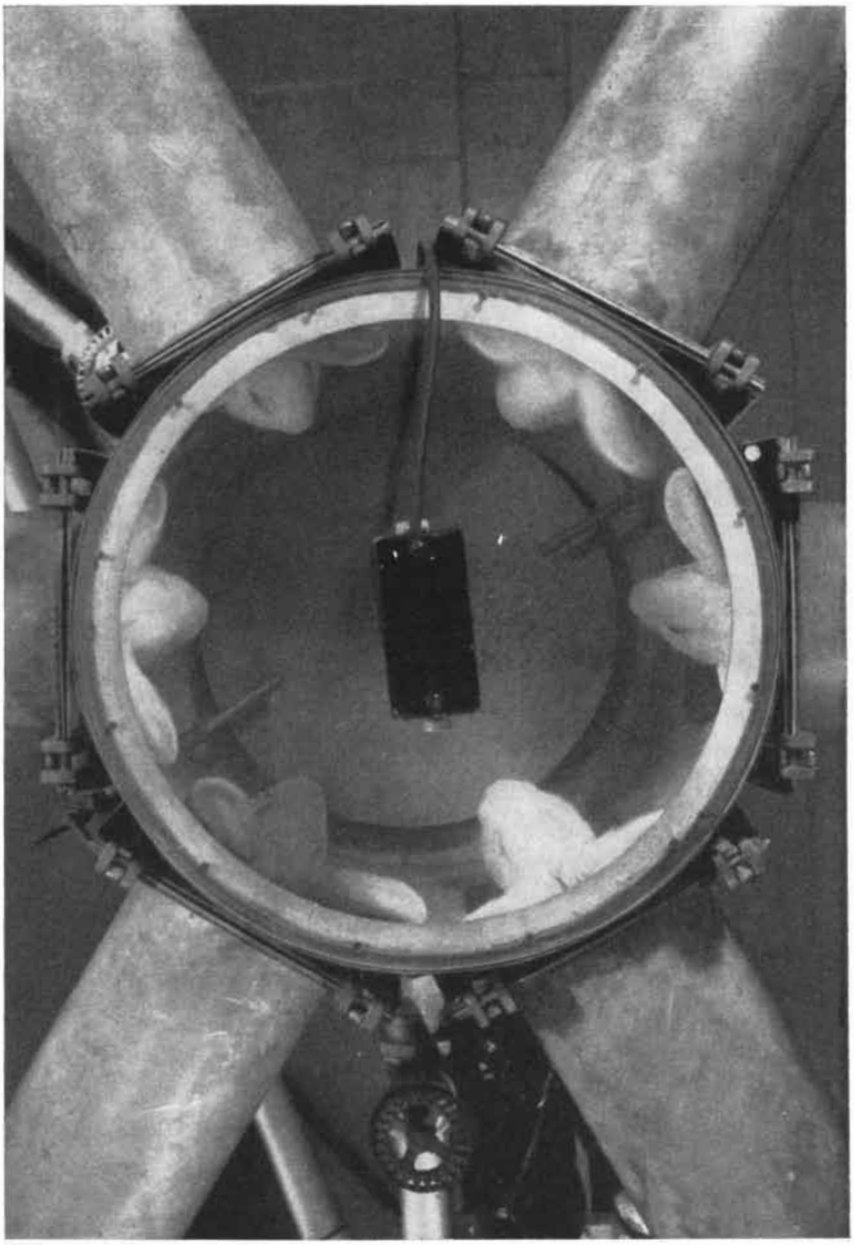


AVIRULENT BACILLI of tuberculosis growing in a liquid medium characteristically clump together in irregular masses. It is believed that this difference between virulent and avirulent forms may be due to their surfaces. This photomicrograph was also made by Bloch.

proteins, nucleic acids, fats and carbohydrates. In this metabolism the tubercle bacillus employs enzymes, just as higher animals do.

Under the electron microscope the body of the bacillus is seen to contain tiny granules, believed to be analogous to the much-studied mitochondria found in animal and plant cells. Probably these are of vital importance to the microbe's physiological processes. They seem to be tiny powerhouses which regulate the use of fuel by the bacillus and operate the machinery for building its structures and new bacilli. There are indications that the enzymes are located in these granules.

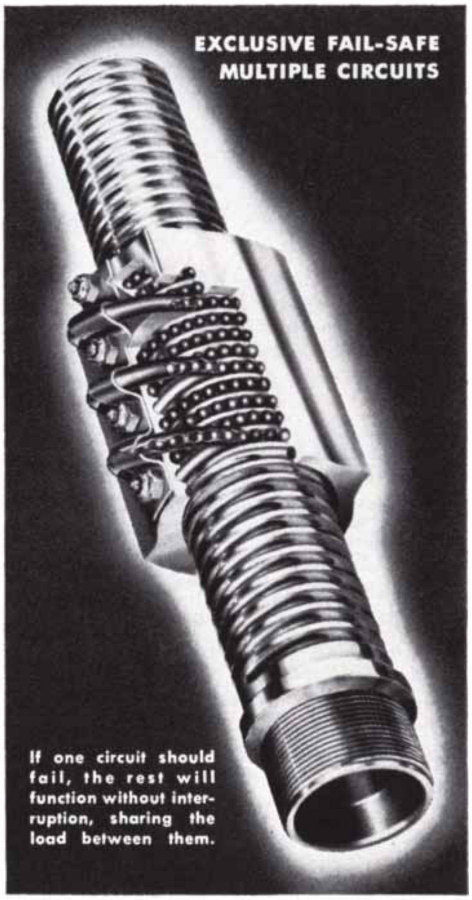
The bacillus not only builds up new substances, permitting it to multiply almost indefinitely, but also gives off waste products and important chemical substances. Perhaps the most interesting of these is tuberculin. Koch himself discovered this substance. When he inoculated tuberculous animals with extracts from bacilli or with the broth in which the microbes had been grown, the animals developed a fever and other



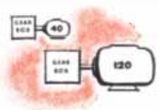
INFECTION CHAMBER at the Henry Phipps Institute of the University of Pennsylvania has been used by Max Lurie to determine the relation between the number of bacilli inhaled by an experimental animal and the number of tubercles in its lungs. Rabbits are held in canisters with their heads inside a chamber into which bacilli are forced by a stream of air. By various techniques the number of bacilli which the rabbits inhale can be determined. Lurie has found that on the average one tubercle is formed for every three bacilli inhaled.

Now—

UNPRECEDENTED BENEFITS FOR ALL YOUR ACTUATOR APPLICATIONS WITH THE SAGINAW BALL/BEARING SCREW



SPACE/WEIGHT SAVINGS PERMIT MORE PAYLOAD



Compared to either Acme screw or hydraulic actuators, the *Safety b/b Screw* saves significant weight and space by permitting the use of smaller motors and gear boxes; eliminating pumps, accumulators, piping, etc.

DEPENDABLE OPERATION DESPITE LACK OF LUBE

Because the *Safety b/b Screw* is inherently so friction-free (operating at 90% to 95% efficiency), it will function with only a small loss of efficiency *even if lubrication fails or cannot originally be provided.*

FAR LESS DRAIN ON ELECTRICAL SYSTEM

By requiring only 1/3 as much torque as a conventional Acme screw for the same amount of lineal output, the *Safety b/b Screw* allows the use of much smaller motors which save a substantial amount of power.

POSITIVE POSITIONING AND SYNCHRONIZATION

Unlike some other types of actuators, the *Safety b/b Screw* permits precision control within thousandths of an inch, plus perfect synchronization of two or more movements—a tremendous aircraft advantage.

RELIABLE PERFORMANCE AT EXTREME TEMPERATURES

Exhaustive laboratory tests prove that the *Safety b/b Screw* operates dependably at both extremely low and high temperatures, ranging from —75° F to +175° F, and up to +900° F with special consideration.

GREATLY DECREASED COMBAT VULNERABILITY

By eliminating highly vulnerable hydraulic lines, accumulators, etc., the *Safety b/b Screw* makes military aircraft actuation far more dependable. It also reduces maintenance, due to decreased dirt sensitivity.

UNITS HAVE BEEN PRODUCED FROM 1½ IN. TO 39½ FT.

SEND TODAY FOR YOUR FREE ENGINEERING DATA BOOK

(or see our section in Sweet's Product Design File).

Saginaw Steering Gear Div.,
General Motors Corp.
Dept. 6A, Saginaw, Michigan

Please send your Engineering Data Book to:

Name—Title ____________________

Firm ____________________

Address ____________________

City __________ Zone ______ State ________

Safety ball bearing Screw by Saginaw

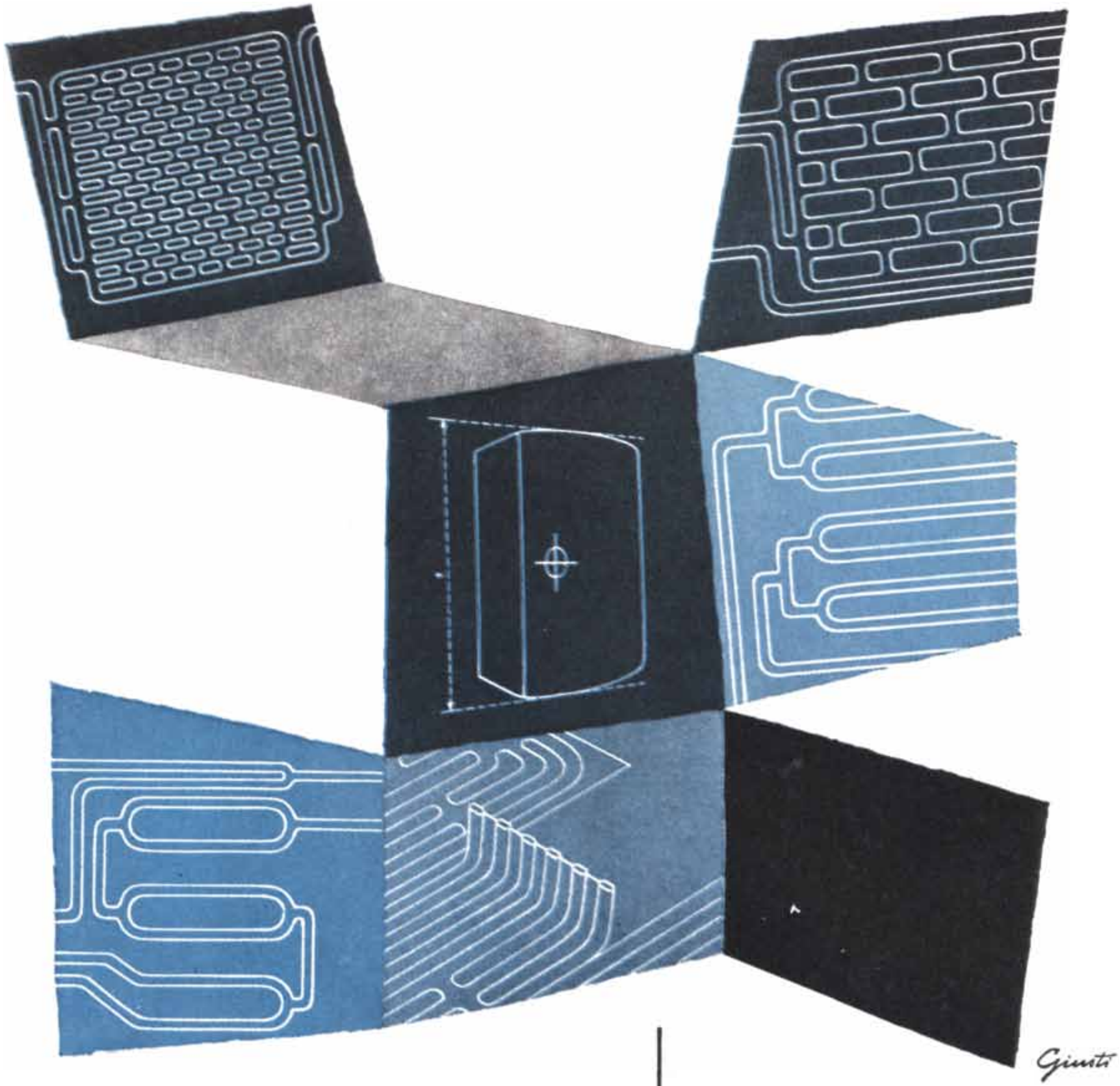
STOCK CULTURES are stored in the incubator of the Henry Phipps Institute. Tubercle bacilli require air and will grow only on the surface. When they are agitated or forced beneath it they die. The flask at right contains a young culture; the flask at left, an old culture with many dead organisms. The medium is essentially composed of glycerin.

signs of illness. He concluded that the bacilli secreted a substance to which the tissues of infected animals became sensitized. From this discovery came the use of tuberculin as a test for infection: it is injected into the skin, and if a local inflammation develops, it is a sign that the person has or has had a tuberculous infection.

Aside from its practical value as a testing substance, tuberculin is important in the disease itself. The growing bacillus constantly secretes a substance to which the patient is sensitive and which makes him sick. Tuberculin is believed to be partly responsible for the fever and malaise accompanying the disease. Much study has been spent on the nature of tuberculin. It is a protein, and several varieties of it occur, which may explain the different degrees of sensitivity to tuberculin observed in animals.

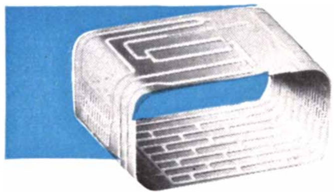
This, then, is the nature of the germ. Now let us examine the battle between it and man, its host. A great deal of attention has been devoted to the attempt to learn the differences between the true, virulent tubercle bacillus and harmless types of mycobacteria—that is, to determine wherein its virulence resides. One well-marked difference is in the form the microbes' colonies take: the virulent colonies grow in a serpentine shape, whereas the nonvirulent types grow in formless clumps. Apparently the serpentine pattern of growth is due to the presence of a water-repellent substance on the surfaces of the virulent bacilli, for their colonies do not grow in this manner when a wetting agent is added to the culture medium [see "Tuberculosis," by René J. Dubos; SCIENTIFIC AMERICAN, October, 1949].

In spite of the discovery of this and other differences between virulent and nonvirulent bacilli, the specific reason for the ability of the virulent type to multiply in animal tissues remains a mystery. The deadly effects, however, are plain enough. Tubercle bacilli can grow in almost every organ of the human body. They have a special predilection for the lungs. They kill tissue and then cause ulcerations which discharge bacilli to spread to other parts of the body. They also escape in sputum, milk



Looking Ahead? Include Western ROLL-BOND aluminum evaporators in your plans for '56

TRADE-MARK



A completed evaporator is entirely self-contained and installation takes but a few minutes. Because of the unique design, voids and frost blisters are impossible.

Already proved by over 300,000 refrigerators in daily use all over America, Western Roll-Bond evaporators will play a large part in the 1956 plans of major refrigerator manufacturers. Now, right now, every 1955 refrigerator being built by one of the largest manufacturers in the business has a roll-bonded evaporator. Leakproof, seamless, with tubes *inside* single, homogeneous sheets, Western Roll-Bond evaporators outmode the tubing and crude, low conductivity welds formerly a part of evaporator design. Now, pattern designs can be changed in days and a complete changeover costs only $50.00, not $50,000.00. Die and press costs are eliminated forever.

Right now is the time to investigate the advantages roll-bonding will offer your industry. Call or write for a folder telling more about roll-bonding, mailed with an actual sample of bonded metal. *Evaporator patterns shown are in production.*

Western ROLL-BOND

TRADE-MARK

METALS DIVISION

OLIN MATHIESON CHEMICAL CORPORATION

EAST ALTON, ILLINOIS

and urine, opening the way for spread of the disease to other persons.

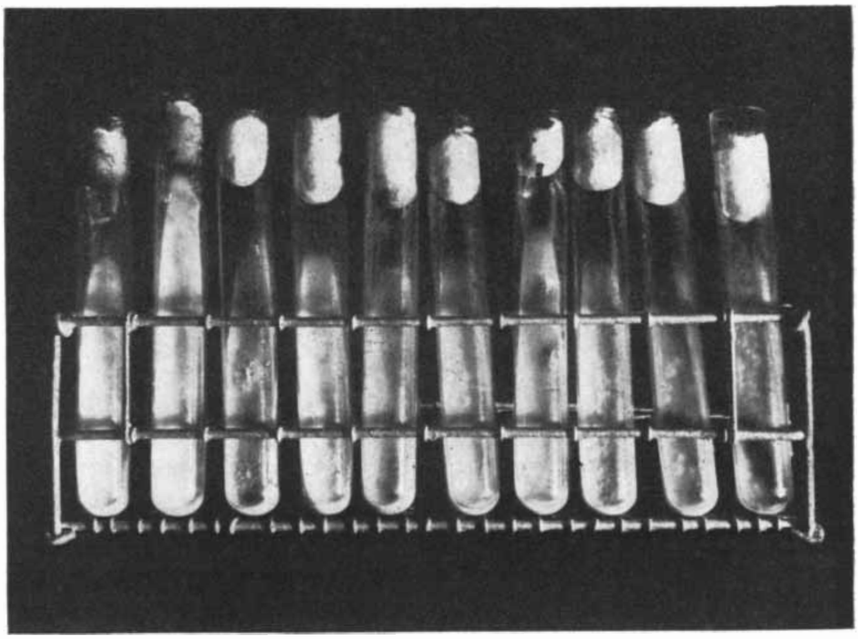
Once the battle is joined, the animal body brings its own powerful forces into play. The fight may go one way or the other. Usually the body wins, but very often the battle is a long one. What are the strengths and weaknesses of the two adversaries?

The tubercle bacillus is well endowed not only to grow in man's tissues but also to survive outside the body under adverse circumstances. It has more resistance than most microbes to heat, cold, desiccation and the common disinfectants. When dry, it can stand a long period of starvation, though it soon succumbs to lack of food and oxygen if moisture keeps its metabolic processes going. And it has a remarkable ability to develop tolerance toward drugs used to suppress it. Streptomycin, para-aminosalicylic acid (PAS) and isoniazid (isonicotinic acid hydrazide) will stop the growth of tubercle bacilli, but every colony of the microbe contains some varieties which are resistant to a given drug. These forms multiply and soon replace the suppressed, susceptible bacilli. The new population is then immune to that particular drug.

Man, however, is equipped with powerful natural defenses against the bacillus. Chief among them are the body's macrophages, or "wandering cells," which can engulf and destroy the tubercle bacillus. Apparently enzymes and some of the hormones (*e.g.*, the sex hormones and cortisone) take part in the destruction process. The macrophages' ability to kill the microbe can be enhanced by vaccination with dead bacilli or with the vaccine called BCG, which is made of a live, weakened form of the bacillus.

Besides engulfing bacilli, the macrophage cells also block them mechanically. The macrophages grow in size, crowd the tissue spaces and wall off infected areas from the blood supply. The island of cells and infected tissue, called a "tubercle," becomes a battleground. Cut off from food and oxygen, many of the bacilli and the tissue cells die, and in dying they break down into substances which tend to inhibit growth of other bacilli. Sometimes, however, the surviving bacilli win the battle, begin to multiply again and break out of the prison chamber to spread to fresh tissues; often they are carried by the very macrophages that entered the area to combat them. At the sites to which they migrate new tubercles form, and the contest starts all over again. When the infected areas are in the lung, neighboring ulcerations may coalesce and destroy large areas of tissue, giving rise to the well-known cavities of tuberculosis.

But the body does not stop fighting. Wherever the bacillus goes it is met by counterattack. As time goes on, the tissues around the battle areas form dense scars which tend to impede the progress of the infection. In order to promote scar formation and slow down mechanical spread of the bacilli, physicians prescribe



DIAGNOSTIC CULTURES taken from experimental animals infected with tuberculosis are generally grown on solid egg medium in test tubes. Each spot on the surface represents a colony that has presumably multiplied from a single organism which was dropped there.

A. J. Nerad joined the Chemistry Department at the General Electric Research Laboratory in 1924 and has been manager of the *Mechanical Investigations Section* since 1948. His fields of interest are fluid mechanics, heat transfer, liquid metals, combustion, and superpressures. Last February it was announced that his group had produced man-made diamonds.

Jets and diamonds

Research by A. J. Nerad, versatile General Electric scientist, has led to widely diversified results

Tony Nerad is a name well known to those who design jet aircraft. Even before the U.S. had entered World War II, he had started on research that led to the development of a new kind of jet combustor. The combustor—simple, compact, and reliable over wide variations in combustion conditions—helped make possible one of the earliest American-designed turbojets. The contributions made by Nerad were battle-tested in Korea, and are important factors in maintaining the high prestige of U.S. jets today.

Recently Nerad helped to make dramatic news again. The General Electric Research Laboratory announced that he had led the team of scientists which produced man-made diamonds. Thirty years of research experience — work on jet combustors, liquid metals, and other projects—enable Tony Nerad to extend this promising area of *superpressure* research. This G-E research in high temperatures and high pressures demonstrates again that expanding our research program — and creating promising opportunities for scientists—contributes to progress.

Progress Is Our Most Important Product

GENERAL ELECTRIC

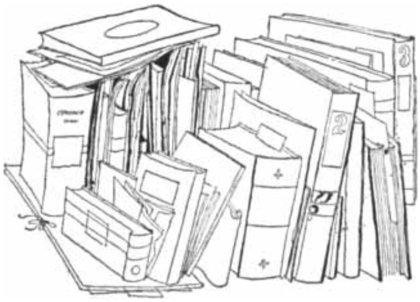
strict bed rest. When a lung is badly infected, they may check the lung's motion of expansion and contraction by injecting air into the surrounding cavity or may immobilize the lung permanently by collapsing it surgically.

Two effective forms of treatment of tuberculosis have been developed in recent years. One is complete surgical removal of an infected lung or parts of the lung. This used to be a dangerous operation, but improvements in anesthesia and new anti-infection drugs have made it safe. The other big advance is chemotherapy, whose spectacular results are well known. How the new drugs against tuberculosis work is still not fully understood, but understanding grows daily. Apparently they act in part by deceiving the microbe. Streptomycin, isoniazid and PAS are chemically similar to certain foods the microbe requires. When the bacillus unwittingly takes them up in place of its true food, they block its metabolism and growth.

As we have seen, some bacilli do not make this critical mistake: apparently these variants carry on their metabolic processes by unusual pathways. However, there is a human countermove: by using two drugs instead of one, we can impede the emergence of resistant strains, for the second drug has a good chance of repressing the few microbes resistant to the first. The ramifications of this three-way contest between the bacillus, the body and drugs are intricate, and furnish a fascinating field for scientific investigators.

Man may finish off the tubercle bacillus quickly if he discovers the secret of the chemical properties that distinguish the virulent bacillus from the nonvirulent forms. Numerous studies are under way to isolate the water-repellent chemicals that seem to be responsible for the unique cordlike, serpentine pattern of the virulent bacillus' colonies. If the chemicals are identified, they may give a final answer concerning how to make the microbe impotent.

In any case, the battle against tuberculosis is slowly being won. Possibly chemotherapy will merely strike the *coup de grâce* in a long struggle in which the human body itself has adapted to defeat the parasite. Just as the bacillus becomes resistant to man's drugs, so man has become more resistant to the bacillus through his own mutations. The human stocks most susceptible to tuberculosis were wiped out long ago. As the survivors, we, like drug-resistant bacilli, are better equipped for the struggle.



BOOKS

A major poll of what Americans think about civil liberties and related matters

by Morton Grodzins

COMMUNISM, CONFORMITY AND CIVIL LIBERTIES, by Samuel A. Stouffer. Doubleday & Company, Inc. ($4.00).

An eminent U. S. civil servant journeying through North Africa found it necessary to travel for several hours on a camel. When his ride was over, he walked away rubbing his seat and said to his companions: "There's an animal constructed by a committee."

Communism, Conformity and Civil Liberties is a camel of a book. The public opinion poll on which the book is based was conceived by the chairman of a committee of the board of directors of the Fund for the Republic. A special committee then reviewed the problem and developed a polling questionnaire. Numerous consultants were consulted. A corps of advisers gave expert advice. Two agencies did the field work: the American Institute of Public Opinion, known as the Gallup Poll, and the National Opinion Research Center, associated with the University of Chicago. Memoranda and criticism were solicited from "many other persons." Finally Dr. Stouffer, chairman of the special committee, was given the task of writing the book. He obviously had a mandate from somebody to do his writing in as popular and nontechnical a manner as possible.

Camels are extraordinarily useful in some areas for some purposes. So is this book.

Technically the volume is of the highest order. Stouffer, who was the chief author of the notable four-volume study *The American Soldier,* is one of the most skilled practitioners of the polling art. His analyses and interpretations, when limited to the data, are always reasonable, cautious and illuminating. The poll itself was carried out with meticulous care. Two complete national samples were drawn. "For the first time in the history of public opinion polling, the work of two different agencies can be compared on an entire questionnaire." The two samples totaled 4,933 persons, selected and interviewed according to the strictly controlled probability method. In addition 1,500 local community leaders were interviewed on the same topics. The two polling groups got almost identical results in their separate polls. The book gives the clearest and simplest description that has been published of how a national poll is conducted, and Stouffer's presentation of the poll data is a model of lucidity.

The text itself is loaded with clichés, grossly repetitive and stylistically dull. However, the book will satisfy the curiosity of biological and physical scientists who wonder what people do when they make noises like social scientists.

It represents one school of current emphasis in social research: the extreme fact-smackers. Stouffer's primary concern is not theorizing, not even theorizing about relationships among facts. He comes with no hypotheses to test. He is concerned with collecting quantifiable units, in this case, attitudes, and in identifying the gross socioeconomic variables (in education, age, sex, geographical location) associated with those attitudes. When he goes beyond these purposes, the humps and the ragged gait of the camel become apparent.

The study contains much interesting and important, though by no means unexpected, data. It demonstrates that U. S. citizens have relatively little concern about the threat of Communism to this country. They are even less concerned about current threats to traditional American civil liberties. Fewer than 1 per cent of the persons in the national sample, responding to a series of unstructured questions, expressed concern over either danger. "Not over 20 out of nearly 5,000 respondents in the cross section volunteered a worry about civil liberties." Most people showed little interest in political issues in general. They were primarily concerned about personal affairs: health, marriage, job, family and a host of miscellaneous problems.

Stouffer rightly concludes that the findings "should be of interest to a future historian who might otherwise be tempted, from isolated and dramatic accounts in the news, to portray too vividly the emotional climate of America in 1954. . . . A picture of the average American as a person with the jitters, trembling lest he find a Red under the bed, is clearly nonsense."

Nevertheless Americans plainly are an intolerant lot. Of the national cross section, not more than 58 per cent would allow a Socialist to make a speech in their community. Only 33 per cent would allow him to teach in a university or college. Only 27 per cent would allow an admitted Communist to make a speech in his community. Only 6 per cent would oppose firing the self-admitted Communist if he were teaching in a college. And 51 per cent answered "yes" to the question: "Should an admitted Communist be put in jail?"

Within this larger picture of intolerance, the data show that younger people are somewhat more tolerant than older ones; that those with greater education are more tolerant than the less educated; that tolerance is lowest in the South and greatest in the Far West, with the East and Middle West in between; that those from urban areas are more tolerant than those from rural areas; that men are more tolerant than women; that (perhaps surprisingly) "regular church attenders are less likely than other people to be tolerant of the kinds of nonconformists . . . about whom we are inquiring." Separating the strands of causation by cross tabulations, Stouffer shows that each of these factors plays its own part. For instance, Southerners are not less tolerant simply because more of them live in rural areas or because they have less education or because of a combination of these two reasons; even when the type of community and level of education are held constant, Southerners are consistently less tolerant than those from other geographical areas.

These are only samples of the pocketfuls of facts that Stouffer offers. They are neatly categorized and appropriately qualified where necessary. They are the valuable heart of this book.

But at almost every point where the analysis goes beyond the bare data, the study is unconvincing. Consider, for example, Stouffer's conclusion that the long-term trend in the U. S. is toward greater tolerance of nonconformists. He bases this conclusion upon the inferences that those moving from youth to middle age today are better educated than in past generations, and that "they are products both of child-rearing practices and of a school system which is more apt to foster tolerance." Stouffer draws the latter inference from responses to questions which indicate that younger people "are less likely to be rigid categorizers and less likely to favor authoritarian or conformist child-rearing practices." This explanation does not seem fully to satisfy Stouffer, for in another place he suggests that "tolerance or intolerance may be a disposition . . . deeply rooted in a man's or a woman's personality structure."

The two explanations are not exactly consistent. The more important fact is that neither is very good. Tolerance and intolerance may indeed vary with education and child-training and with variations in personality structure. But changing international and national situations certainly have a more profound effect upon levels of tolerance than any of these things. Stouffer himself, in another connection, cites poll data showing that the number of *college-educated* people who would deny freedom of speech to Communists increased from 31 per cent to 71 per cent between 1945 and 1953, and that among the less educated intolerance on this score increased from 42 per cent to 78 per cent.

The cold war with the U.S.S.R. and the attendant climatic change within the U. S. have been responsible for the growth of public intolerance. The march of history has obviously been more important than the march upward in the age scale of the educated cohorts. What has happened in the United Nations building has been more important than what happened in the nursery. And greater tolerance in the future will come with a more pacific world. Certainly this tolerance will not come, whatever the level of education and whatever the habits of child-raising, if the cold war gets hotter.

Community leaders were more tolerant, in virtually every category, than the national cross section of population. These "leaders," to meet sampling difficulties, were chosen only from cities of 10,000 to 150,000 population. An attempt was made in each city to interview one representative from each of 14 areas, including public officials, political party leaders, industrial and union leaders, heads of patriotic groups, newspaper publishers and various other prominent persons.

The consistently higher tolerance scores of the leaders so chosen are illustrated by these comparisons: on the question whether a Socialist should be allowed to speak in the community, 84 per cent of the leaders answered "yes," compared with 58 per cent of the general population; on the question of allowing a Socialist to teach in a college, the relative proportions approving were 48 per cent and 33 per cent; on allowing an admitted Communist to speak, 51 per cent and 27 per cent; on whether a college teacher found to be a Communist should be allowed to hold his job, 11 per cent and 6 per cent.

Stouffer takes considerable comfort from the greater tolerance of the leaders. But it is certainly more significant that 89 per cent of the leaders would not allow a Communist to teach than that 5 per cent more of the leaders than of the cross section would. Even among the leaders, barely one half would allow a Communist to make a speech. These are sobering data to those who take seriously the importance of freedom to democratic life.

Do the evidences of gross intolerance indicate that our nation, dedicated to freedom, is on the verge of giving up its first principles? Stouffer believes that they do not, and he puts his main faith in information and education by "responsible leaders." The real question here is: Which leaders—the 49 per cent who would deny a Communist even the privilege of free speech? Actually I think there are grounds for a cautious optimism in the fact that the leaders in Stouffer's sample are far from the most significant group influencing public attitudes in this country. In the first place, these community leaders were all chosen from the smaller cities: no leaders from cities larger than Tacoma, say, are represented. Even such cities as Des Moines, Yonkers, Springfield, Mass., or Flint, Mich., were too large to qualify. Almost certainly leaders in the largest cities or leaders of the great national voluntary organizations and of the national government would exhibit far greater tolerance than the sample from the small cities. In the second place, there are reasons for believing that the community leaders chosen for polling are precisely the group with the least influence. People's attitudes and action are for the most part influenced by primary groups—the small face-to-face groups in which continuous human interaction takes place. The importance of the primary group has been indicated by diverse research: in studies of children and adults; in assessing what motivates action in voting, work, army life, play and criminal activity, to name only a few areas. The interplay between opinion leaders in primary groups and other leaders is clouded and complex, but a good case can be made that the principal interaction is between leaders of the largest groups—the nation, the church, the union, the industry—and the small, face-to-face groups. It is almost as if the very large groups supply goal definitions and the very small groups supply the energy and the motive power. One can see this in a bond drive, in recruiting soldiers, or in establishing attitudes toward Communists. However the relationship is formulated and whatever the matter at hand, the leaders that Stouffer polled do not seem to be of first influence.

"To take a hand in the regulation of society," de Tocqueville wrote, "is the American's biggest concern, and, so to speak, [his] only pleasure." Today one can only doubt the accuracy of the French visitor's observations or marvel at the changes a century has brought. The contemporary fact is in any case clear: the average American's round of life is played largely without political concern. Except in an acute international crisis or the quadrennial presidential elections, politics do not loom large in his activity and thinking. His waking hours are concerned with family, job, business, hobby, entertainment.

Stouffer's poll data indicate that the persons least concerned about public issues are the most intolerant. And this is a fundamental tip-off that the intolerance and ignorance the U. S. people frequently display in polls do not signify that the Republic is on its last legs. The fact is that the poll data, as Stouffer wisely points out, reveal only attitudes, latent tendencies which are not necessarily translated into action. An attitude in favor of denying free speech to a Socialist (or Communist) may not at all be followed by action. Typically the person holding the attitude may be busy with other things more important to him. Or the Socialist concerned may be the town character, or Aunt Maisie's saintly but witless uncle, or (as in the case of Norman Thomas) a distinguished personage apart from the Socialist label.

Of even greater importance, the questions asked in the poll involve issues concerning which ordinary citizens rarely have or exercise direct responsibility. It is therefore not of great immediate or practical concern that 75 per cent of the community leaders and 88 per cent of the cross section say they would deny atheists the right to teach in a college. Those who are competent in this field, those to whom the issue is relevant, those whose decisions will have consequences are the administrators and teachers in institutions of higher education. And one can be certain that their actual answers—whatever answers they may give in a poll—do not so discriminate against the irreligious. In most real-life situations the question is not even asked.

In interpreting poll data a social scientist probably has more difficulty than a physical or biological scientist does when he interprets laboratory results. The variables are more numerous. The sources of data—human beings—are more complex. The situation can never be exactly reproduced. Many variables are completely uncontrollable. Answers to the interviewers' questions are themselves one type of human behavior, but this behavior may be meaningless, or relatively unimportant, as a predictor of later behavior that may occur in a different social context, one that is less purely verbal and that is fraught with greater social consequences. The poll data may be absolutely accurate—but they may have meaning only as poll data.

The low level of political awareness and competence found among most of the persons polled must be interpreted with great caution. It is less important to the democracy that the least informed and most irresponsible persons make intolerant judgments than that the well-informed and responsible make tolerant ones. Even the fact that many citizens of a democratic nation are politically apathetic is not crucial: it is in totalitarian nations that citizen participation in politics reaches a high point. The important point is that there should be leaders competing to lead, and that a peaceful and orderly change of leaders remains possible. As long as the ignorant and the apathetic can become informed and active, as long as program followers can become program leaders, democracy retains its basic strength.

Those with a passion for liberal democracy will not minimize the deficiencies in sensitivity and knowledge revealed in the electorate. This study reminds them once again that democracy is a process, as well as a product, and that neither the process nor its product ever achieves perfection. It will also spur to greater effort those who find politics important and who find the present state of things unpalatable.

The immediate practical point is that illiberal attitudes on the part of even

powerful elements in the society do not sound the death knell of the Republic. In 1791 the First Amendment of the Constitution stated without equivocation that "Congress shall make no law . . . abridging the freedom of speech." Barely seven years later, when the cold war was with France, not Russia, the sedition acts of 1798 made it a felony to "combine or conspire together with intent to oppose any measure . . . of the government of the United States . . . or to write, print, utter, or publish . . . any false, scandalous, and malicious writing . . . against the government." The hotheads and breast beaters of the day believed the Republic was doomed. Thomas Jefferson's advice then is still good: "A little patience and we shall see the reign of witches pass over."

Short Reviews

THE STORY OF MAN, by Carleton S. Coon. Alfred A. Knopf, Inc. ($6.75). Professor Coon, an ethnologist and anthropologist at the University Museum in Philadelphia, tells the story of man's development from the emergence of *homo sapiens* to today's impious and feverish preparations to journey to other planets. The tale is spun with immense verve and exhibits a wide, sure knowledge of archaeology, history and related subjects. It discusses man's adaptation in physique and culture to the changing circumstances of his environment, his religion, tools, and cooking habits, his agricultural and industrial pursuits, his communities and governments, his methods of warfare, his wisdom and folly in the use of natural resources. Coon is learned, but neither stuffy nor pedantic. He emphasizes the subjects of greatest interest to himself and is not too timid to indulge in conjectures, to air his prejudices. This personal approach breathes life into the account but also leads to disproportion in treatment. For example, twice as much space is allotted to British and Dutch trading companies as to the role of mathematics in human history; the Eskimo and Polynesian cultures receive almost as much attention as the whole of history from the 18th century to the present. Nevertheless Coon's book is a rewarding and most enjoyable survey.

THE DANCING BEES, by Karl Von Frisch. Harcourt, Brace and Company ($4.00). THE BEHAVIOR AND SOCIAL LIFE OF HONEYBEES, by C. R. Ribbands. Hale Publishing Company ($4.50). These are two excellent popular accounts of the life and labors of the honeybee. Von Frisch is famous for his researches on communication among bees. In this book, the first English translation of his own work, he not only describes his experiments on bee language but covers all aspects of bee life. A final chapter is devoted to the communities of bumblebees, ants and wasps. Von Frisch's style is charming and exceptionally clear; his story is well illustrated with photographs and diagrams. Ribbands is the principal scientific officer of the bee department at the British Rothamsted Experimental Station, where a good deal of work has been done repeating Von Frisch's experiments and testing his conclusions. In somewhat more comprehensive fashion than Von Frisch, Ribbands reviews the knowledge gained about bees, from the Indian bees' practice of "absconding" (migrating) to the cool hills in summer to the "timid and anxious" behavior of robber bees, which can't seem to make up their minds when to enter a strange hive and are often undone by their suspicious actions, leading the hive guards to attack them. Ribbands' attractively written book will appeal to beekeepers and scientists as well as ordinary readers.

PHYSICS OF THE PLANET MARS, by Gérard de Vaucouleurs. The Macmillan Company ($10.00). The study of Mars began with description of its geography. Vaucouleurs in this book deals mainly with the more sophisticated phase that began about 30 years ago: use of modern instruments to examine the planet's atmosphere, climate, polar caps, bright and dark areas, internal constitution and structure. Much has been learned, much remains unknown. Opinion is sharply divided as to whether there is vegetation on Mars, but those, including G. P. Kuiper, who have studied it most intensively incline to believe it does grow a sort of moss. As for the vexed question of the canals, the enigma remains unsettled. Vaucouleurs' monograph has photographs and an excellent bibliography.

THE ORIGINS OF PSYCHOANALYSIS, by Sigmund Freud. Basic Books, Inc. ($6.75). Between 1887 and 1902 Freud wrote 287 letters to his friend Wilhelm Fliess, a Berlin physician. The letters were preserved by Fliess, found their way to a secondhand dealer in Germany during the Nazi period, and, thanks to the efforts of Maria Bonaparte, survived for publication. Two thirds of the letters, ably translated by Eric Mosbacher and James Strachey, appear in this volume. The period covered by the correspondence was crucial in Freud's development; during these years he published his first essays on neuroses, *Studies on Hysteria, The Interpretation of Dreams, The Psychopathology of Everyday Life.* This was also the period of Freud's self-analysis. Fliess's letters to Freud have not been found, so the reader is in a sense—as Ernst Kris remarks in the introduction—like a bystander listening to someone speaking on the telephone. Fliess himself was a nonentity who promulgated half-dotty theories, but he served as one of the great sounding boards of modern science. Freud loved and admired him for many years, confided in him and gave him a step-by-step account of the birth of psychoanalysis. In these letters he reports every turn and twist, every failure and thrilling revelation, every torment and frustration and triumph in his groping for light. The letters are wonderful not only as vivid records of the growth of a majestic system, but also for the picture they present of Freud himself. They show his kindness, the exquisite sensitivity of his insight, the clarity and fluency of his style, his humor, his prodigious capacity for work. This is a major book, an absorbing piece of reading.

JUNGLE QUEST, by Edward Weyer, Jr. Harper & Brothers ($3.50). Dr. Weyer, an anthropologist, explorer and editor of *Natural History* magazine, tells the story of his solo expedition to the Mato Grosso to find Orlando Villas Boas, a tiny, courageous, dedicated Brazilian who had spent a dozen years in the Amazon wilderness devoting himself to helping the Indians. Weyer found Boas, but the meeting was in a sense an anticlimax to earlier adventures which included visits to Chavante villages and several weeks spent at an idyllic lakeside settlement of Camayura Indians. Weyer describes admirably the ways of these joyful, peaceful people, who wear no clothes and seem at once more plausible, more innocent and more virtuous than Adam and Eve before the fall. An unpretentious and unusually interesting book by a thoroughly likable man.

DIGGING UP THE PAST, by Sir Leonard Woolley. Thomas Y. Crowell Company ($3.50). A revised edition of a readable primer of archaeology. The author, a distinguished figure in his profession, gave the lectures on which this book is based a quarter-century ago. They describe how expeditions are organized and sites chosen, the actual field work, the evaluation of the material. It is clear from these pages that while archaeology now has important new dating methods and other special techniques, there is still no substitute for the dedicated, knowledgeable and discriminating man with the spade—and that there are no finer writers on archaeology than Sir Leonard Woolley.

THE PASSENGER PIGEON, by A. W. Schorger. The University of Wisconsin Press ($7.50). A hundred years ago the passenger pigeon was the most common bird in the U. S. If the estimates of various reputedly reliable observers are to be credited, its population numbered more than two billion. James Audubon described a flight of these birds as being "like a torrent, and with a noise like thunder," the wheeling and twisting columns resembling "the coils of a gigantic serpent." Other witnesses reported the darkening of the sky for hours by solid masses of passenger pigeons flying at 60 miles per hour in tiered columns a mile wide and hundreds of miles long. The passenger pigeon is now extinct. The last survivor, Martha, died in the Cincinnati Zoo on September 1, 1914. The story of the species' extermination by another species, man, is told by Professor Schorger of the Department of Wildlife Management at the University of Wisconsin. His scholarly and absorbing book treats also of the bird's behavior, habits and natural history. Illustrations.

RADIOISOTOPE CONFERENCE, edited by J. E. Johnston. Academic Press, Inc. ($18.30). These two volumes report the proceedings of the Second Radioisotope Conference in 1954, sponsored by the Atomic Energy Research Establishment of Harwell in England. Among the topics discussed are therapeutic and diagnostic uses of radioisotopes, animal physiology and pathology, biochemical applications, plant nutrition, uses in chemistry, metallurgy, physics and industrial engineering. The roster of contributors includes scientists from several countries and shows clearly the diversity and international character of studies in the constructive applications of radioactivity.

DETERIORATION OF MATERIALS, edited by Glenn A. Greathouse and Carl J. Wessel. Reinhold Publishing Corporation ($12.00). This is a cooperative volume; its various articles discuss the vulnerability to "ruin's wasteful entrance" of metals, wood products, paper, leather, plastics and rubber, electrical and optical instruments, photographic equipment and the like. It describes methods of preventing damage by climate, chemical and physical agents and biological organisms. The book has many striking photographs.

The Neolithic Cultures of the British Isles, by Stuart Piggott. Cambridge University Press ($13.50). Professor Piggott, using information from an exhaustive survey of museum materials and field monuments, has woven together a remarkable picture of British farm communities at the beginning of the second millennium B.C. He describes the implements used in agriculture, the methods of pasture and tillage, trade and intercommunication, crafts and hunting practices, home building, burial arts. A handsome book, with many illustrations.

Notes

Legal Medicine, by Thomas A. Gonzalez, Morgan Vance, Milton Helpern and Charles J. Umberger. Appleton-Century-Crofts, Inc. ($22.00). The second, enlarged edition of a standard handbook.

Chemistry and Chemical Technology of Cotton, edited by Kyle Ward, Jr. Interscience Publishers, Inc. ($20.00). Fourteen articles discuss various aspects of the subject.

Partial Differential Equations, by I. G. Petrovsky. Interscience Publishers, Inc. ($5.25). A translation of lectures given at the Moscow State University by a prominent Russian mathematician. For graduate students.

The British Isles, by L. Dudley Stamp and Stanley H. Beaver. Longmans, Green and Co. ($9.50). The fourth edition, extensively rewritten, of an authoritative geographic and economic survey.

The Vitamins, edited by W. H. Sebrell, Jr., and Robert S. Harris. Academic Press, Inc. ($15.00). The third volume of a comprehensive survey. Its 18 chapters cover subjects ranging from p-aminobenzoic acid to research on new growth factors.

Atomic Science, Bombs and Power, by David Dietz. Dodd, Mead & Company ($4.50). An unpretentious and very satisfactory performance by a veteran science reporter. Illustrations.

Medicine and Science, edited by Iago Galdston. International Universities

Press, Inc. ($3.00). New York Academy of Medicine Lectures to the Laity, including papers by Hans Selye and Paul Rosch on "The Renaissance in Endocrinology," by David M. Levy on the "Relation of Animal Psychology to Psychiatry," and by Harold G. Wolff on "Stress, Emotions and Bodily Disease."

Variable Stars & Galactic Structure, by Cecilia Payne-Gaposchkin. John de Graff, Inc. ($3.50). Lectures which Dr. Payne-Gaposchkin, of Harvard University, delivered at the University of London in 1952.

Biochemistry of Cancer, by Jesse P. Greenstein. Academic Press Inc. ($12.00). The second edition of a survey by the chief of the biochemistry laboratory of the National Cancer Institute. It contains much new material.

Statistical Analysis in Chemistry and the Chemical Industry, by Carl A. Bennett and Norman L. Franklin. John Wiley & Sons, Inc. ($8.00). The most complete survey of the use of modern statistics in chemistry and chemical technology.

Dynamical Theory of Crystal Lattices, by Max Born and Kun Huang. Oxford University Press ($8.00). An essay on the properties of crystals.

Essays in Sociological Theory, by Talcott Parsons. The Free Press ($6.00). The second edition of this important collection contains eight new essays dealing with problems of topical interest, including the social structure of pre-Nazi Germany, sociological aspects of Fascist movements and social structure in the light of psychoanalysis.

Actions of Radiations on Living Cells, by D. E. Lea. Cambridge University Press ($6.00). The second edition of a standard work.

Geochemistry, by V. M. Goldschmidt, edited by Alex Muir. Clarendon Press ($11.05). The late noted geologist's survey of the whole field of the distribution of the chemical elements in the earth and the atmosphere.

Emotions and Bodily Changes, by Flanders Dunbar. Columbia University Press ($15.00). Dr. Dunbar's book, which in this fourth edition runs to 1,200 pages, is an important guide for specialists and an engrossing volume for browsers—those who believe in the soma as well as those who plump for the psyche.

THE AMATEUR SCIENTIST

An observatory built by a high-school senior and how to reconstruct a famous spectroscope

Atoms and molecules, when struck a sharp blow by a hammer of atomic dimensions, ring like bells. The ear is not sensitive to the electromagnetic waves they emit, but the eye is. All light originates in this way. Just as every bell makes a characteristic sound of its own, depending upon its size and shape, so each of the hundred-odd kinds of atoms and their myriad molecular combinations radiate (or absorb) light of distinctive colors. The instrument physicists use to sort out the colors, and thus identify substances, is the spectroscope. This powerful instrument is relatively simple in principle and not difficult for amateurs to build. Yet it is one of the most useful tools in the scientist's kit. During the first half of this century it has helped to answer an incredible number of scientific questions—more than the telescope and microscope combined.

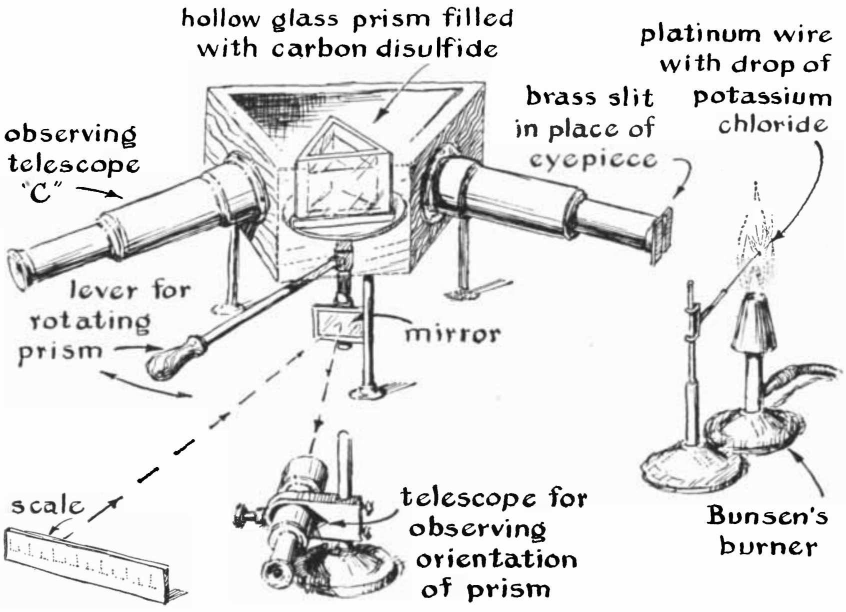
Accordingly, spectroscopy has become a specialized and important branch of physics. Any substance, whether a piece of cheese or a rusty hairpin, can be made to emit light by heating it. When the resulting light is sent through a spectroscope, the rays separate into lines or bands of colors which not only tag the responsible atoms but may reveal many secrets of how they are combined.

Light waves are only about one 50,000th of an inch long. With a good spectroscope, however, you can measure their size within a few trillionths of an inch, or about a billionth of the thickness of the paper on which this magazine is printed. With this information as a guide, chemists have learned how to take molecules apart and reassemble them into substances with new and desirable properties. About 20 kinds of molecules have been manufactured in the laboratory for every one chemists have identified in nature. The tool contributing most to this analysis and synthesis is the spectroscope.

Isaac Newton laid the foundations of spectroscopy when he observed that a prism bends rays in the blue end of the spectrum more than those nearer the red end. On February 6, 1670, Newton wrote Henry Oldenburg, then secretary of the Royal Society:

"To perform my late promise to you, I shall without further ceremony acquaint you that in the year 1666, I procured me a triangular prism, to try therewith the celebrated phenomena of colors. And in order thereto, having darkened my chamber and made a small hole in my window-shuts, to let in a convenient quantity of the Sun's light, I placed my prism [so that the ray] might be refracted to the opposite wall. It was at first a very pleasant divertissement to view the vivid and intense colors produced thereby, but after awhile, applying myself to consider them more circumspectly, I became surprised to see them in oblong form which according to the laws of refraction, I expected should have been circular. . . . I took two boards and placed one of them behind the prism at the window so that the light might pass through a small hole made in it for the purpose and fall on the other board which I placed about 12 feet distance. Then I placed another prism behind this second board so that the light trajected through both boards might pass through that also. . . . This done, I took the first prism in my hand and turned it to and fro slowly about its axis so much as to make the several parts of the image cast on the second board successively pass through the hole in it that I might observe to what places on the wall the second prism would refract them. I saw . . . that the light on the (violet) end did in the second prism suffer a refraction considerably greater than the light tending to the other end (red) . . . and that according to their particular degrees of refrangibility they were transmitted through the prism to divers parts of the opposite wall."

With this demonstration Newton's service to spectroscopy came to an end. He apparently failed to see any of the fine detail which gives the spectrum its



A spectroscope reconstructed according to the directions of Robert Bunsen significance. Nevertheless he subsequently stated that the sorting of the colors could be carried further by the use of improved prisms and lenses.

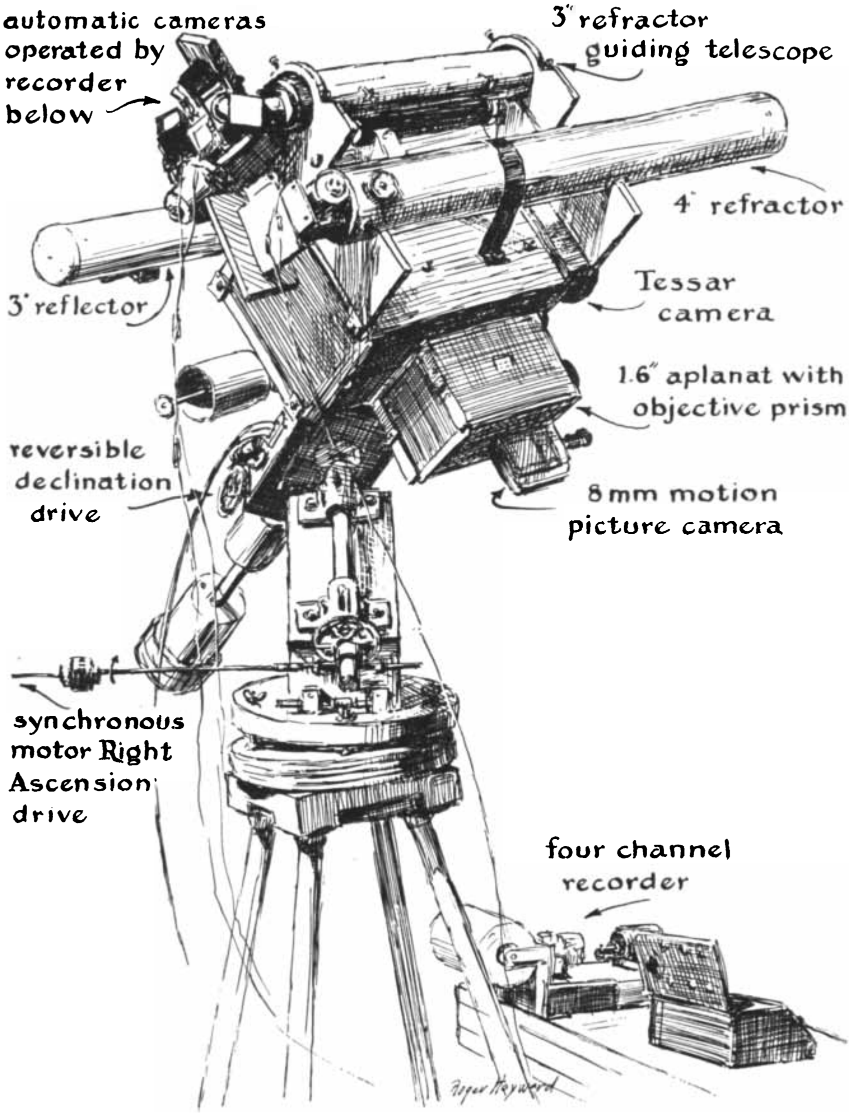
It is difficult to understand why Newton did not reduce his spectroscope to convenient laboratory form. He almost had it in principle. Yet he and his successors were content to work in darkened rooms for nearly two centuries. Even Joseph von Fraunhofer's epoch-making discovery of the dark absorption lines, which split the solar spectrum into thousands of parts, was made with a setup that filled his laboratory. To view the slit in the "window-shut," beyond his prism, Fraunhofer used a theodolite telescope placed behind the prism—an improvement which enabled him to make good measurements of the angles through which the light was bent. The clear view of the slit thus afforded disclosed "an almost countless number of strong and weak vertical lines," which close examination proved were "in the sunlight." Fraunhofer could not explain the lines, but he made an accurate chart of about 700 of them and designated eight of the most prominent ones by the letters A to H, by which they are still known.

The meaning of the dark lines remained a mystery until 1859, when they were explained by the Heidelberg physicists Robert Bunsen and Gustav Kirchhoff. They made the profound discovery that gases through which a ray of light passed would absorb certain narrow portions or colors of the light. The absorptions were signaled by dark lines in the spectrum. They also demonstrated that if the absorbing gas itself was heated to incandescence, then the dark lines of absorption became bright lines of emission, which stood out on the dark spectral band if there were no other source of light.

In the course of their experiments Bunsen and Kirchhoff reduced the size and design of the prism-type spectroscope to substantially its present form. Amateurs who would like to experiment with one may enjoy building the instrument according to the directions written by Bunsen 96 years ago.

"It is well known," he wrote, "that many substances have the property when they are brought into a flame, of producing in its spectrum certain bright lines. We can base a method of qualitative analysis on these lines that greatly broadens the field of chemical research and leads to the solution of problems previously beyond our grasp.

"The gas lamp previously described



A photographic telescope built by Philip Lichtman of Washington, D. C.

[Bunsen's gas burner] gives a flame of high temperature but low luminosity. Into this flame we introduced for investigation a small quantity of chlorate of potassium which had been recrystallized six or eight times. The apparatus we have used for investigating spectra is shown [*see illustration on the opposite page*]. The box [holding the prism] is blackened on the inside. Its two inclined sides carry two small telescopes. The ocular of the one facing the test flame is replaced by a plate in which is a slit formed by two brass blades. The burner is placed before the slit. The end of a fine platinum wire, bent into a small loop and supported by an apparatus stand, passes into the flame; on this hook is melted a globule of the chloride previously dried. Between the objectives of the two telescopes is placed a hollow prism with a refracting angle of 60 degrees and filled with carbon disulfide. The prism rests on a brass plate that can be rotated by a vertical shaft. The shaft carries on its lower end a mirror, above which an arm attaches which serves as a handle for turning the prism and mirror. Facing the mirror is another small telescope arranged to give an image of the horizontal scale, placed a short distance away. By rotating the prism, one can make the entire spectrum of the flame pass before the vertical cross-hair in the ocular of the viewing telescope. To every point in the spectrum, there corresponds a certain reading of the scale."

With this instrument Kirchhoff and Bunsen made the series of elegant investigations which founded the modern science of spectroscopy. Their explanation of the Fraunhofer lines and discovery of the elements cesium and rubidium inspired scientists all over the world to take up the new field of investigation and raised public interest in science to a high pitch.

Unfortunately Bunsen omitted one critical detail of construction that has plagued instrument makers ever since. He failed to specify the kind of cement he used to join the glass slabs of his hollow prism and seal in the foul-smelling, volatile, explosive and poisonous carbon disulfide.

R. B. Nevin of Christchurch, New Zealand, has made Bunsen-type prisms with wax as the sealer. He describes them as follows:

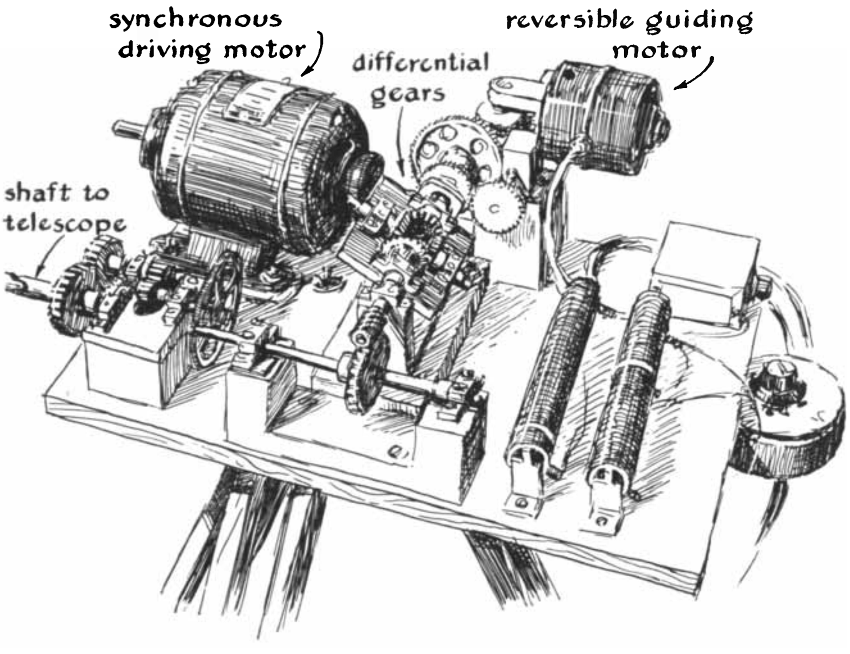
"My 60-degree prisms are made of eighth-inch plate glass which has never heard of such a thing as a figure. The glass is cut into pieces 2.5 by 2 inches, accurately oblong. Using a carborundum stone, I bevel the long edges slightly on one side at an angle of 30 degrees to the horizontal, and similarly bevel both sides of the shorter edges. The three slabs are then assembled on the bench as an equilateral triangle, the bottom one being stuck with anything handy if it won't stay put. A few bits of sealing wax are put in the top groove, and a gas flame is gently wafted along the glass until the wax melts. It is then spread with a match stick and given more heat until liquid. Next it is coaxed firmly but gently into the groove with the stick. More wax is applied until the groove is filled level with the glass edges. Then the whole is allowed to cool. A Bunsen burner flame about half on and just nonluminous is correct. If the flame is too intense, it heats the glass unevenly and cracks it. The procedure is repeated for the remaining two grooves. If the glass has been cut squarely and beveled properly, the edges will fit without adjustment. The wax holds to the ground edges tenaciously and is easy to flake off the polished surfaces where it is not wanted.

"The assembly is very strong for its dimensions. A triangular bottom for the box is then cut about a sixteenth of an inch larger than the assembled walls. The upper edges, upon which the walls will rest, are similarly ground, beveled and cemented to the previously completed subassembly. Gentle finishing touches with the flame to give a smoothly finished job can be applied to taste. The important precaution is: Do not rush the job. The sudden application of heat to one spot will crack the glass.

"When the prism is thoroughly cool, water can be poured into it, and when you look at a source of white light through it you will see all the colors of the rainbow. Glycerin in place of water will improve the prism's definition slightly, although its dispersion is about that of water and of crown glasses. It is significantly lower than flint glass. Perhaps the best liquid of all is carbon disulfide. Unfortunately it is a splendid solvent for sealing wax!

"That's about all there is to it. I whipped through a quite serviceable prism the other day in about 30 minutes of careful work—from cutting the glass to filling it with water."

Liquid prisms offer a number of distinct advantages to the amateur. They are easy and cheap to make, especially in



The drive of Lichtman's telescope

large sizes. They also allow a wide choice of materials and dispersions. Their principal disadvantage is that the dispersive power of liquids varies greatly with changes in temperature. Moreover, temperature gradients within the liquid create inhomogeneities in dispersion with a consequent loss of resolution. The Fraunhofer lines blur and merge unless the liquid is maintained at uniform temperature.

Roger Hayward, after making the drawing of Bunsen's spectroscope shown here, volunteered a few practical tips out of his experience with liquid prisms. "Carbon disulfide," he wrote, "is terrible stuff. In addition to being smelly and explosive, it is a particularly insidious, chronic poison which can produce permanent damage to the spinal cord and brain. It is like playing with a bunch of uncaged cobras. Never handle it except under a ventilating hood.

"The best substitutes for carbon disulfide from an optical point of view are monobromonaphthalene, ethyl cinnamate (expensive), an aqueous solution of barium-mercuric bromide and oil of bitter almonds, in that order. The prism should be made with a glass bottom. The difference between the temperature coefficient of glass and that of brass makes a leakproof joint between the two difficult to achieve. Glass is the simplest material to use because the pieces can be ground to fit. Perhaps litharge and glycerin would make a good cement. Few liquids dissolve it.

"Those who wish to avoid the labor of building the two small telescopes used in this instrument may buy a pair of the popular-priced, low-power telescopes now on the market. I have a small spectroscope that uses a telescope and collimator with apertures of only three quarters of an inch. It will not separate Fraunhofer's D line of sodium but will resolve the yellow lines of mercury.

"Incidentally, Bunsen's way of rotating the prism to scan the spectrum makes you shudder. Of course he knew no better. Using fixed telescopes, he had to set the angles in a way which did not allow him to focus on any part of the spectrum at minimum deviation. Thus all measures of angles were made from an arbitrary, nonreproducible point. When provision is made for rotating the telescopes around the prism, the point of minimum deviation for a single line in the spectrum is easily found. Then rotation of one of the telescopes can be measured from such a position and a reproducible measure made.

"An easy way to make a good slit is with safety-razor blades. A thin, doubleedged blade snapped in two in the middle gives a fine pair of jaws. It is a painstaking job to file a pair of slit jaws, even as short as a quarter inch. The slit should be only two or three thousandths of an inch wide if you want to see detail.

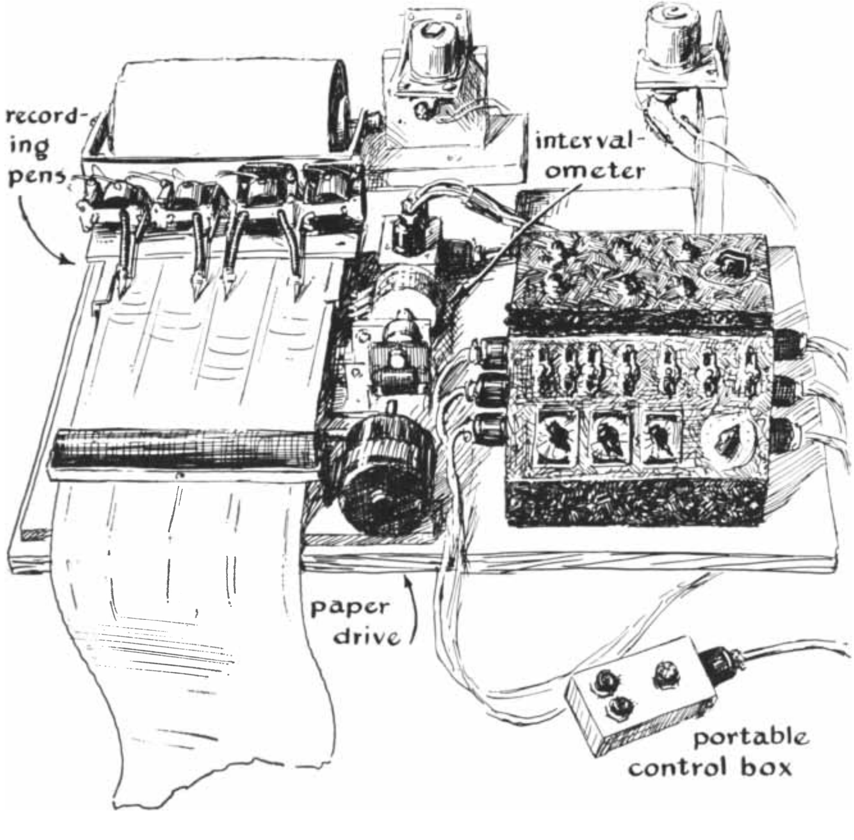
"As to light sources, a neon lamp makes a dandy. Some 40 clear lines are visible, from the yellow-green down to the deep red. I have a little lamp in a quartz envelope because there is another nice bunch of lines in the near ultraviolet. Incidentally, I built a quartz spectrograph back in 1938. All the parts were home-built—prism, mirrors, slit and all. It displays a photographable spectrum about nine inches long which has to be taken in two-inch bites. This instrument became the prototype of a commercial spectroscope which sells for about a kilobuck. Nothing has been published on it, but if readers express a hankering for a description, I should be pleased to write it up for this department."

Not all amateurs who go in for astronomy enjoy the challenge of ultra-precise craftsmanship involved in making a telescope or can afford to spend the necessary time. Consequently some of them simply buy a commercial telescope; others purchase the optical parts—oculars, mirrors, objective lenses and prisms—and assemble them in a home-built mounting.

One of the latter is Philip Lichtman, a high-school senior of Washington, D. C. Before he was 16, he demonstrated a remarkable talent for designing good mounts and making them of war surplus parts plus odds and ends.

"I have been interested in astronomy for as long as I can remember," writes Lichtman, "but I did not undertake the construction of a telescope until four years ago. After studying *Amateur Telescope Making* and *Amateur Telescope Making—Advanced,* I mounted a three-inch mirror acquired through a supply house. This project introduced me to the tricks and frustrations of such jobs as machining ball-bearing races for axis housings, turning tapered shafts from bar stock, indexing setting circles and so on. It also taught me how to adapt an ambitious design to the limitations of an inexpensive six-inch lathe.

"Since the instrument was to be used for photography, it was provided with an equatorial mounting, setting circles and an electric drive. Clamps were provided for both right ascension and declination. The system was wired to provide controlled variation of the speed in right ascension, and the slow motion in declina-



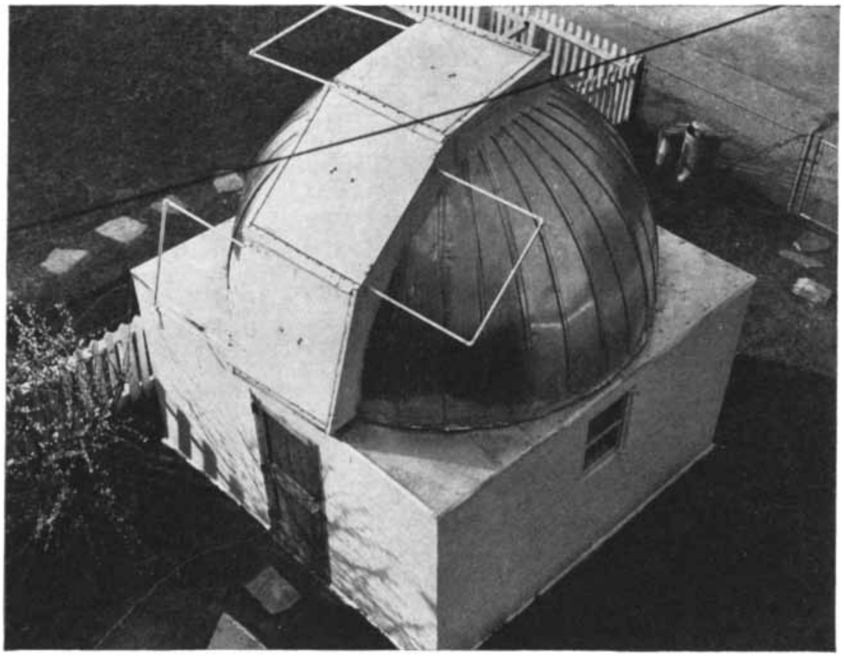
A four-channel recorder built by Lichtman tion could be regulated manually. Guiding was effected at the eyepiece through a push-button control box held in the hand. Besides the three-inch mirror and its optical train, the tube also carried a 1.6-inch finder with coated objective and illuminated cross-hairs and a two-inch astrocamera adapted for cut film 2¼ by 3¼ inches.

"It soon became obvious that the camera was much too slow ($f/12$) for nebular photography. A search of the second-hand market finally turned up a four-inch Zeiss Tessar photographic objective with a speed of $f/5$. This was set up for 8-by-10-inch plates, but it weighed far too much for the little three-inch mounting. Because my lathe would not take large parts, hard maple was selected as the basic material for a new and heavier mounting. The axes chosen for this job were saw-arbor shafts about 1¼ inches in diameter. They turned in babbitt bearings. This mounting was intended exclusively for photography and hence required a precise drive. I used a synchronous motor with fast and slow motions derived from a variable-speed motor through a train of differential gears [*see drawing on page 124*]. With the exception of the gears, the entire assembly was homemade. The arrangement worked perfectly and enabled me to make very 'tight' exposures. A variable-speed, reversible declination drive was then added to correct differential refraction and misalignment of the polar axis during long exposures, as well as for following the moon in declination. Guiding was accomplished at a magnification of 150 diameters with a three-inch, coated war-surplus achromat of 25 inches focal length and a Goodwin-Barlow lens. Two pedestals were made for this instrument: one a six-inch water pipe filled with and set in concrete in my back yard; the other, a portable affair with four legs."

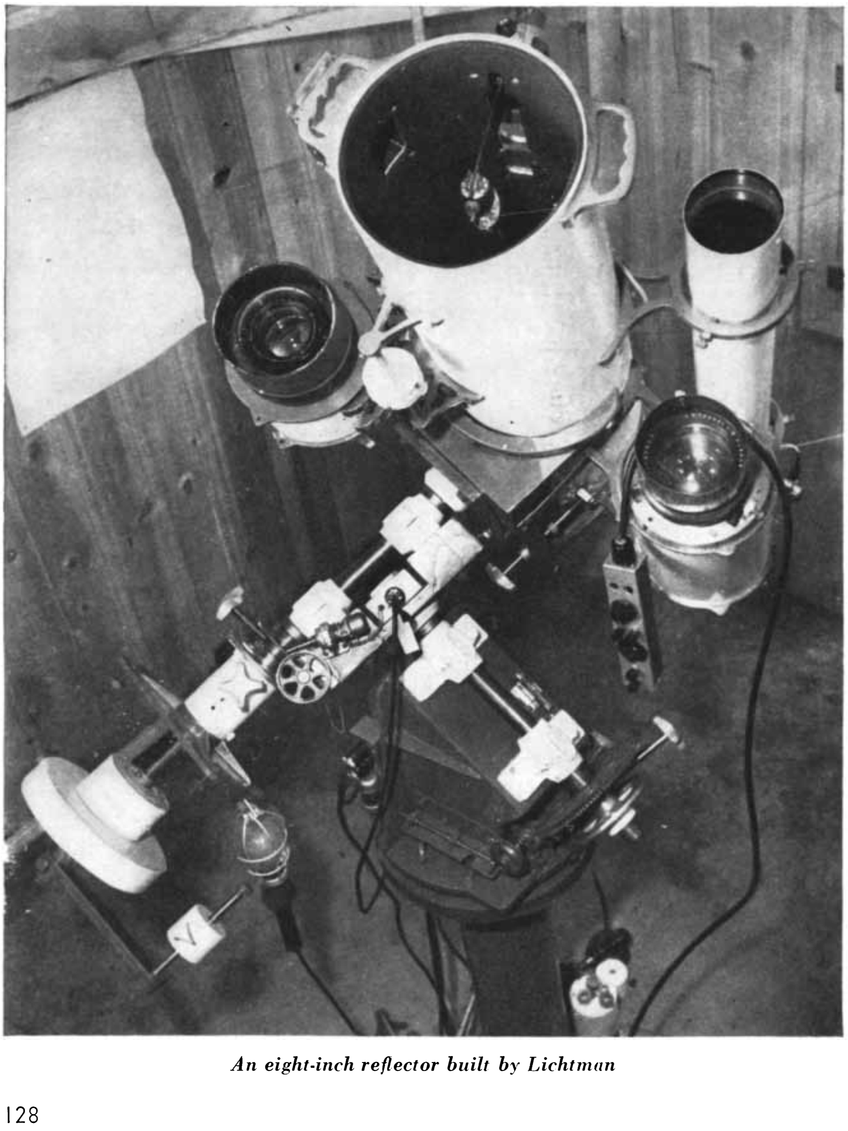
A version of this equipment as modified by Lichtman for the solar eclipse of last June is shown on page 123. He built all of the cameras and arranged two of them to operate automatically from a home-built four-channel recorder [*drawing on the opposite page*].

"The recorder," he writes, "triggers the two cameras independently and registers the time of exposure. The third channel records manual determinations of eclipse contact times and the fourth records time signals broadcast from the Bureau of Standards radio station WWV. The cameras are tripped by solenoids energized by a built-in timing motor operating at one revolution per minute.

"After a demonstration of the com-



The dome of Lichtman's back-yard observatory



An eight-inch reflector built by Lichtman

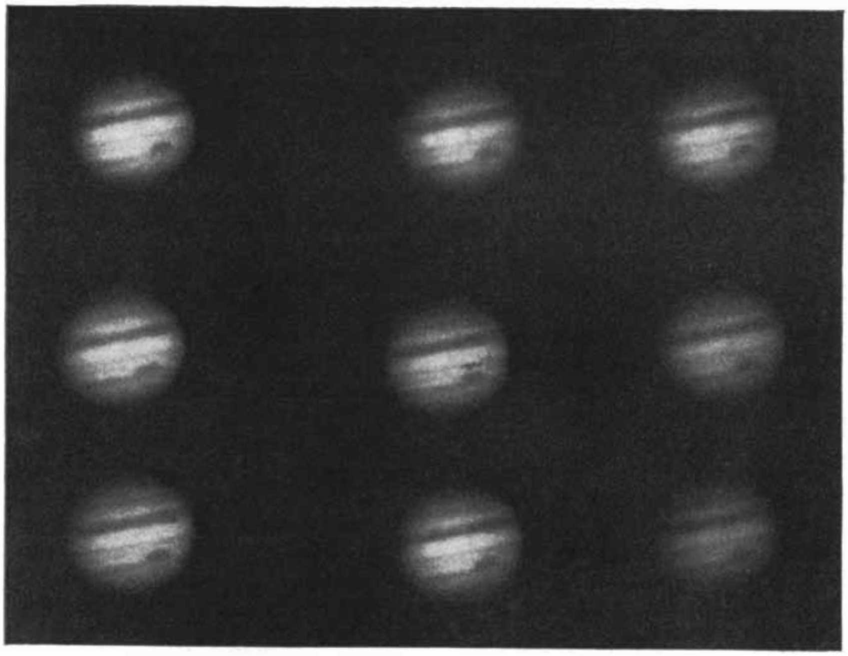
pleted rig, my father agreed to haul it and me to Keweenaw Peninsula in Michigan for the total eclipse last June. Everything was set up and fully tested the evening prior to the big event. You can guess what happened the next morning. The sun rose behind one of the densest fogs ever observed on the Peninsula! The paper tape was so soggy it refused to go through the recorder—even for a demonstration.

"The investment of time and labor was not a total loss, however. I entered some of my work in a national science contest for high-school students and fortunately won a cash award sufficient to pay for one of the exquisite mirrors by the California optician Thomas Cave. It is an *f*/8 of eight inches aperture and what appears to be a perfect figure.

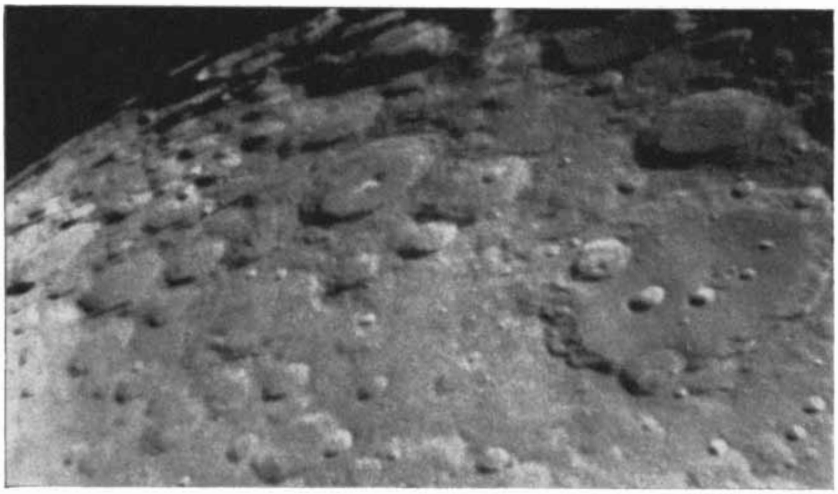
"The design of an appropriate mounting for this mirror was undertaken immediately. It would be my last major project until after college years, so I decided to go all out. A mirror of this size and speed represents a pleasing compromise for amateur work: it is not too slow for nebular photographs nor too fast for point objects; the plate scale is large enough to show fine detail in photographs made at the prime focus but not so large that the image suffers greatly from bad seeing. The focal length of approximately 65 inches is sufficient for planetary and lunar photography. I decided to equip for all of these types of photography.

"Since I was unable to machine axes larger than those used in the eclipse camera, I decided to limit all overhang to a minimum and make do with the saw-arbor shafts. Wood was too weak for the type of mounting needed, and welded plate was too expensive. Happily someone suggested aluminum castings. As things turned out, they proved to be less expensive than any material investigated. So the mount was designed around ribbed castings made from my own patterns.

"The project took all my spare time for a considerable part of a year. But when it was completed, I owned a telescope which makes celestial photography a real pleasure [*see bottom photograph at left*]. It has electric drives in both right-ascension and declination, setting circles that can be read direct to two minutes and half of one degree respectively, push-button control of slow motion, tight clamps, and even little flashlights for lighting the setting circles! The tube is of rolled aluminum an eighth of an inch thick, welded at the seam. Aside from the optical parts and rough castings, this weld was the only job in the



Nine images of Jupiter on a plate made with Lichtman's eight-inch reflector



The southern limb of the moon photographed with the eight-inch reflector

The Great Nebula in Orion photographed with the four-inch Tessar

instrument done by a professional. For adequate ventilation the tube was made three inches larger in diameter than the mirror. Its exterior was painted white and the interior was lined with sheet cork and finished in flat black. A small fan near the mirror ventilates the inside before a night's work begins. It vibrates too much, however, to be used continuously during the observing.

"The mirror cell is a three-point flotation system. It consists of three radial arms spaced at 120-degree intervals. The system is adjustably mounted to the tube. The mirror rests on three steel balls embedded in the radial members and is held in place by arms projecting from them.

"By providing both coarse and fine rack-and-pinion focusing, the design anticipated the use of oculars and cameras of widely varying focal length. The diagonal spider is a single-arm affair supported by the ocular carriage, so that it can move longitudinally with respect to the tube. The diagonal is rotatable so that light may be deflected either to the eyepiece or to a Newtonian-focus camera mounted at about 90 degrees with respect to the eyepiece.

"The finder is a three-inch $f/5$ coated surplus objective equipped with illuminated cross-hairs and a wide-field Erfle ocular. The guide telescope, a 4⅜-inch refractor, has rack-and-pinion focusing and a movable tailpiece so that it may be set on a bright star slightly outside the limited field of the reflector. A cross-ruled illuminated reticule simulates the field of view of the reflector when used at the extremely high plate scale necessary for planetary photography. This refinement enables me to put nine images of Jupiter on each sheet of the 2¼-by-3¼ cut film.

"The long-focus reflector is supplemented by an $f/2.5$ Aero-Ektar camera of seven inches focal length, by a new housing for the four-inch Tessar and by two multipurpose units. One of these is a projection camera which can increase the reflector's equivalent focal length to 240 feet. The other is a simple plate holder which may be inserted in the eyepiece adapter of any standard telescope.

"Like city-bound amateurs everywhere, we in Washington are plagued by a brilliantly lighted night sky. Blue exposures made with the Tessar objective and Eastman spectroscopic plates fog almost black in 30 minutes. I doubt that there is a real cure for the trouble. I have succeeded in punching through the glow some 200 times, however. Sometimes I use filters which transmit the hydrogen alpha line and block out city lights."

INDEX OF ADVERTISERS

JUNE, 1955

BIBLIOGRAPHY

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

ALBERT EINSTEIN: 1879-1955

ALBERT EINSTEIN: PHILOSOPHER-SCIENTIST. Edited by Paul Arthur Schilpp. Tudor Publishing Company. 1950.

EXPERIMENTAL PSYCHOSES

EXPERIMENTAL PSYCHIATRY III: A CHEMICAL CONCEPT OF PSYCHOSIS. M. Rinkel, R. W. Hyde and H. C. Solomon in *Diseases of the Nervous System*, Vol. 15, No. 9, pages 259-264; September, 1954.

EXPERIMENTAL SCHIZOPHRENIA-LIKE SYMPTOMS. Max Rinkel, H. Jackson DeShon, Robert W. Hyde and Harry C. Solomon in *The American Journal of Psychiatry*, Vol. 108, No. 8, pages 572-578; February, 1952.

SCHIZOPHRENIA: A NEW APPROACH, II. RESULT OF A YEAR'S RESEARCH. A. Hoffer, H. Osmond, and J. Smythies in *Journal of Mental Science*, Vol. 100, No. 418, pages 29-45; January, 1954.

RADIO WAVES FROM THE SUN

HARMONICS IN THE SPECTRA OF SOLAR RADIO DISTURBANCES. J. P. Wild, J. D. Murray and W. C. Rowe in *Australian Journal of Physics*, Vol. 7, pages 439-459; 1954.

RADIO EVIDENCE OF THE EJECTION OF VERY FAST PARTICLES FROM THE SUN. J. P. Wild, J. A. Roberts and J. D. Murray in *Nature*, Vol. 173, No. 4403, pages 532-534; March 20, 1954.

THE SUN. Edited by Gerard P. Kuiper. University of Chicago Press, 1953.

JAMES CLERK MAXWELL

THE LIFE OF JAMES CLERK MAXWELL. Lewis Campbell and William Garnett. Macmillan and Co., 1882.

THE SCIENTIFIC PAPERS OF JAMES CLERK MAXWELL. Edited by W. D. Niven. Dover Publications, Inc., 1953.

A TREATISE ON ELECTRICITY AND MAGNETISM. James Clerk Maxwell. Dover Publications, Inc., 1954.

LEARNING IN THE CANARY

DISCRIMINATION LEARNING IN THE CANARY. Nicholas Pastore in *Journal of Comparative and Physiological Psychology*, Vol. 47, No. 5, pages 389-390; October, 1954.

SPATIAL LEARNING IN THE CANARY. Nicholas Pastore in *Journal of Comparative and Physiological Psychology*, Vol. 47, No. 4, pages 288-289; August, 1954.

ANTIBIOTICS AGAINST PLANT DISEASES

ANTIBIOTICS AND PLANT DISEASE. C. Leben and G. W. Keitt in *Journal of Agricultural and Food Chemistry*, Vol. 2, No. 5, pages 234-239; March, 1954.

ANTIBIOTICS AND PLANT HEALTH. W. J. Zaumeyer in *Journal of Agricultural and Food Chemistry*, Vol. 3, No. 2, pages 112-116; February, 1955.

MOVEMENT OF ANTIBIOTICS IN HIGHER PLANTS. S. H. Crowdy and D. Pramer in *Chemistry and Industry*, No. 7, pages 160-162; February 12, 1955.

COMPUTER MEMORIES

PROCEEDINGS OF SYMPOSIA ON LARGE-SCALE DIGITAL CALCULATING MACHINERY. *The Annals of the Computation Laboratory of Harvard University*, Vols. 16 and 26. Harvard University Press, 1948 and 1951.

HIGH SPEED COMPUTING DEVICES. Edited by William Warren Stifler, Jr. McGraw-Hill Book Company, Inc., 1950.

THE GERM OF TUBERCULOSIS

BIOCHEMICAL DETERMINANTS OF MICROBIAL DISEASES. René J. Dubos. Harvard University Press, 1954.

CONSTITUENTS OF MYCOBACTERIA. Florence B. Seibert in *Annual Review of Microbiology*, Vol. 4, pages 35-52; 1950.

THE METABOLISM OF THE TUBERCLE BACILLUS. W. F. Drea and A. Andrejew. Charles C Thomas, 1953.

THE AMATEUR SCIENTIST

EXPERIMENTAL SPECTROSCOPY. Ralph A. Sawyer. Prentice-Hall, Inc., 1944.

AMATEUR TELESCOPE MAKING. Edited by Albert G. Ingalls. Scientific American, Inc., 1952.

AMATEUR TELESCOPE MAKING—ADVANCED. Edited by Albert G. Ingalls. Scientific American, Inc., 1952.

AMATEUR TELESCOPE MAKING—BOOK THREE. Edited by Albert G. Ingalls. Scientific American, Inc., 1953.

another new product by Brush...

puts microvolts in writing

LATEST ADDITION to Brush Direct-writing Recording Systems is this "Chopper Stabilized" Amplifier. Designed to permit oscillographic recording of very low level voltages, it not only provides a gain of 10,000 but does so with extremely high stability over an extended frequency range.

Brush Recording Systems give you immediate answers in writing . . . of stress, strain, vibration, force, electrical variables, etc. Investigate Brush Recording Systems . . . to save engineering time and simplify data analysis.

BRUSH ELECTRONICS COMPANY

DIVISION OF
CLEVITE CORPORATION

For complete information write Brush Electronics Co., Dept. B-6, 3405 Perkins Avenue, Cleveland 14, Ohio. Brush representatives are located throughout the United States. In Canada: A. C. Wickman, Ltd. Toronto.

Kidney for an Atomic Fish

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

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

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

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

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA